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MINERAL'RESOUROES OF ALASKA

REPORT ON PROGRESS OF INVESTIGATIONS. IN

1924

BY

PHILIP S. SMITH AND OTHERS

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MINERAL INDUSTRY OF ALASKA IN 1924

By PHILIP S. SMITH

INTRODUCTION

This volume is the twenty-first of a series of annual blllletins[1] summarizing the results achieved during the year in the investigation of the mineral-resources of Alaska and treating of the mineral deposits and of the statistics of mineral production of the Territory.[2] This volume, like those previously issued, has for its chief purpose the prompt publication of the more significant economic results of the year. The articles included are mainly statements of preliminary results and may be modified when the field material is more fully studied. Those who are interested in any particular problem or district are therefore urged to procure a copy of the complete report on it as soon as it is available.

The information included in this volume could not have been prepared without the data furnished by many residents of the Territory, some of whom have rendered this assistance for many years. However, many still fail to report their mining operations. To those who fail to report because of fear that their confidential data may be disclosed to competitors or others who might use the information to the sender's disadvantage the Survey would say that all schedules of production are regarded as confidential, are not open to inspection, and are not used in any form that would disclose the production of individuals. Even members of the Survey who are working in other parts of Alaska than those to which the specific reports relate do not have access to them. To those who refrain from reporting because of the small size of their production the Survey would say that the accuracy of its results depends upon having reliable data from every operator, even from those who have produced nothing during the current year. As the final figures are based in part on estimated production of all claims, if a claim produced nothing definite information of that fact may prevent an erroneous estimate.

The Survey appreciates the efforts made by prospectors and miners throughout the Territory in filling in and transmitting its schedules and would gladly avoid asking for unnecessary information or simplify its inquiries. It therefore welcomes constructive criticism as to how these desirable objects may be effected. In return; it aims to give the best statistical information that it can

[1] The preceding volumes in this series are U. S. Geol. Survey Bulls. 259, 284, 314, 345, 379, 442, 480, 520, 542, 592, 622, 642, 662, 692, 712, 714, 722, 739, 755, and 773.

[2] The statistics in this report have been compiled principally by Miss Erma C. Nichols.

regarding the developments during the year in the mineral industry of Alaska. In the interest of increasing its value to the Alaska mining industry as a whole and to each operator individually the Geological Survey requests more complete and prompter return of its schedules by the Alaska mining operators. To be of service the Survey reports should be in the hands of the users at the earliest possible moment. Delays in returning the schedules mean delay in publication of the results, so that anyone who delays sending in his report not only causes additional expense but also decreases the value of the result.

It is impossible to record here the names of all who have rendered aid to the Geological Survey during the past year, as the list would include more than a thousand names.

Special acknowledgment should be made to the Territorial mine inspector and resident engineer of the Bureau of Mines, who furnished the data on coal production, as well as other valuable information; to N. L. Wimmler, also of the Bureau of Mines, for information about gold placers; to George Parks, now Governor of Alaska, and H. K. Carlisle, of the General Land Office; to the directors and other officers of the Bureau of Mines and Bureau of the Mint; to the collector and other officers of the Alaska customs service; to the officers of the Alaska Railroad; to Charles H. Flory, forest supervisor for Alaska; to John C. McBride and the Alaska Juneau Gold Mining Co., of Juneau; Thomas Vogel, of Haines; J. H. Cann, of Chichagof; Thomas G. White, of Katalla; the Kennecott Copper Corporation, of Kennicott; Thomas Larson, of Chitina; J. M. Elmer, of Dempsey; S. W. Jensen and H. W. Nagley, of Talkeetna; Alex Liska and Sumner Smith, of Anchorage; Louis Huber, of Seldovia; Arthur Moose Johnson, of Chulitna; J. H. Lander, of Wasilla; Charles Zielke, of Nenana; Carl F. Whitham, of Chisana; A. W. Amero, of Beaver; J. J. Hillard, of Eagle; Alfred Johnson, of Deadwood; John C. Boyle and Frank Slaven, of Circle; the First National Bank, George Hutchinson, and G. E. Jennings, of Fairbanks; Charles E. M. Cole, of Jack Wade; J. H. Elden, of Steel Creek; the Miners & Merchants Bank, of Iditarod; E. J. Stier, of Flat; Frank Speljack, of Ophir; George W. Huey, of Wiseman; Tom Plunkett, of Fortuna Ledge; J. W. Wick, of Russian Mission; B. J. Bower, of Long; Lynn Smith, of Ruby; A. Stecker and John Haroldsen, of Kwinak; the Miners & Merchants Bank, A. W. Kah, and R. W. J. Reed, of Nome; E. M. Marx, of Teller; T. P. Roust, of Candle; A. S. Tucker, of Bluff; James C. Cross and Lewis Lloyd, of Shungnak; and J. J. Elliot, of Haycock.

GENERAL FEATURES

In presenting this annual inventory of the progress of mining in Alaska many facts are set forth which show that the Territory is really a treasure box and not the liability which some people, who do not know the country, suppose it to be. For instance, the accompanyingtable, which gives the value of the mineral production of Alaska, shows a total of more than $535,000,000 from this source alone,. and minerals form less than half of the total wealth, which includes fish, lumber"furs, and·other products that the Territory has furnished. However, the mineral production for 1924, as compared with that for 1923, decreased about $2,900,000, This is a cause for regret, especially as more than $1,500,000 of this decrease is due merely to the fact that the market price of copper was 1.6 cents a pound lower in 1924 than in 1923-really not a matter that reflects in any manner on the. productivity of the Territory.

Value of totalmi1'leral production of Alaska, 1880–1924

By years,				By substances	
1880-1890	$4,193,919	1909	$21,140,810	Gold	$347,240,798
189L	1,014,211	1910	16,875,226	Copper	'167,812,879
1892	1,019,493	191L	20,720,480	Silver	9,950,593
1893	1,104,982	1912	22,581,943	CoaL	4,140,480
1894	1,339,332	1913	19,547,292	Tin	946,227
1895	2,588,832	1914	19,109,731	Lead	930,313
1896	2,885,029	1915	32,790,344	Platinum (placer)	111,773
1897	2,539,294	1916	48,386,508	Antimony	237,500
1898	2,329,016	1917	40,694,804	Marble and other products (including lode platinummetalsl	'3,713,713
1899	5,425,262	1918	28,218,935		
1900	7,995,209	1919	19,62,6,824		535, 084, 27.6
1901	7,306,381	1920	23,330,586		
1902	8,475,813	192L	16,994,302		
1903	9,088,564	1922	19,420,121		
1904	9,627,495	1923	20,330,643		
1905	16,490,720	1924	17,457,333		
1906	23,501,770				
1907	20,840,571		535,084,276		
1908	20,092,501				

A clearer picture of the state of the ,mining industry in 1924 is afforded by the following table, ,in which the total mineral output is distributed among.the,various metals and mineral, products. According to this table the production of gold, lead, tin, and miscellaneous mineral products increased, while copper, silver, and coal decreased. The platinum metals derived from placers decreased about, $400, but the production of platinum metalsreally increased greatly, for, as explained mOre fully on pages 24–25, the platinum metals derived from lodes are included in the miscellaneous mineral products.

Mineral output of Alaska, 1923 and 1924

	1923		1924		Decrease or increase in 1924	
	Quantity	Value	Quantity	Value	Quantity	Value
Gold fine ounces	289,539	$5,985,314	304,072	$6,285,724	+14, 533	$+300,410
Copper pounds	85,920,645	12,630,335	74, 074, 207	9,703,721	-11,846,438	−2, 926, 614
Silver coo_coo_fine ounces	814,649	668,012	669,641	448,659	-145,008	-219,353
Coal short tons	119,826	755,469	99,663	559, 980	-20,163	−195, 489
Tin, metallic do	1.90	1,623	7,00	7,028	+5,10	+5,405
Lead do	410	57,400	631	100,899	+221	+43,499
Placer platinum metals fine ounces	25.90	3,004	21.98	2,594	-3.92	-410
Miscellaneous mineral products, including petroleum, marble, gypsum, and lode platinum metals		229,486		348,728		+119,2,42
		20,330,643		17,457,333		-2,873,310

The decrease in silver is mainly a natural consequence of the decreased production of copper. The decrease in production of coal, about 20,000 tons, was due in large part to a serious fire in one of the largest mines. The decrease in both coal and silver is nearly offset by the increase in gold. On the whole, therefore, the decrease in 1924 may be considered as resulting from decreased production of copper. Further discussion of the details regarding the different metals and mineral products is given under each metal or material in later pages of this report.

The earlier volumes of this series contain complete tables of the production of all valuable metals for each year since they were first mined. With a view to reducing the size and cost of this volume many of these tables have been condensed, so that only the annual statistics for the last nine years are given and the production for the earlier years is grouped as one item. The reader interested in obtaining the more complete record should consult Bulletin 773.

Although complete tables have now been worked up for the annual production of gold, silver, copper, coal, tin, lead, placer platinum metals, and antimony, there are a number of mineral products, such as petroleum, gypsum, marble, and lode platinum metals that have not been so tabulated and either have not been determined or have been reported in the table on page 3 as miscellaneous mineral products. The following table has therefore been prepared, so that information as to the value of these miscellaneous mineral products should be readily available in one place.

Value of output of miscellaneous mineral products of Alaska, including petroleum, gypsum, marble, and other products, 1901-1924

Year	Value	Year	Value	Year	Value
1901	$500	1910	$96,408	1919	$214,040
1902	255	1911	145,739	1920	372,599
1903	389	1912	165,342	1921	235,438
1904	2,710	1913	286,277	1922	266,296
1905	710	1914	199,767	1923	229,486
1906	111,965	1915	205,061	1924	348,728
1907	54,512	1916	326,737		
1908	81,305	1917	203,971		
1909	86,027	1918	171,452		3,713,713

GOLD

TOTAL PRODUCTION

For many years gold was practically the only metal that was produced in any quantity in Alaska, and even now the value of the total production of gold far exceeds that of any other mineral. The following table gives the total annual production of gold for the last nine years and the gross output from 1880 to 1915. This table shows that altogether nearly $350,000,000 worth of gold has been recovered since gold mining first began in the Territory in 1880. As indicated in this table, the amount of gold produced in 1924 was about $300,000 greater than in 1923, and furthermore most of the increase came from the lode mines rather than from the placers. Additional information is given regarding the different types of deposits from which gold was produced and the different areas from which it came.

Gold and silver produced in Alaska, 1880–1924

	Gold	Silver	Value of gold by sources

Source	Gold		Silver	
	Fine onnces	Value	Fine ounces	Value
	131,018.01	$2,708,383	75,284	$50,440
	645.37	13,341	572,078	383,292
	172,408.50	3,564,000	22,279	14,927
	304,071.88	6,285,724	669,641	448,659

GOLD LODES

The production from the gold lodes amounted in 1924 to more than 17,500 oUhces of fine gold, having a value of about $360,000 above thatin 1923. No new mines became notable producers during the year, and only a few mines that were producers in 1923 discontinued production in 1924. Nineteen mines which are here classed as gold mines because gold is the dominant metal in their ores and whose production was valued at more than $1,000 during the year, reported productionin 1924, the-same number that reported in 1923. Alliode properties that produced less than $1,000 during the year are regarded as prospects.

The accompanying table gives information regarding the gold and silver produced from the gold mines in Alaska in 1924, by districts, *Gold and silver produced from gold-lode mines in Alaska in 1924, by districts*

District	Number of mines	Ore mined (short tons)	Gold		Silver	
			Fine ounces	Value	Fine ounces	Value
Southeastern Alaska	6	3,112,507	111,035.43	$2,295,306	68,911	$46,170
Willow Creek	4	8,075	9,765.83	201,878	754	505
Fairbanks district	5	4,528	4,870.05	100,673	1,295	868
Other districts	4	a 2,795	5,346.70	110,526	4,324	2,897
	19	3,127,905	131,018.01	2,708,383	75,284	50,440

a Including small amounts of galena are.

The mines of southeastern Alaska continued to yield the greatest amount of gold, and of these the mine of the Alaska Juneau Gold Mining Co. was by far the largest producer. The record of this company is shown by the report of its operations which it publishes each year. The following table, taken from that report, shows the recovery of gold as well as the other metals from this mine:[3]

Production of Alaska Juneau mine, 1893-1924 a

Year	Ore (tons)			Metals recovered			
	Total	Fine milled	Coarse tailings rejected	Gold	Silver (ounces)	Lead (pounds)	Total value
1893-1913	507,254	330,278	176,976	$707,730	Lost in tailings		$707,730
1914-1915	242,328	239,918	2,410	251,655	6,192	117,031	261,326
1916	180,113	180,113		115,022	2,844	61,068	121,379
1917	677,410	677,410		429,262	12,248	296,179	460,666
1918	592,218	574,285	17,933	430,124	11,828	273,297	459,445
1919	692,895	616,302	76,593	499,002	16,431	359,762	542,714
1920	942,870	637,321	305,549	732,870	23,348	487,574	791,390
1921	1,613,600	904,323	709,277	969,703	40,619	550,913	1,035,251
1922	2,310,550	1,108,559	1,201,991	1,296,157	49,404	687,315	1,388,679
1923	2,476,240	1,134,759	1,341,481	1,427,199	41,876	755,423	1,514,774
1924	3,068,190	1,367,528	1,700,662	1,907,374	63,191	1,256,857	2,055,782
	13,803,668	7,770,796	5,532,872	8,766,098	267,981	4,845,419	9,339,136

a Compiled from published reports of mining company.

Some slight discrepancies between the figures in this table and those used by the Geological Survey are due principally to the fact that the price of some of the metals used by the Geological Survey in preparing its estimates is based on the average price for the year rather than on the actual price received by the producers. For instance, the price of lead, as computed from the figures given in the company's report, was 8.42 cents, whereas the price used by the Survey is 8 cents a pound, These differences are usually small, but in the example just cited the value of the lead given in the company's report is greater than the value of the whole production of lead in Alaska as given in the table on page 22, which was computed by the Survey. The report of this company further shows

[3] Alaska Juneau Gold Mining Co., Tenth Ann. Rept., for 1924, published Mar. 3, 1925.

that operations were carried on for 362 days during the year, that its mining and milling plants, which had an average capacity of 7,430 tons a day at the beginning of the year, had been increased at the end of the year to 9,520 tons a day, and that the average number of tons mined per day for the entire year was 8,476.

The Alaska Juneau Gold Mining Co. also continued throughout the year its development of the Ebner mine, which lies adjacent to its property. In the report of the company for 1923 Bradley said:[4]

Litigation over the boundary line between the Alaska Juneau property and the westerly adjoining Ebner property has been settled by an agreement that resulted in our taking possession of the entire Ebner property, which possession is to continue after November 2, 1925, either as long as we mill an average of a thousand tons per day from the westerly side of an agreed-upon line between the Alaska Juneau and Ebner properties and equally divide the net profits, or as long as we employ a minimum of five men preparing the Ebner mine for profitably producing a thousand tons per day.

Good headway is being made on the preparatory work, and the management expected that by November, 1925, a thousand tons of ore a day would be coming from the Ebner mine.

Prospecting and development work on gold lodes was carried on in many of the other parts of the Juneau district. On Admiralty Island, in this district, a belt of metamorphic rocks, which extends from Funter Bay to Hawk Inlet, contains a great number of large well-defined quartz fissure veins with shoots carrying gold values. Several of these veins are being prospected on the properties of the Admiralty-Alaska Gold Mining Co. and the Alaska Dano Co. on Funter Bay and by Charles Williams and others on Hawk Inlet. A description of these properties by Buddington is given in another paper in this bulletin.

Work at the mines of the Chichagof Development Co., the Hirst-Chichagof Mining Co., and the Apex El Nido Mining Co., all on Chichagof Island in the Sitka district, was continued actively throughout the year, and the mines report a considerable production of gold. A new mill was put in operation during the year at the Apex-El Nido property. The success of these mines has stimulated interest in prospecting for gold lodes in this region, and doubtless this search for new ore bodies will be in some places successful.

The only other mine in southeastern Alaska in which a gold lode was productively mined during 1924 was in the Ketchikan district, where the Kassan Gold Mining Co. reports renewed mining at the Julia mine, near Hollis, throughout part of the year.

In the Copper River district the only mine which has been classed with the gold-lode mines was that of the North Midas Copper Co.,

[4] Bradley, F. W., Alaska Juneau Gold Mining Co. Ninth Ann. Rep't., for 1923, published Mar. 11, 1924.

in the Chitina region near Strelna. This mine, although placing emphasis on copper in its name, has been considered a gold lode because the most valuable part of its production is gold.

Very little gold-lode mining was carried on in the Prince William Sound region. The largest production came from the old Ramsey-Rutherford mine, on the east side of Valdez Glacier, but some production was reported from the Tuscarora mine near Shoup Bay. Toward the end of the summer preparations were under way for further prospecting on the Little Giant claim on Mineral Creek, in the Valdez district. A number of men were engaged and a compressor installed to reopen the Cliff mine, near Shoup Bay.

Mining in the Kenai district was continued at the Lucky Strike mine of the Alaska Minerals Co., 'formerly the Hirshey mine, at the head of Palmer Creek near Hope. Further discoveries of gold-quartz lodes at Nuka Bay, on the south shore of Kenai Peninsula, indicate that this may be the center of a large area of mineralization. According to report, a mill was to be installed there during 1924, and several of the veins are said to show promising indications. The Alaska Hills Mines Corporation, near Seward, also reported the recovery of some gold from its lode claim known as the Paystreak.

No important new developments are reported from the Willow Creek region during the year. The largest gold-lode production came from the War Baby claim of the Willow Creek mines, on Craigie Creek. None of the other mines of this company were in operation. The Fern Gold Mining Co.'s property, near the head of Archangel Creek, showed a considerable increase in production owing to the discovery of a rich shoot of ore. The Mabel, on the ridge west of the lower part of Archangel Creek, was operated for part of the season. The only other mine in the district that reported having recovered any lode gold during the year is that of Elder & Thorpe, in the schist area near the mouth of Grubstake Gulch.

The Fairbanks district showed probably the greatest rate of increase in 1924 over 1923 of all Alaskan camps in its production of lode gold, for its output of gold in 1924 was more than $100,000, as compared with an output of less than $25,000 in 1923. The largest amount of work was in the general neighborhood of Ester Dome, especially near the head of St. Patrick Creek. Here Tyndall, Henderson, and McLoughlin, on the Mohawk claim, have taken out a considerable quantity of excellent ore. They have the only mill that is operating in the region. Most of the metal that is recovered is in the form of free gold. Sulphides, especially stibnite, and some galena and blende are fairly abundant in the ore, but no attempt is made to recover the gold intimately associated with them. The only other claim on Ester Dome which is reported to have milled any gold ore is the First Chance, operated by Sam Stay & Co. Some development work was done on other claims in the neighborhood; but many of the owners have been "marking time," as negotiations are reported to have been in progress for a large consolidation of properties and their operation by companies not now active in the district. Lode prospecting in the vicinity of Fairbanks Creek has received a new impetus, and the Crites & Feldman Hi Yu mine still continues to be a consistent producer. The old Rhoads-Hall mine, on Bedrock Creek, a tributary of Cleary Creek, operated by Gustafson Bros., and the Wyoming claim, on the same stream, both produced some gold. Much of the work done at the Gustafson mine, however, was "dead" work required in reopening the mine, which had stood idle for several years, and in developing an adequate new systematic plan for mining the deposit.

The only productive lode-gold mining in the Kuskokwim basin was at the Whelan mine, in the Nixon Fork country. This general region was visited by a Survey party in 1924, and the geology and economic facts regarding it are described in considerable detail by J. S. Brown in another chapter of this bulletin. The gold recovered this year was mined during the winter of 1923-24 and was milled in the 20-stamp mill owned by the Alaska Treadwell Gold Mining Co., which had been leased to an association that included the owners of the Whelan mine. This mill was operated for 73 shifts, after which the mine and mill were practically closed down, though further prospecting in the neighborhood was undertaken.

In addition to the lode gold won from the lode mines discussed in the preceding pages, considerable gold was also recovered from the mines classed as copper lodes, which are described on pages 20-22. The gold recovered from the copper lodes amounts to 645.37 ounces of fine gold, valued at $13,341.

GOLD PLACERS

GENERAL FEATURES

Gold placers are widely distributed through Alaska. Because in the early stages of their development many placers can be mined with relatively little heavy equipment and because the resulting product is small in bulk and high in value in comparison with its weight, they can be mined profitably in rather inaccessible regions where transportation facilities are poor. Even in the most remote parts of the Territory some gold still comes from placers. The cost of operating deposits by hand labor is, however, relatively high, and a decrease in cost can be effected only by the installation of suitable machinery or the leading to the properties of large volumes of water under control. Most of the developed camps have reached the stage where the known rich bonanzas have been worked out and successful operation requires good mining practice and considerable labor-saving machinery. A person now undertaking placer mining must therefore either be prepared to go into the more inaccessible parts of the Territory or have sufficient capital to provide rather extensive equipment and to buy up claims staked by others. In other words, placer mining in Alaska is fast ceasing, if it has not already ceased, to be a business in which poor men inexperienced in mining can quickly become wealthy. It is still, however, a kind of work in which a person without much money can probably make as comfortable a living as can be made in the States with perhaps no more work and with the added attraction and disadvantage that the prospector is his own boss.

The total production of placer gold, distributed according to the districts in which it is produced, is shown in the following table:

Statistics of placer mining in Alaska in 1923 and 1924

Region	Number of mines		Value of gold produced		
	1923	1924	1923	1924	Decrease or increase, 1924
Southeastern Alaska	5	4	$3,500	$7,000	+$3,500
Copper River region	12	9	144,000	130,000	-14,000
Cook Inlet and Susitna region	35	39	247,000	168,800	-78,200
Yukon basin	365	374	1,644,000	1,740,500	+96,500
Kuskokwim region	30	25	292,000	268,700	-23,300
Seward Peninsula	66	84	1,270,000	1,245,000	-25,000
Kobuk region	8	5	8,000	4,000	-4,000
	521	540	3,608,500	3,564,000	-44,500

In addition to the gold and silver some platinum and tin are (cassiterite) are recovered in the course of placer mining.

The foregoing table shows that the production of gold from the placer mines in 1924 was almost identical with the amount produced from the same source in 1923. This correctly indicates the actual condition, that placer mining in the two years was done on practically the same scale and that there were no new strikes that affected the production to a marked degree, nor did any of the large formerly productive camps show decided increase in output. Although not yet reflected in their effect on production, several important events that took place during the year before long should stimulate placer mining, especially in the Fairbanks and Nome districts. One of these events was the announcement, in August, that the Hammon Consolidated Gold Fields and the United States Smelting & Refining Co. had effected a consolidation of certain of their Alaskan holdings under the joint ownership of a company known as the Fairbanks Exploration Co. This consolidation had been in effect only a few months when, in the spring of 1925, the announcement was made that the United States Smelting & Refining Co. had taken over all the holdings of the Hammon corporation in Alaska, including the dredges at Nome as well as the many claims in the Fairbanks district. It is still too early to predict what developments will be undertaken in the near future, but the well-known success of the company in carrying through vigorously any work it undertakes gives every assurance that the properties will be brought to a producing stage as early as the most expert mining methods will permit. Not only will this enterprise have a direct effect on the mining industry of the Territory but it will be of indirect benefit in educating new miners in Alaskan methods and will afford work for many who will use some of the wages they earn as stakes to do some prospecting on their own account.

Another consolidation of claims, many of which have lain idle for several years, was effected by a company supposed to represent mainly English capital. The main area in which this company has acquired ground is in the vicinity of Engineer Creek, in the Fairbanks district. This arrangement was made late in the year, and the plan of development has not yet been announced. Carefully managed mining in this region on a large scale, backed by adequate funds, should give attractive returns on the investment and be of benefit not only to the producing company but also to the mining industry as a whole and to all the activities of the district tributary to the area in which the work is done.

An interesting experiment that is being tried in one of the drift mines on Little Eldorado Creek in the Fairbanks district is the mining of frozen ground by blasting rather than by thawing it with steam or water. According to J. S. Brown, this experiment was tried at the mine of the Idaho Mining & Leasing Co. At this property the shaft is about 175 feet deep and from it about 800 feet of drifts have been driven. The mining practice here is to use a general long-wall system of undercutting by blasting the frozen gravels, taking out 3 to 4 feet of the gravels and 2 to 3 feet of the upper bedrock. The frozen gravel is said to stand well without thawing, but the material broken by blasting that contains the gold thaws rapidly when exposed to the air for a short time, and its subsequent treatment for the recovery of the gold is the same as that for other thawed material. If this system proves practicable it should have considerable application in many of the deep placers both of Seward Peninsula and of the interior of Alaska.

NOTES ON THE PLACERS BY REGIONS

Southeastern Alaska.-The only places in southeastern Alaska in which placer mines were worked in 1924 were the Juneau region, the Porcupine district, and the Yakataga district. In none of these places, however, were more than two claims worked and at none was more than a few thousand dollars in gold produced. All the gold came from stream placers except from two in the Yakataga district, where marine beach sands were mined. The total production for all of southeastern Alaska is shown in the table on page 10.

Copper River region.-Three districts in the Copper River region reported some production of placer gold. In the order of their output these were the Nizina, Chistochina, and Nelchina districts. A good-sized mine on Chititu Creek and another on Dan Creek and two small ones, one each on Rex and Dan creeks, were the only mines that were in operation in the Nizina district. With the exception of the Slate Creek Mining Co.'s work on Slate Creek, all the placer mines in the Chistochina and Nelchina districts were very small. There was only one other placer mine in the Slate Creek district and three in the Nelchina. The production of placer gold for all of the Copper River region is given in the table on page 10.

Cook Inlet-Susitna Basin.-The Yentna was by far the most productive district in the Cook Inlet-Susitna Basin region. Here 23 different mines, including one dredge, produced placer gold worth $136,900. Most of the mines produced only a few thousand dollars in gold and only a few produced more than $10,000.

In the Kenai district the placer production, which was $27,900, came from 10 mines, most of them, except the claims on Crow Creek, producing less than $5,000 each in gold and some of them only a few hundred dollars. These small producers were located on Canyon, Bear, Lynx, Mills, Resurrection, and Sixmile creeks, and on Resurrection River and Nuka Bay.

In the Valdez Creek district four claims, three of which were on Lucky Gulch and one on White Creek, mined a little placer gold.

Yukon basin.-The scope of placer mining in the Yukon basin is summarized briefly in the following table, which affords a ready comparison between the placer production in 1924 and in 1923. As shown in the table, there was an increase in 1924 over 1923 of about $100,000, a large part of which might be attributed to the increased production in the Fairbanks district.

Placer gold produced in Yukon basin, 1923 and 1924, by districts

District	Value of gold		Number of mines	
	1923	1924	1923	1924
	$619,000	$680,400	88	74
	228,000	207,100	20	21
	164,000	189,500	26	20
	153,000	161,200	23	19
	114,000	90,200	24	26
	72,000	84,600	32	32
	62,000	83,400	18	22
	53,000	31,800	42	51
	42,000	17,900	6	6
	37,000	54,000	20	27
	23,000	23,400	9	8
	23,000	49,800	11	19
	16,000	16,000	8	8
	13,000	12,500	13	13
	13,000	18,800	13	18
	12,000	19,900	12	10
	1,644,000	1,740,500	365	374

it is rather surpnsmg that most of the camps that made the greatest production showed so little change in the two years. In fact, the order of the first seven districts, based on production of placer gold, showed no change. A considerable amount of the placer gold from the Yukon region is recovered by dredges. A large amount of drift mining is done, especially in the Fairbanks, Tolovana, Fortymile, and Koyukuk districts. Many of the districts in the Yukon basin are now so close to relatively good transportation facilities that the more prosperous ones have rather extensive equipment. Some of the camps, however, are difficult of access, and further road building and trail making should unquestionably be undertaken, as this work would undoubtedly stimulate production and lead to the development of new deposits.

As already noted, the Fairbanks district, with which the Richardson district has been included in the table given below, produced the most placer gold. The table shows the amount of placer gold produced by camps on the different streams in the Fairbanks district for 1923 and 1924 and from the beginning of mining on the different streams, the first gold having been taken from the district in 1903.

Gold production by streams in Fairbanks district

	1923	1924	Approximate total to date
Cleary Creek and tributaries	$54,000	$97,600	$23,349,900
Goldstream Creek and tributaries	201,000	226,000	15,512,000
Ester and adjacent creeks	54,000	102,600	11,600,000
Dome and Fairbanks creeks	225,000	181,500	16,892,100
Vault Creek and tributaries	32,000	15,900	2,749,000
Little Eldorado Creek.	20,000	33,900	2,414,000
All other creeks	17,000	22,900	740,000
	603,000	680,400	73,257,000

In the Iditarod district two dredges and the Chicken Creek Mining. Co. on Chicken Creek and the Alpha Mining Co. on Flat Creek were the largest of the 21 mines that were operated in 1924. None of the others produced as much as $10,000 in gold. Other creeks in this district that yielded placer gold were Granite, Happy, Cripple, and Willow creeks. Mining in the Tolovana district was reported by several mines on Livengood, Lillian, Amy, Ruth, and Willow creeks, named in the order of decreasing production of gold. Of the 20 producers in this district 6 produced at least $10,000 in gold. Outside of three dredges-two on Ganes and one on Yankee Creek-the production of placer gold in the Innoko district came from 16 mines, the largest of which produced less than $20,000. More than 26 placer mines were in operation in the Circle district, and all of them except the dredge on Mastodon Creek were relatively small operations, none of which produced as much as $10,000 in gold.

None of the mines in the Ruby district produced more than a few thousand dollars in gold in 1924. In the Tolstoi district, which has been tabulated with the Innoko district, the production was almost negligible. An increase in production was reported by the Hot Springs district, especially from American Creek and Sullivan Creek and its tributaries in the western part of the district, and Omega and Eureka creeks and tributaries in the eastern part of the district. More than 50 placer mines were active in the Fortymile district. The greatest production came from Jack Wade Creek and its tributaries, Chicken Creek, and Fortymile River proper, but with few exceptions most of the claims individually produced only a few hundred dollars worth of gold.

In the Chandalar district the placer gold came mainly from Big Creek and from Big Squaw and Little Squaw creeks. The placer mines on the Koyukuk report an increased production over 1923. Most of the 27 properties that were mined, however, produced only a few thousand dollars worth of gold each. The most productive placer mining in the Chisana district was on Bonanza and Little Eldorado creeks, and about the same amount of gold was produced as in 1923. In the Eagle district the production of placer gold came from Seventymile River and its tributaries, especially Alder, Crooked, and Fox creeks, from Fourth-of-July Creek, and from American Creek and its tributaries, especially Discovery Fork. On Hunter Creek and Little Minook Creek were the most productive placer camps in the Rampart district. Most of the mines were small, and each produced only a few thousand dollars worth of gold. The report of the Richardson district has been tabulated with that of the Fairbanks district, as there are only two operating mines in it. The largest of these mines is that of the Salcha Mining Co. on Caribou Creek, a tributary of Salcha River, and the other is on Democrat Creek.

In the Bonnifield district placer gold was produced by 13 small mines, none of which recovered more than a few thousand dollars worth of gold. In the Kantishna district also the placer gold was mined by a number of small plants, many of which recovered only a few hundred dollars worth of gold and the largest only a few thousand dollars.

Information from different sources regarding mining in the Marshall district is not in entire accord. Apparently in 1924 the greatest production came from Flat, Willow, Buster, Disappointment, and Montezuma creeks.

Kuskokwim basin.—The placer gold produced in the Kuskokwim basin came from the Mount McKinley, Georgetown, Tuluksak-Aniak, and Goodnews districts. The greatest production in the Mount McKinley district, in fact in the entire Kuskokwim basin, was made by the Kuskokwim Dredging Co.'s dredge on Candle Creek. The largest of the other placer camps in this district were on Moore, Hidden, and Holmes creeks, with several small producers on other creeks near McGrath. Notes on the economic geology of the Nixon Fork country, including a description of some of the areas that have been prospected or worked for gold placers, are given in a report by J. S. Brown that forms another chapter of this bulletin.

In the Georgetown district some placer mining was done at two properties on Donlin Creek. In the Tuluksak-Aniak district, 10 placer mines produced some gold. The largest amount of mining was done on Canyon and Bear creeks, but even the largest producers recovered only a few thousand dollars in gold. Four small mines were worked in the Goodnews district. With the exception of the property on Watermuse Creek only a little gold was produced by each of the other operators.

Seward Peninsula.—Placer mining in Seward Peninsula was done on essentially the same scale as that maintained during the past two or three years, and about the same production was made. As heretofore, the dredges contributed the most gold, but the amount was somewhat less than that produced in the preceding year. The decrease was due in part to the discontinuance of some of the older dredges and to the fact that some of the newer ones were in operation only a part of the season. The following table gives a comparison between the amounts of gold won by different methods of mining in Seward Peninsula in 1923 and in 1924.

Placer gold produced in Seward Peninsula in 1923 and 1924, by methods of mining

Method	Number of mines		Value of gold	
	1923	1924	1923	1924
Dredging	16	16	$1,017,620	$895,210
Drifting	10	7	51,290	38,700
Other methods of mining	40	61	201,090	310,090
	66	84	1,270,000	1,245,000

The great increase in the number of mines worked by methods other than drifting and dredging is in part real but in part due to the inclusion of a number of prospects, some of which produced at most only a few hundred dollars' worth of gold and were not included in the records for 1923, though the gold they produced was included in the total production of that year. Practically all the increase in production by methods of mining other than dredging and drifting came from the Nome region. In the following table the placer gold produced in Seward Peninsula in 1923 and 1924 is distributed by districts, so far as possible without disclosing the production of individual mines. This table indicates that the Nome district made a very large increase in production, whereas the Solomon, Casadepaga, and Council districts, which have been grouped together, showed the greatest decrease.

Placer gold produced in Seward Peninsula, 1923 and 1924, by districts

District	Number of mines		Value of gold	
	1923	1924	1923	1924
Nome	18	20	$598,000	$848,500
Solomon, Casadepaga, and Council	11	21	449,000	217,600
Koyuk	11	11	59,000	51,700
Kougarok	9	14	50,000	31,600
Fairhaven	10	13	107,000	82,600
Port Clarence	7	5	7,000	13,000
	66	84	1,270,000	1,245,000

In the Nome district, in addition to the production from seven dredges, the greatest amount of gold came from ground on Little Creek that was hydraulicked by the Hammon Consolidated Gold Fields. Other creeks from which a considerable amount of gold in the aggregate was taken were Anvil, Boulder, and Last Chance, Osborn, Rock, and Sunset creeks, and from the old second beach line. The greatest production from the districts here grouped as the Solomon, Casadepaga, and Council districts came from six dredges. Five mines in the Solomon district, one in the Casadepaga, and nine in the Council district are the only other mines where productive work was in progress. In the Koyuk the greatest mining activity was on Dime and Sweepstakes creeks. Drift methods for underground mining of deposits are extensively used at several claims, especially on the lower part of Dime Creek and on some of the bench claims. The aggregate production from these drift mines is considerably greater than that from the properties in this district that are using other methods of mining. One dredge was operated during part of the season on Dime Creek. The placer deposits on Dime Creek are of special interest because some of them carry platinum metals.

Mining in the Kougarok district was carried on at 14 properties, two of which were mined by dredges. Even the largest of the mines operated by other mining methods than dredging produced only a few thousand dollars worth of gold. In the Fairhaven district the greatest amount of gold was mined by three camps on Inmachuk River. Considerable gold was recovered by two mines on Patterson Creek, two on Candle Creek, and one on Bear Creek. Some production was also reported from the new camp on Koopuk Creek, a tributary of the Buckland, but the general reports from that region are not so favorable for extensive developments as some had been led to expect from the earlier rumors.

Most of the placer gold mined in the Port Clarence district in 1924 came from mines of Dick, Coyote, and Gold Run creeks, although a very small amount was also obtained from placers on Windy Creek and Bluestone River.

Kobuk region.—In the Kobuk region three properties in the vicinity of Shungnak and one on Klery Creek produced a small amount of gold. Mining in the region as a whole appears to have been little more than prospecting. The records regarding the region, however, are far from complete, and most of the data used in preparing the foregoing estimates are based on information obtained from different sources, some of which do not appear to be fully reliable.

DREDGING

The use of dredges for winning gold from placers continued to be a highly successful method of mining. Although the general facts regarding the production by dredges have already been given in the general tables of placer production, it has been desirable to make special mention here of the work done during the year by the dredges. The amount of gold produced by this form of mining, in spite of the fact that two more dredges were in operation, decreased somewhat from the amount produced in 1923. The large new dredge of the Hammon Consolidated Gold Fields at Nome was not completed and in running order until October 7, so that it had a rather short season. The following list of the dredges and the different districts in which they were operated during the season of 1924 shows that there were 27 dredges operated in Alaska during that year, of which 16 were in Seward Peninsula, 9 in the Yukon basin, and one each in the Kuskokwim and Susitna basins:

Seward Peninsula:
- Council district:
  - Northern Light Mining Co., Ophir Creek.
  - Wild Goose Mining & Trading Co., Ophir Creek.
  - Mebes & Hansen, Albion Creek.
- Kougarok district:
  - Alaska Kougarok Co., Kougarok River.
  - Behring Dredging Corporation, Kougarok River.
- Koyuk district: Dime Creek Dredging Co., Dime Creek.
- Nome district:
  - Bangor Dredge Co., Anvil Creek.
  - Alaska Mines Corporation, Snake River.
  - Dexter Creek Dredging Co., Dexter Creek.
  - Hammon Consolidated Gold Fields (three dredges), on or near Little Creek.
  - A. H. Moore, Osborn Creek.
- Solomon district:
  - Iversen & Johnson, Big Hurrah Creek.
  - Lomen Reindeer & Trading Corporation, Solomon River.
  - Shovel Creek Dredging Co. (Nylen, Hultberg, and others), Shovel Creek.

Yukon Basin:
- Circle district: Berry Dredging Co., Mastodon Creek.
- Fairbanks district:
  - Fairbanks Gold Dredging Co. (two dredges), Fairbanks Creek.
  - Chatham Gold Dredging Co., Cleary Creek.
- Iditarod district:
  - North American Dredge Co., Otter Creek.
  - J. E. Riley Investment Co., Otter Creek.
- Innoko district:
  - Flume Dredge Co., Yankee Creek.
  - Guinan & Ames Dredging Corporation, Ganes Creek.
  - Innoko Dredging Co., Ganes Creek.

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

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

About 45 per cent of Alaska's total production of gold from placers in 1924 was won by dredges. The following table shows the value of the gold recovered by dredges since this type of milling began in 1903:

Gold produced by dredge mining in Alaska, 1903–1924

Year	Number of dredges operated	Value of gold output	Gravel handled (cubic yards)	Value of gold recovered per cubic yard
1903-1915		$12,431,000		
1916	34	2,679,000	3,900,000	069
1917	36	2,500,000	3,700,000	.68
1918	28	1,425,000	2,490,000	057
1919	28'	1,360,000	1,760, 000	077
1920	22	1, 129, 932	1, 633, 861	.69
1921	24	1, 582, 520	2, 799, 519	.57
1922	23	1,767,753	3,186,343	055
1923	25	1,848,596	4, 645, 053	o040
1924	27	1,563,361	04,342,667	036
		28, 287,162		

• See text (pp.19-20) for basis of estimate.

The average lengtJl of the operating season for the dredges that furnished reports of their work was approximately 100 days, but there was wide variation in the. extremes. So far as can, be told from the incomplete records in hand, the Hammon Oonsolidated Gold Fields operated two of its dredges in the vicinity of Little Oreek in the Nome district from May 1 to December 6, an operating season of 220 days. The two dredges that were operated the next longest period were both in the Iditarod region. One of these dredges reported operating from June 12 to November 17, and the other from June 1 to November 1, or 158 and 153 days, respectively. May 1 was the earliest date on which any dredges started ,work, and most of them did not begin until July and closed down in October.

Mining by dredges is less affected by variations in rainfall than almost any other type of mining, but this year several of the dredges reported considerable difficulty owing to rather sudden rises and falls in near-by streams which destroyed dams or made it necessary to dig an unusual depth in bedrock to keep the boats afloat.

For several years the Survey has prepared a statement regarding the, amount of, ground handled by the dredges ,during' the year. This information has considerable interest and value, but in 1924 only 18 of the 27reports of dredges that have come to the Survey have given data from which this information could be computed. Therefore, rather than to make estimates of theamo11l1t, of yardage handled by the companies that did not report, it has seemed best to give only the amount actually stated by the 18 companies that reported. These companies 'dredged 3,476,656 cubic yards, of, gravel and from that material obtained the equivalent of fine gold valued at $1,257,565. The average recovery was therefore 36 cents a cubic yard. This is somewhat lower than the value of gold recovered by the dredges in 1923, when the average was 40 cents. If this factor of 36 cents applies to the ground of those companies that did not report, the total volume of the gravel dredged in 1924 was 4,342,667 cubic yards, as compared with 4,645,053 cubic yards handled by the dredges in 1923. On the whole, however, the dredges that reported the volume of gravel they had mined were those of the larger companies, and therefore they could handle profitably ground of lower tenor than the smaller dredges could. It therefore seems probable that the average fine gold recovered per cubic yard by the dredges that did not report and that is not included in the foregoing table probably was higher and might bring up the average per cubic yard. The total cubic yardage mined would then be less than the estimate given above, for that was computed by dividing the total gold output of the dredges by the average fine gold content.

A healthy sign in the undertaking of many of the newer dredging projects has been the more thorough examination of the ground in advance of any extensive outlay of money. Although mining enterprises necessarily face many uncertainties in actual operations, there are many factors which can be determined in advance, and neglect to determine them is bound to be detrimental. Among the most obvious, but in the past one of the most frequently disregarded factors, is the tenor and character of the ground to be dredged. Adequate sampling and testing by drilling well repay their cost and are now generally carried on extensively before any large new project is undertaken. Many of the smaller operators, however, who especially need this sort of information, still do not make adequate outlays for getting it.

COPPER

Copper ores are widely distributed in Alaska, but only in regions readily accessible to transportation have productive mines been developed. Even in those parts of Alaska near the coast many known prospects are still lying idle because of the lack of capital or because, at the present price of copper, the ore will not repay the high cost of necessary supplies and equipment. Copper was produced in 1924 mainly in the Chitina region of the Copper River basin by the Kennecott Copper Corporation, the Mother Lode Coalition Mines Co., and the Green Butte Copper Co.; on Latouche Island in Prince William Sound by the Kennecott Copper Corporation; and in the Ketchikan district of southeastern Alaska by the Alaska Palladium Co. The relative order of their production is the order in which the districts are named. Altogether more than 74,000,000 pounds of copper was produced from the different mines, and at the average price of copper that prevailed in 1924 the output was worth over $9,700,000. This output came from lode mines whose dominant valuable mineral was copper and from a lode project near Seldovia, though a few thousand pounds of copper.were also recovered from placer operations in the Copper' River basin. **In** addition a little copper was recovered from lodes of the Strelna district, in which gold p:redominates, and from the silver-lead lode of the Kantishna district.

Copper, Silver, and gold produced at Alaska oopper mines, 1900–1924

Year	Mines oper- ated·	Ore mined (tons)	Copper		Silver		Gold	Total valueof metals
			Pounds	Valne	Fine ounces	Valne		
190()-1915	--------	1,232,396	220, 773, 969	$35, 031, 225	2,351,726	$1,297,756	$1,059,357	$37, 388, 338
1916	18	617, 264	119,654,839	29,484,291	1, 207, 121	794,.286	188,977	30,467,554
1917	17	659,957	88,793,400	24,240,598	1,041,153	857,911	265,900	25,364,409
1918	17	722,047	69,224,951	17,098,563	719,391	719,391	107,635	17,925,589
1919	8	492, 644	47,220, 771	8,783,063	488,034	546,598	63,795	9,393,456
1920	8	766,095	70,435,363	12,960,106	682,033	743,416	18,868	13, 722,390
1921	6	477,121	57,011,597	7,354, 496	544,311	544, 311	11,689	7,910,496
1922	5	581,384	77,967,819	10,525,655	623,518	623,518	15,069	11,164, 242
1923	6	731,168	85, 920, 645	12,630,335	715,040	586, 333	33, 633	13,250,301
1924	5	761, 779	74,074,207	9,703,721	572,078	383,292	13, 341	10,100,354
		7,041,855	911, 077, 561	167, 812, 053	8,944,405	7,096,812	1,778,264	176, 687, 129

[a] Properties producing less than $1,000 are not counted as mines but are considered prospects.

There was a decrease of more than 11,000,000 pounds in the amount of copper produced in 1924 from the amount produced in 1923, and as the average price of copper was 1.6 cents less in 1924 than in 1923 the value showed an even greater decrease. It should be remembered, however, that 1923 was marked by a rather unusually large production of copper in Alaska and that the production for 1924 was more than 5,000,000 pounds greater than the average production for the preceding six years. A large part of the decrease was due to lessened production by the Kennecott Copper Corporation, for, according to the statements in its published annual reports, the copper sold was 50,945,719 pounds in 1923 and 42,985,532 pounds in 1924. At the Kennecott mine of this company a ,serious fire early in August, 1924, destroyed part of the power plant, but by great efforts and marked engineering ingenuity the mine and mill were kept in almost continuous operation. A temporary power installation was practically completed before. the end of September, so that there was only slight interruption. Two mines in southeastern Alaska that produced several hundred thousand pounds of copper in 1923-in part: from old dumps and material that had been mined several years before—were not in operation in 1924.

Prospecting and development work, according. to Moffit, was continued at Rua Cove on Knight Island, at the Hemple property in Landlocked Bay, at one or two neighboring prospects on Landlocked and Fidalgo bays, and on Hogg Bay at the southwest end of Bainbridge Island. Exceptifor annual assessment work on the claims of the Hubbard-Elliott Copper Co. on Elliott Creek and on claims on

KotsinaRiver there was no prospecting for copper in the western part of the Chitina Valley.

Buddington reports that work on the copper claims near Lake Bay in the Ketchikan region was continued.

In addition to copper the mines classed as copper mines produced. some gold and a good deal of silver and palladium, The gold and silver from this source are included in the tables on pages 3 and 5. The palladium is included under miscellaneous mineral products in the table on page 4.

SILVER AND LEAD

Practically all the silver produced in Alaska in 1924 was a by-product from the gold lodes and placers and from the copper lodes. Nearly all the lead came from deposits classified as gold lodes. One mine, however, was operated primarily for the silver and lead contained in its ore. This mine was the Alpha mine in the Kantishna district, but as its output was small and could not be listed separately without disclosing confidential information, it has been tabulated as one of the gold mines and is so treated in the following statements.

The following records show the amount of silver and lead recovered from. the various types of mines classified according to the dominant valuable mineral they contain.

Silver and lead obtained from gold lodes, gold placers, and copper lodes in 1924

	Silver		Lead	
	Ounoes	Value	Pounds	Value
Gold lodes	75,234	$50,440	1, 261, 239	$100,899
Gold placers:				
Dredges	9,272	6,212		
Others	13,007	8,715		
Copper lodes	572,[illegible]78	383,292		
	669, 641	448,659	1,261, 239	100,899

The silver obtained from the gold lodes came from 19 mines and a few prospects; that from the gold placers from 540 mines; and that from the copper lodes from 5 mines. The lead was obtained from 6 lode mines or prospects. According to the table on page 6, which was compiled from the published annual reports of the Alaska Juneau Gold Mining Co., that company's mine at Juneau alone produced 1,256,857 pounds of lead.

Although, as noted above, only one small silver-lead mine reported production in 1924, at several mines the development work that was being done should soon result in adding new names to the list of producers and materially swell the yield of these metals. According to A. F. Buddington, prospecting in the vicinity of Hyder has disclosed ore that is sufficiently rich to lead the owners of one property, the Riverside, to feel justified in going ahead with the construction of a mill, and promising ore has been found at several other prospects in the district. Additional notes on this district are contained in a paper by Mr. Buddington that forms a later part of this report. A detailed survey of the region was undertaken near the close of the fiscal year 1925 by Mr. Buddington, and a summary statement of the results will probably be available for inclusion in the next progress report.

Prospecting for silver-lead lodes was also in progress in the Wrangell district on the Lake claims.

Further development work on certain of the silver-lead claims in the Kantishna district has uncovered ore that will probably reach the market in 1925.

An examination of an interesting ruby silver lode, in the upper Susitna basin about 9 miles east of Chulitna station on the Alaska Railroad. was made by S. R. Capps. He states that too little development work to permit an estimate of the size and value of the ore body has yet been done. A picked sample of the, ore, however, tested by the Bureau of Mines, showed a silver content of nearly 120 ounces of silver to the ton, although selected samples, cut continuously across the vein, according to the best mining practice, showed less than 33 ounces of silver to the ton. A complete statement of Mr. Capps's observations, together with notes on the laboratory examination of the material by M. N. Short, is given in another chapter of this bulletin.

A silver-lead prospect situated about 14 miles south of Ruby was visited by J. S. Brown, who believes that the amount of ore so far discovered is too small to justify the risk of further expenditure in that place under present conditions. However, he says that similar surface outcroppings in that region justify at least sufficient prospecting to determine their size and richness. The full statement of Mr. Brown's observations regarding this prospect form a later chapter in this bulletin.

Lead produced in Alaska, 1892–1924

Year	Tons	Value	Year	Tons	Value	Year	Tons	Value
1892	30	$2, 400	1904	30	$2,580	1916	820	$113,160
1893	40	3,040	1905	30	2,620	1917	852	146,584
1894	35	2,310	1906	30	3,420	1918	564	80,088
1895	20	1,320	1907	30	3,180	1919	687	72,822
1896	30	1,800	1908	40	3,360	1920	875	140, 000
1897	30	2.160	1909	69	5,934	1921	759	68,279
1898	30	2,240	1910	75	6,600	1922	377	41,477
1899	35	3,150	1911	51	4,590	1923	410	57,400
1900	40	3,440	1912	45	4,050	1924	631	100,899
1901	40	3,440	1913	6	528'			
1902	30	2,460	1914	28	1,.344		7,236	930,313
1903	30	2,520	1915	437	41,118			

TIN

Eleven tons of tin ore, equivalent to 7 tons of metallic tin, was obtained from placers in the Port Clarence district, Seward Peninsula, and in the vicinity of Tofty in the Hot Springs district, Yukon-'ranana region. Although small in amount, the production in 1924 was considerably larger than it has been for the preceding three years and may be taken as a sign of revival of interest in the mining of this metal. No direct information regarding the renewal of tin operation in Seward Peninsula has been received, and little is definitely known about the mining there except that the tin ore came from Goodwin Gulch. The tin ore from the vicinity of Tofty was a by-product recovered in the course of the placer gold mining. The bedrock source of the tin ore in the Tofty region has not been discovered, and the heavy overburden makes the tracing of the placer tin to its source difficult.

Tin produced in Alaska, 1902–1924

Year	Ore (tons)	Metal (tons)	Value	Year	Ore (tons)	Metal (tons)	Value
1902	25	15	$8,000	1915	167	102	$78,846
1903	41	25	14,000	1916	232	139	121,000
1904	23	14	8,000	1917	171	100	123,300
1905	10	6	4,000	1918	104.5	68	118,000
1906	57	34	38,640	1919	86	56	73,400
1907	37.5	22	16,752	1920	26	16	16,112
1908	42.5	25	15,180	1921	7	4	2,400
1909	19	11	7,638	1922	2.3	1.4	912
1910	16.5	10	8,335	1923	3	1.9	1,623
1911	92.5	61	52,798	1924	11	7	7,028
1912	194	130	119,600				
1913	98	50	44,103		1,623.3	1,002.3	946,227
1914	157.5	104	66,560				

PLATINUM METALS

Platinum metals were produced both from lodes and from placers in Alaska in 1924. The only lode from which platinum metals were recovered is the one at the Salt Chuck mine of the Alaska Palladium Co. on Kasaan Peninsula, in the Ketchikan district, southeastern Alaska. This mine, formerly called the Goodro mine, was originally started as a copper mine and is still so considered in the statement regarding copper production on page 20, but its most valuable metallic product now is palladium, one of the platinum group of metals. The output of this mine so far exceeds that of all the other producers of platinum metals in Alaska that the Survey is not able to state the amount without disclosing confidential information, which is precluded by its obligation to all producers. Consequently the value of the production of lode palladium has been lumped with other ores and minerals under the general heading "MIscellaneous minerals," in the table on page 4. The copper ore from this property,as well as the gold and silver, are included in the appropriate places in the tables on pages 3, 5, and 21. The general geology and mineral composition of this lode has been described by Mertie,[5] who states that the country rock is a basic intrusive igneous rock (pyroxenite), in which the ore minerals are distributed in grains and small patches as ore shoots, but that the ore deposit was formed later than the inclosing rock.

Nowhere in Alaska have the platinum metals been found in placers in sufficient quantities to make their recovery for themselves alone profitable. Platinum metals, however, were obtained from concentrates that were recovered from gold placer mining operations on Dime Creek in the Koyuk district of Seward Peninsula; on Slate Creek in the Chistochina district, Copper River basin; on Granite Creek in the Ruby district; and on Metal Creek in the Kenai Peninsula. Altogether 28 ounces of crude platinum metals, equivalent to 21.98 ounces of fine platinum metals, was recovered from these placer deposits. The value of these metals, computed as worth $118 for each fine ounce, is $2,594. This production is somewhat less than that in the last few years, for in 1921, 1922, and 1923 the production of fine platinum metals from these placers was 40, 28.3, and 25.9 ounces, respectively.

The bedrock source of the platinum metals found in the placers is not definitely known, though it was probably in the basic igneous rocks, usually of dark-green color and of high specific gravity. The discovery of the bedrock source is not likely unless search is specially directed toward this object. When it is remembered that in the Dime Creek region only about 1 ounce of platinum is found to 125 to 300 ounces of gold, the carefulness with which the search must be conducted will be apparent. This same general relation between the platinum metals and gold prevails in the other placer platinum deposits of Alaska.

MISCELLANEOUS METALS

The demand that arose during the war for many of the less common ores has subsided to such an extent that practically none of the Alaskan deposits of such minerals as those containing antimony, tungsten, chromium, and molybdenum shipped any ore during 1924. A small production of quicksilver from the Thrift mine, in the Iditarod-Kuskokwim region, was reported. This mine is about 23 miles north of the Crooked Creek landing on Kuskokwim River. The old furnace, which had four tubes, broke down soon after it was started late in 1924, but all the equipment necessary for the construc-

[5] Mertie, J. B., jr., Lode mining in the Juneau and Ketchikan districts: U. S. Geol. Survey Bull. 714, pp. 121–127, 1921.

tion of a new12-tube mill, with a rated capacityof 5 tons a day, has been delivered and will be installed as soon as possible next season. Developments at the mine are reported to .be progressing satisfactorily, and the ore at the depth reached by the shaft that is being sunk is said to be fully as good as that found near the surface.

Buddington reports that some prospecting was done on several molybdenite claims at various places on Lemesurier Island in Cross Sound, southeastern Alaska, especially near Willoughby Cove. Fuller notes on the geology of these deposits is given in the report by Buddington in a later chapter of this bulletin. Interest has continued in the prospecting and development of some nickel-bearing deposits on Chichagof, Baranof, and Yakobi Islands. These deposits were recently described by Buddington,[6] who states that most of the deposits are associated with basio intrusive igneous rocks (norite, gabbro} and that the geology of the region adjacent to some of the deposits bears a close similarity to that of the great nickel deposits at Sudbury, Ontario. No nickel ore·from these mines, 'however, was reported to have been smelted in 1924.

Development work is reported to have been continued on a bismuth-bearing lode in the hills on Eva Creek, Nenana district, a few miles east of the railroad.

COAL

The most extensive coal mining in Alaska was in the Matanuska and Healy River fields, adjacent to the Alaska Railroad. The coals that are being mined in the Matanuska field are high-grade bituminous coals, whereas those mined in the Healy River neld are lignites, Four mines in the Matanuskafield and two in the Healy River field reported some production of coal during the year. In addition, a small amount of subbituminous coal was mined by Eskimos from outcrops along the shores of Wainwright Inlet in northern Alaska, and a little lignite was mined for local use on KugrukRiver in Seward Peninsula. The total coal produced from all these sources was 99,663 tons, valued at approximately $600,000. Too great reliance should not be placed on the statement of the value, for the prices used in the computations were based in part on the contracts placed by the Alaska Railroad for relatively large orders. For the fiscal year 1924 the railroad bought over 60,000 tons of coal of all grades, from all nelds, at an average price of $5.63 a ton, and the contract prices for coal from theMatanuskaneld for the fiscal year 1925 were $7.50, $5.80, and $5.25 a ton, respectively, for lump, fine,

[6] Buddington, A. F., Mineral investigations in southeastern Alaska: U. S. Gool. SUrvey Bull. 773, pp. 95-113, 1925.

and steam sizes, and for coal from the Healy River field $4.25, $3.50, and $2.50, respectively, for similar sizes.

In spite of the fact that Alaska contains vast stores of coal and in spite of the fact that many of the coal mines could produce each year more coal than they now do, a great deal of the local market is still supplied by coals imported mainly from British Columbia and from the State of Washington. In 1924 nearly 45 per cent of the coal used in Alaska was imported. If the amount of coal used in the maintenance of the Alaska Railroad is deducted from the total amount used in the Territory it will be seen that the present Alaskan production is practically the same as it was six or eight years ago, before the railroad was built, and that about the same amount of coal was imported then as now.

Coal produced and consumed in Alaska, 1880–1924

Year	Produced in Alaska, chiefly subbituminous and lignite		Imported from States, chiefly bituminous coal from Washington • (short tons)	Imported from foreign countries, chiefly bituminous coal from British Columbia • (short tons)	Total coal consumed (short tons)
	Short tons	Value			
	71,633	$456,993	679,844	1,079,735	1,814,047
	12,676	57,412	44,934	53,672	111,282
	54,275	268,438	58,116	56,589	168,980
	75,816	413,870	51,520	37,986	165,322
	60,894	345,617	57,166	48,708	166,768
	61,111	355,668	38,128	45,264	144,503
	76,817	496,394	24,278	33,776	134,871
	79,275	430,639	28,457	34,251	141,983
	119,826	755,469	34,082	43,205	197,113
	99,663	559,980	40,161	41,980	181,804
	711,986	4,140,480	1,056,686	1,475,166	3,226,673

• Compiled from Monthly Summary of Foreign Commerce of the United States, 1905–1924, Bureau of Foreign and Domestic Commerce. No figures on imports before 1899 are available.

Some exploratory work was done during the year on the high-grade coal of the Matanuska and Bering River fields, though none of this coal was marketed. S. R. Capps, of the Geological Survey, who studied the coal fields of the upper Matanuska Valley, reports that the coal-bearing area on the south flank of Anthracite Ridge contains beds carrying excellent anthracite coal, which is exposed at many places. At a place on the head of West Fork of Purinton Creek a bed of anthracite nearly 40 feet thick crops out. In this area, however, the coal-bearing formation is highly disturbed by folding, crumpling, and faulting, as well as intruded by bodies of igneous rock, such as dikes and sills. The coal beds appear to lie in synclinal basins, most of the upper part of the folds having been removed by erosion. These beds no doubt contain considerable anthracite coal of high grade, but whether the beds are sufficiently large and continuous to justify the expense of mining is uncertain in view of the cost of building a railroad to the area. Very little prospecting has been done on the anthracite beds, and whether they include workable bodies of coal can be proved only by extensive exploration, both on the surface and underground. The complete report by Mr. Capps is now awaiting publication by the Survey, but no definite date for its issue can yet be set.

The parties engaged in exploring Naval Petroleum Reserve No. 4 in northern Alaska in 1924 report a great extension of the coal fields previously known in the coastal region near Cape Lisburne. The coal-bearing rocks extend eastward through the central part of the reserve and evidently carry an enormous quantity of bituminous or subbituminous coal.

Some idea of the amount of coal available may be obtained from the measurements on Kukpowruk and Utukok rivers, where of 69 coal outcrops 30 contained minable beds of coal 3 feet or more thick and aggregating 187 feet of coal. This region is so remote that there is little likelihood of any of its coal being used in the near future except locally. However, in a region where trees are entirely absent this fuel has a special value, and the coal will doubtless play an important part in making possible the development of any oil resources that may be discovered in the region. A comprehensive report on the coals, as well as the other geologic information on this northern country, is in preparation, but it will probably be a year or more before it is published. A statement regarding the results of the work done in the region in 1923, however, has been printed,[7] and a summary statement which deals mainly with the possibilities of the presence of oil forms another chapter of this bulletin.

PETROLEUM

The Katalla field, situated near the south-central coast of Alaska, still continues to be the only producing oil field of the Territory. The oil produced here in 1924 came from 16 small wells, all on patented claims owned by the Chilkat Oil Co. The oil is refined at the company's own plant and is marketed in the form of gasoline and distillate, which has a ready sale and is said to be of especially high grade. No new wells were completed and no old wells were abandoned during the year. The quantity and value of the petroleum produced has been included in the table on pages 3-4, under the heading "Miscellaneous mineral products."

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[7] Paige, Sidney, Foran, W. T., and Gilluly, James, A reconnaissance of the Point Barrow region, Alaska: U. S. Geol. Survey Bull. 772, v, 33 pp., 9 pls., 1925.

Petroleum products shipped to Alaska from other parts of the United States, 1905–1924, in gallons [a]

Year	Heavy oils, including crude oil, gas oil, residuum, etc.	Gasoline, including all lighter products of distillation	Illuminating oil	Lubricating oil
1905	2,715,974	713,496	627,391	83,319
1906	2,688,940	580,978	568,033	83,992
1907	9,104,300	636,881	510,145	100,145
1908	11,891,375	939,424	566,598	94,542
1909	14,119,102	746,930	531,727	85,687
1910	19,143,091	788,154	620,972	104,512
1911	20,878,843	1,238,865	423,750	100,141
1912	15,523,555	2,736,739	672,176	154,565
1913	15,682,412	1,735,658	661,656	150,918
1914	18,601,384	2,878,723	731,146	191,876
1915	16,910,012	2,413,962	513,075	271,981
1916	23,555,811	2,844,801	732,369	373,046
1917	23,971,114	3,256,870	750,238	465,693
1918	24,379,566	1,086,852	382,186	362,413
1919	18,784,013	1,007,073	3,515,746	977,703
1920	21,981,569	1,764,302	887,942	412,107
1921	9,209,102	1,403,683	2,021,033	232,784
1922	15,441,542	1,436,050	2,095,675	345,400
1923	12,285,808	4,882,015	473,826	454,090
1924	14,412,120	5,554,859	566,431	506,364
	311,279,633	38,646,315	17,852,115	5,551,278

[a] Compiled from Monthly Summary of Foreign Commerce of the United States, 1905 to 1924, Bureau of Foreign and Domestic Commerce.

The search for oil in the Alaska Peninsula still continues. W. R. Smith, of the Geological Survey, who visited this region during the field season of 1924, reports that drilling in the Cold Bay district was continued on the Pearl Creek dome by the Standard Oil Co. of California, whose Lee No. 1 well had been drilled to a depth of 3,017 feet, where it struck a rather strong flow of water and some gas. The Associated Oil Co. suspended drilling at a depth of 950 feet in June, 1923, but renewed operations in June, 1924, and continued drilling during the remainder of the year. The latest reported depth of the Associated well is 2,170 feet. Although drilling has been carried on with difficulty at considerable expense, and to a greater depth than was at first considered necessary, both wells have given showings of oil, and the companies expect to test the dome thoroughly. The Government road from Kanatak to Becharof Lake was completed late in the fall of 1923 and was used during the summer of 1924 by the operating companies. The new road does not shorten the distance to the wells, but it avoids a hard climb over the mountains. A few claims were surveyed during the summer. A more complete statement by W. R. Smith regarding the geology and oil developments in this region, accompanied by a structure contour map of the Salmon Creek-Bear Creek anticline, forms a later chapter of this bulletin.

The search for oil in Naval Petroleum Reserve No. 4, in the extreme northern part of Alaska, is still being continued by the Government through parties sellt out by the Geological Survey. A report[8] covering the work of the Survey parties in 1923 in the region has already been printed, but the results obtained in 1924 will be included with the. work of parties now in the field and will not be published in separate form. The interest in this northern field, however, has led to the preparation of a summary statement of the present knowledge regarding the possibilities of the. presence of petroleum in the region, and this statement forms a separate chapter of this volume.

STRUCTURAL MATERIALS

Shipments of marble from southeastern Alaska began in 1902, and since 1904 quarrying has been an important industry. Most of the marble produced has come from the north end ·of Prince of Wales Island, where the only large quarries (those of the Vermont Marble Co.) are located. Th'ere are, however, many other places in southeastern Alaska where marble has been found. The broad geologic relations of some of these other localities for marble and -limestone are discussed in a paper by A. F. Buddington, which forms a chapter of this bulletin. The value of the marble produced in 1924 was somewhat greater than in 1923.

The only commercial deposit of gypsum which has been found in Alaska is on the eastern shore of Chichagof Island, in the Sitka district. Gypsum has been quarried at this place every year since 1906, but the mine then operated by the Pacific Coast Gypsum Co. was closed down in December, 1923, and remained idle until August; 1924, when it was taken over by the Standard Gypsum Co. Since that time the main activity has consisted in prospecting the ground and laying out plans for a new mill and the development of the mine. For these reasons the production in 1924 was very much less than in the preceding year.

[8] Paige, Sidney, Foran, W. T., and Gilluly, James, op. cit.

ADMINISTRATIVE REPORT

By PHILIP S. SMITH

REVIEW OF THE WORK OF THE YEAR

Systematic investigations and surveys of Alaskan mineral resources have been carried on uninterruptedly by the Geological. Survey since 1898, and even before that year some of the geologists and engineers of the Survey had been assigned to special investigations within the Territory. During this period of more than a quarter of a century about two-fifths of Alaska has been mapped and all the larger known mineral deposits have been studied to some extent. Practically all of this work was organized, administered, and largely participated in by Alfred H. Brooks, chief Alaskan geologist, who died suddenly November 22, 1924. Mr. Brooks, through his long experience, sympathetic understanding of the problems of the mineral industry in a frontier country, and broad technical knowledge, was in large measure personally responsible for the application of sound scientific principles to the search for and development of the Territory's mineral resources. S. R. Capps served as acting chief Alaskan geologist after the death of Mr. Brooks until March 31, 1925, and on April 1, 1925, Philip S. Smith was designated to take charge of the branch.

The following table indicates the areas that have been geologically and topographically mapped by the Geological Survey. The figures, of course, do not include any surveys in Alaska conducted by other Government organizations.

Areas surveyed by Geological Survey in Alaska, 1898-1925, *in square miles*

Fiscal year	Areas covered by geologic surveys			Areas covered by topographic surveys		
	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; 2oo-foot contours)	Detailed (scale 1:62,500; 25.50, or 100 foot contours)
1898-1924	73. 200	123. 665	5, 657	51.680	163.430	3,936
1925	4.300	18.590	190	4.300	17.470	130
	77,500	142, 255	5,847	55, 980	180, 000	4,066
Percentage of total area of Alaska	39			41		

In this summary table only the net areas surveyed in earlier years are given. Furthermore, an area that has been surveyed on more than one scale is tabulated only in the column for the largest scale on which it has been mapped. For instance, the region adjacent to Nome, which in the early days was surveyed on an exploratory scale, later mapped on a reconnaissance scale, and still later on a detailed scale, is reported only as covered by detailed mapping. Therefore there is no duplication of areas reported under the different kinds of geologic or topographic surveys. On the whole, the areas covered by geologic surveys are coincident with those covered by topographic surveys, so that nearly two-thirds of the Territory has not yet been mapped by the Geological Survey.

Many of the surveys and investigations of Alaskan mineral resources, however, do not readily lend themselves to tabulation in terms of area or other intercomparable units of measurement. Among such studies may be mentioned the collection of statistics regarding the annual production of the different ores and minerals or the bringing together in one report all available data regarding the known oil or coal resources of the Territory. Furthermore, for several years the Geological Survey conducted investigations relating to the water resources of the Territory, maintaining at times as many as 80 gaging stations and making each year several hundred stream measurements.

The funds directly appropriated for the Survey's Alaskan work that were available for the fiscal year 1925 comprised $75,000 carried in the Interior Department bill for 1925, which became immediately available on the signing of the act, June 5, 1924, and $72,000 carried in the Interior Department appropriation act for the fiscal year 1926, which became available March 3, 1925. In addition a transfer of funds amounting to $75,000 was made available to the Survey by the Navy Department for the continuation of the investigation of Naval Petroleum Reserve *No. 4*, in northern Alaska. Two of these appropriations were legally available for expenditure and some money was expended from both during the fiscal year 1924; all three of them were available and used to pay for expenses during the fiscal year 1925; and the balance of the Navy funds and the regular 1926 appropriation are available for expenditures during the fiscal year 1926. The expenditures from all these funds have been accounted for under the methods and procedure laid down by law or by the regulations of the Treasury Department, but these methods do not lend themselves to showing the costs during a field season or concerning individual projects. The labor and expense of determining the precise expenditures for the different jobs by years would far exceed the value of the resulting analysis, and therefore these expenditures have not been accurately computed. The following statements give only in round figures the principal uses to which the funds were put during the fiscal year 1925. The amount expended in starting off the parties in advance of the beginning of the fiscal year in the field season of 1924 practically offset the amount used to start the parties at the end of the fiscal year 1925 to begin the work of the field season of 1925. Thus, except for the work financed by the Navy Department, which will be analyzed separately, the funds used for the fiscal year 1925 were $75,000.

The following table shows the approximate allotment for salaries and field and office expenses for the fiscal year 1925:

Expenditures from funds directly appropriated for Survey's work in Alaska

Branch administration	$3,850
Other technical salaries	21,750
Branch clerical and drafting salaries	5,400
Services rendered by other Survey units, including editing, duplicating-machine service, accounting, and other services	7,000
Office expenses, stationery, telegrams, photography, and other expenses	2,000
Field expenses	28,000
Airplane mapping by Navy Department	7,000
	75,000

An analysis of the allotment of the $75,000 transferred to the Geological Survey by the Department of the Navy is as follows:

Allocation of funds for surveys in Naval Petroleum Reserve No. 4, northern Alaska

Administration	$2,500
Other technical salaries	17,100
Clerical and drafting salaries	3,300
Services rendered by other Survey units, including editing, accounting, instruments, and other services	2,900
Office expenses, including stationery, photography, telegrams, and other expenses	900
Field expenses	36,000
Allotted to work in progress for fiscal year 1926	11,000
Balance for contingencies	1,300
	75,000

The items in the table regarding Alaskan branch expenditures for "other technical salaries, field expenses, airplane mapping," and $1,500 of the item for clerical salaries, amounting in all to $58,250, have been allotted for the different kinds of surveys and investigations in progress during the fiscal year 1925, as follows:

General investigations	$3,750
Geologic surveys	33,400
Topographic surveys	19,150
Statistics of mineral production	1,950
	58,250

It has been impossible to show accurately in the foregoing table the expense that should appropriately be distributed to topographic and geologic surveys, for two parties were engaged in work of both kinds. Each of these parties cost between $6,000 and $7,000, and their principal work was topographic mapping, so that, except for the geologists' salaries and a few hundred dollars spent for their traveling and subsistence, the whole amount might properly be included in the item for topographic surveys. On the other hand, the parties obtained many geologic data that could not have been obtained by separate geologic parties except at an additional expense of at least $3,000 a party. In spite of the uncertainty, it has seemed best to divide the field expenses of both parties equally between topographic and geologic surveys, though by so doing geologic surveys bear perhaps an unduly heavy charge; or, to state the matter in another way, the economy of $6,000 to $7,000 effected by attaching geologists to the. topographic parties is not adequately reflected by the table.

The different kinds of work reported in the foregoing table were carried on in many parts of Alaska. The following table indicates the approximate distribution of the work by geographic divisions for the fiscal year:

General investigations	$3,750
Southeastern Alaska	16,750
Prince William Sound	8,300
Matanuska region	5,150
Southwestern Alaska	9, 775
Mount McKinley region	3,150
Nixon Fork,region	6,800
Upper Yukon	2,625
Statistics of mineral production (inclUding $1,500 for clerical saries)	1,950
	58,250

The work that has been segregated in the two preceding tables under the heading" General investigations" comprises four separate studies. One was the study of the broader aspects of the general geologic history of Alaska as affording an insight into the origin and distribution of mineralization. This work was carried on by Alfred H. Brooks and is part of a comprehensive study to which all the detailed investigations have contributed. The field areas specially visited during the year were in southeastern Alaska, in the Prince William Sound region, and in the country adjacent to the Alaska Railroad. A little time was devoted by James McCormick to his revision of the "Geographic dictionary of Alaska," a valuable Survey publication issued in 1906, which has been out of stock for many years. The other two projects were paleontologic investigations required in correlating the fossils brought in by the different geologists from their field investigations. The study of the fossil flora of the Tertiary rocks, to which Arthur Hollick devoted about three months, is of special importance in correctly interpreting certain of the coal formations. The other paleontologic studies related principally to the older rocks, mainly Paleozoic, and were of great value in furnishing data used by the geologists in investigating deposits of metalliferous minerals.

Five distinct projects were undertaken in southeastern Alaska, two of which were executed during the field season of 1924 and the others during the field season of 1925. In the field season of 1924 A. F. Buddington continued geologic studies in the Ketchikan and Wrangell. regions, visiting many of the mines and prospects, including those in the Hyder district, at the head of Portland Canal. He collected many new data regarding the general geology of southeastern Alaska in relation to the ore deposits and did additional reconnaissance geologic mapping, especially on the southwest coast of Prince of Wales Island. A summary of the results of his work appears as a separate chapter in this volume.

In the same season R. M. Wilson continued the detailed topographic mapping of the Hyder district that had been started during the preceding fiscal year by E. S. Rickard, who was injured in the course of his duty in the field. The field surveys were completed, and after the office work, which required thecomplitation of numerous topographic data from photographs, was finished, Mr. Wilson returned to his former duties with the topographic branch.

For the field' season of 1925 Mr. Buddington has been detailed to map the geology of the hitherto unsurveyed areas in the extreme southwestern part of the Ketchikan region and then to do the detailed' geologic surveying of the area topographically mapped by Mr. Wilson in the Hyder district. Only a portion of this workwill be completed during the fiscal year, but it will be continued in the next fiscal year.[1]

R. K. Lyntleft late in May, 1925, to do some reconnaissance topographic mapping in the Ketchikan district and then to join a party of surveyors from the General Land Office who are carrying on subdivisional surveys in the vicinity of Wrangell Narrows, where Mr. Lynt will make a detailed topographic map.

Negotiations have been in progress for several months with the Air Service of the War Department and later with the Buteau of Aeronautics of the Navy Department for the airplane photographing of the islands of southeastern Alaska, in the belief that the resulting prints would greatly expedite the topographic mapping

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1 The reader's attention is called to the fact that this report was written and submitted as: of June 30, 1925. Many of the projects which, are mentioned as in progress will have been completed before this report is issued, since considerable delay in printing is unavoidable.

of the region and facilitate determination of the geology and mineral resources. The Navy Department agreed to do this work, and $7,000 was turned over to it for that purpose under the fortifications act. The work will be done as soon as the necessary preparations can be completed. No field operations have been in progress this year under this grant, but ultimately it will furnish photographs of probably 18,000 square miles. It is hoped that this aerial survey may be the forerunner of surveys in some of the coastal tracts in other parts of Alaska that are traversable on foot with great difficulty and at a cost so high that their survey is not warranted under present conditions.

In the Prince William Sound region F. H. Moffit continued during the field season of 1924 the study of the ore deposits and related geology of the western part of the Sound and visited Valdez, Cordova, and the Kennicott region, in the Copper River basin, for the purpose of keeping in touch with recent developments bearing on mineral resources; he returned to Washington in the fall to work up his field notes. Mr. Moffit again left for the same general region in May, 1925, and will continue the reconnaissance geologic mapping not only to the end of this fiscal year but also into the next.

S. R. Capps spent the field season of 1924 in the upper Matanuska region, with K. K. Landes as geologic assistant, mapping in detail the extension of the coal-bearing rocks and determining the geologic history of the region as it bears on the other mineral resources of that area. Mr. Capps has completed a manuscript report on this work which is now in hand for critical examination with a view to its publication as a bulletin. Late in this fiscal year, in the field season of 1925, Mr. Landes was assigned to complete the reconnaissance geologic mapping of an unsurveyed area between Matanuska and Knik rivers that is known to hold promise of deposits of metallic minerals of value, and the results of his work will probably throw light on the general geology of a large tract of contiguous territory.

In southwestern Alaska during the field season of 1924 W. R. Smith carried on reconnaissance geologic mapping of an area previously topographically surveyed in the Cold Bay region. This region is a part of the Alaska Peninsula where geologic indications favorable for the accumulation of oil pools have been reported and considerable activity has been displayed in prospecting. A preliminary report on the geology and mineral resources of the region forms part of this bulletin. In February, 1925, Mr. Smith left Washington to serve as geologist in the explorations being conducted in northern Alaska in Naval Petroleum Reserve No. 4.

In the field season of 1925 R. H. Sargent, topographer, and R. S. Knappen, geologist, will continue previous surveys of Alaska Peninsula southwestward from a point near Cold Bay to Chignik. It is expected that these surveys will practically complete the reconnaissance examination of the probable oil-bearing areas of the peninsula, as farther west igneous rocks probably form most of the country.

The surveys in the Nixon Fork region of the Kuskokwim were in charge of R.H. Sargent, with J. S. Brown, geologist. These surveys were made during the field season of 1924. A general description of the geology of the region has been prepared and transmitted for publication as part of this volume.

A geologic reconnaissance party in charge of S. R. Capps during the field season of 1925 examined the country adjacent to Mount McKinley, especially those parts which, from earlier exploratory surveys and reports of prospectors, are believed to contain metallic minerals of value. In addition to these surveys Mr. Capps win probably visit some of the mining camps in the Kantishna and Chulitna districts to obtain data on recent mining developments.

J. B. Mertie, jr., for all of the fiscal year until April, 1925, was engaged in naval petroleum work in northern Alaska. In May, 1925, he left Washington to carryon geologic investigations in the region lying on both sides of Yukon River westward from the international boundary as far as Circle. Although his party win study many places that have not been hitherto examined by Survey geologists, the main purpose of the work is to correlate all the observations that have been made in the region, some of which are not in accord and most of which have not been reviewed in the light of more complete and detailed geologic information that has been accumulated both from this region and from other parts of the Territory since the original observations were made.

All the projects above described that were started late in this fiscal year during the field season of 1925 will be continued into the fiscal year 1926. Most of the parties are out of reach of ordinary means of communication, so that it is not possible at this time to state just what part of the different projects each accomplished this fiscal year. On the whole, however, much of the time will have been spent in getting to the field and starting the work, so that at most each party has spent less than a month in actual surveys. In other words, as the usual field season is about a hundred days, the parties have probably completed approximately one-quarter of the field work of their respective projects during the fiscal year.

The geologic and topographic work done by the Survey for the Navy Department in Naval Petroleum Reserve *No. 4* commenced with the dispatch of three parties to northern Alaska as early as possible in 1923. On the completion of the field work the scientific and technical personnel returned to 'Vashington and spent the winter and spring in compiling their maps and reports. This report has been printed and is now available for distribution. While the parties that worked in 1923 were still engaged in this office work two other parties, in charge of Philip S. Smith, with J. B. Mertie, jr., geologist, and Gerald FitzGerald and R. K. Lynt, topographers, left Washington in January, 1924, and carried on surveys from the areas hitherto mapped in the Koyukuk Basin into the unmapped region in the southern and eastern parts of the reserve. These parties completed their field work at Barrow late in August and returned to Washington to prepare their maps and reports.

During the open season of 1924 W. T. Foran, geologist, and O. L. Wix, topographer, went by sea to Wainwright and thence surveyed a strip of country in the western and southern parts of the reserve and tied with earlier surveys of Noatak River, returning to Washington at the end of the field work. On completion of Mr. Foran's work he left the Survey to accept employment with an oil company in South America, and Mr. Wix returned to the topographic branch.

In February, 1925, another party in charge of Gerald FitzGerald, topographer, with W. R. Smith as geologist, left Washington to carryon further surveys in the southern part of the reserve. This party has been entirely out of reach of mail or even telegraph since early in April, so that the precise areas covered during this fiscal year can not be learned until they return in the fall. It is expected, however, that they will have covered much of the mountain region lying between Noatak River and the streams flowing northward into the Arctic Ocean from a point near the Kugururok to the Aniuk. It is planned that they will return to Washington in October and will then complete their maps and reports.

FUTURE WORK

Although the Survey's work in Alaska has been largely instrumental in furnishing a basis on which not only the mineral industry but also other industries might proceed with assurance as to soundness of the information furnished, it has covered only a little more than a third of the Territory with maps and reports that are at least of exploratory standard. There remains over 350,000 square miles that ultimately should be surveyed, but of this area about one-half is of such character that its survey in the near future does not seem warranted if weighed against the probability of finding profitable mineral deposits in it. However, there are areas aggregating nearly 200,000 square miles of now unmapped territory that should be surveyed as soon as funds and personnel are available. Among these areas southeastern Alaska is probably the most important and should receive early attention. In addition to containing metallic and nonmetallic minerals of commercial value, it also contains enormous water-power resources that will be of great value in the development of the mineral industry and in the utilization of the forest products. Next in order of importance is the completion of surveys in the broad arc of the Alaska Range and contiguous territory. This work would not only bear directly on the search for mineral deposits but also, because much of the area is in the general vicinity of the Alaska Railroad, it should indirectly contribute to the success of that Government enterprise. In northern Alaska the mountain and highland belt, which is from 100 to 300 miles wide and which stretches from the international boundary to the Arctic Ocean on the west, a distance of 500 miles, though it has only here and there" been surveyed, shows indications that give foundation for the belief that valuable mineral deposits occur in it and that assistance in finding these deposits can be afforded by a thorough understanding of the geology of the region.

In addition to the distinctly areal surveys, there is also need for comprehensive studies and reports on the various larger problems relating to the different mineral resources, such as gold and copper. Already reports on the tin, coal, oil, and antimony deposits of Alaska have been published, and similar reports should be undertaken for many of the other metallic and nonmetallic minerals. The accumulation of data regarding. much of the Territory has now reached a stage where the compilation of a general geologic map of the Territory is warranted. A start has been made in the correlation and compilation of all the available geologic information relating to the country adjacent to the Alaska Railroad, and a similar compilation of the data relating to southeastern Alaska is in progress. Enterprises of this sort not only focus attention on the areas in which mineral deposits of value may be sought with some probability of success but. also serve to mark out those areas where the geologic conditions indicate that there is small likelihood of certain types of deposits and thus prevent the useless waste of further time and money.

MINERAL INVESTIGATIONS IN SOUTHEASTERN ALASKA

By A. F. BUDDINGTON

INTRODUCTION

In the Sitka district the continued operation of the Chicagoii' and Hirst-Chicagof gold mines and the installation, and operation of a new mill at the Apex-EI Nido property in 1924, all on Chichagof Island, have stimulated a renewed interest in prospecting for gold ores.

In the Juneau district a belt of metamorphic rock, which extends from Funter Bay to Hawk Inlet on Admiralty Island and contains a great number of large, well-defined quartz fissure veins, was being prospected on the properties of the Admiralty-Alaska Gold Mining Co. and the Alaska-Dano Co. on Funter Bay and of Charles Williams and others on Hawk Inlet. The Admiralty-Alaska Co. was driving a long tunnel which is designed to cut at depth several large quartz veins. On the Charles Williams property a long shoot of ore has been proved on one vein and a large quantityo:f quartz that assays low in gold.

In the Wrangell district the only property being prospected during .1924 to an extent greater than that required for assessment work was the silver-lead vein on the Lake claims, east of Wrangell.

In the Ketchikan district; as reported, the Dunton gold mine,near Hollis, was operated during 1924 by the Kasaan Gold Co. and the Salt Chuck palladium-copper mine by the Alaskan Palladium Co., and development work on a copper prospect was being carried on at Lake Bay.

In the Hyder district the outstanding feature for 1924 has been the development of ore shoots at the Riverside property to the stage which has been deemed sufficient to warrant construction of a 50-ton millto treat the ore by a combination of tables an.d flotation. The valuable metals in the ore are gold, silver, and lead. Development work was being carried forward on-the Daly-Alaska property, and good ore shoots are reported to have been found in crosscuts. On Fish Creek the Rovland group was in process of. development by

Arthur Moll, and associates, of Ketchikan, and it is reported that a tunnel will be started on the Fish Creek property. On Texas Creek several new discoveries of gold-silver-lead veins have been made. The Forest Service expects to have a pack trail for horses completed to the Chickamin Glacier by fall.

GOLD PROSPECTS

FUNTER BAY TO HAWK INLET, ADMIRALTY ISLAND

General geology.-A belt of schist and phyllite, with a great number of well-defined quartz fissure veins, extends for about 7 miles from Funter Bay to Hawk Inlet, on Admiralty Island. On the Funter Bay side of Mount Robert Barron the veins of this belt were being prospected on the properties of the Admiralty-Alaska and Alaska-Dano companies (Nowell-Otterson) and on the Hawk Inlet side by Charles Williams and others. Funter Bay is on the north endo! Admiralty Island, about 18 miles west of Juneau in a direct line, but 50 miles by water route. Hawk Inlet is about 13 miles south of Funter Bay. Both inlets have deep water to the head and afford favorable sites for docks in many places. A range of mountains extends from Funter Bay to Hawk Inlet with a maximum altitude of 3,450 feet on Mount Robert Barron. The slopes are forested to an altitude of about 2,500 feet, and there is adequate timber for mining uses. The mineralized belt on Funter Bay has been previously described by Wright,[1] Eakin,[2] and Mertie.[3]

The schists include three general types-greenstone schists, light-colored micaceous quartz schist, and black crinkled graphitic phyllite.

The greenstone schists form the predominant country rock in the Funter Bay area. Mertie describes them as comprising chlorite schist, mica schist, quartz-chlorite schist, quartz-chlorite-mica schist, zoisite-chlorite schist, albite-zoisite schist, albite-chlorite schist, and albite-mica schist. A specimen of the rock from the face of the tunnel on the Admiralty-Alaska property, 2,200 feet from the portal, consists of quartz, epidote, chlorite, and albite, with a little calcite, zoisite, actinolite, titanite, and apatite.

Quartz schist with mica along the foliation planes is the country rock north-northwest and northwest of the main camp on the Charles Williams property, including the summit ridge. At Funter Bay similar schist appears to overlie the greenstone schists and come in

[1] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pp. 141-150, 1906.

[2] Eakin, H. M., Lode Illining in the Juneau gold belt: U. S. GeoL Survey Bull. 662, pp. 84-92, 1917.

[3] Mertie, J. B., Lode mining in the Juneau and Ketchikan districts: U. S. Geol. Survey Bull. 114, pp. 11'3-118, 1921.

just above the Heckler blanket vein on the Admiralty-Alaska property, at an altitude of about 1,300 feet. The quartz schist is also present on the Alaska-Dano property. Black graphitic phyllite is intercalated in the quartz schist and greenish chloritic schist, in the beds near the greenstone schist contact. A typical specimen of the quartz schist was found to consist of quartz associated with considerable microperthite and with a little muscovite.

The phyllite forms the country rock on the Charles Williams property between the house on the shore and the main camp. "The beds uSllally consist of crinkled black graphitic phyllite with local slickensided and crumpled zones, intimately penetratedhy thin quartz seams. Both the quartz veins and the phyllite in many places show isoclinal plication.

Eakin[4] .states that the bedded rocks on the Admiralty-Alaska property in general. lie in broad and gentle folds, though locally intense crumpling and close folding on a small scale are apparent, and that over considerable areas both schistosity and bedding are near the horizontal. The schists of the belt near Funter Bay have in part a northeast strike. At the southeast end of the Alaska-Dana property, on the other hand, the schists strike N. 20° W. and dip steeply eastward; on the Williams property they strike mainly between N. 20° W. and N. 10° E. and dip 40°-90° E.; and along Hawk Inlet, south of the Williams property, they strike from, N. 20° W. to N. 40° W.

Near Funter Bay there are two sets of quartz veins, one striking N.45°-60° E., and the other N. 20°-35° W., approximately parallel to the strike of the schists. On the Williams property the veins strike chiefly between N. 15° E. and N. 30° E., or 20° to 30° more to the east than, the schists and phyllites, and dip steeply eastward. The walls of the veins are very commonly slickensided. and polished.

In the Funter Bay area several varieties of igneous rock have been described by Mertie,[5] including albite granite, albite diorite, and albite trachyte. In the tunnel on the Admiralty-Alaska property there are dikes of sadie trachyte at 400 and 900 feet from the portal of the tunnel. At, the surface, about 100 feet southeast of the place where the air pipe line crosses the water ditch, there is a dike of highly altered diorite. This rock is completely recrystallized to an aggregate of uralite, zoisite, chlorite, and albite. Another,similar mass of intensely altered and recrystallized diorite is exposed along the ditch under the cable. Mertie[6] discusses, the significance of the sodic or albitic character of these rocks as follows:

This feature is of more than passing interest when considered in relation to the sodic character of the intrusive rock at the Treadwell mines, on Douglas

[4] Op. cit., p. 35. [5] Op. cit., pp. 114-115. [6] Op. cit., p. 115.

Island, about 15 miles to the east. It is not unlikely that mineralization at these two localities took place at the same general period and had a similar origin.

Eakin[7] gives the following description of the structural relations of the quartz veins:

Joint systems on both large and small scales cut the bedded rocks at high angles with the schistosity and bedding or near the vertical. The major joint planes in places persist for hundreds and even for a thousand feet or more with great regularity in strike and dip. Such large fractures were probably accompanied by some differential movement between the blocks which they separate, but there is no definite evidence of the maximum displacement. These planes are generally marked by quartz veins, which range in thickness, in the different individuals observed, from mere films to nearly 60 feet. At one locality four approximately parallel veins were measured in a section 330 feet across, whose thickness aggregated 90 feet. * * * T-shaped and L-shaped bends in some of the veins indicate differential movements amounting to at least the thickness of the veins. Other veins which gradually thin out to their ends do not have this significance. Faults later than the veins and offsetting them occur only here and there, according to present evidence.

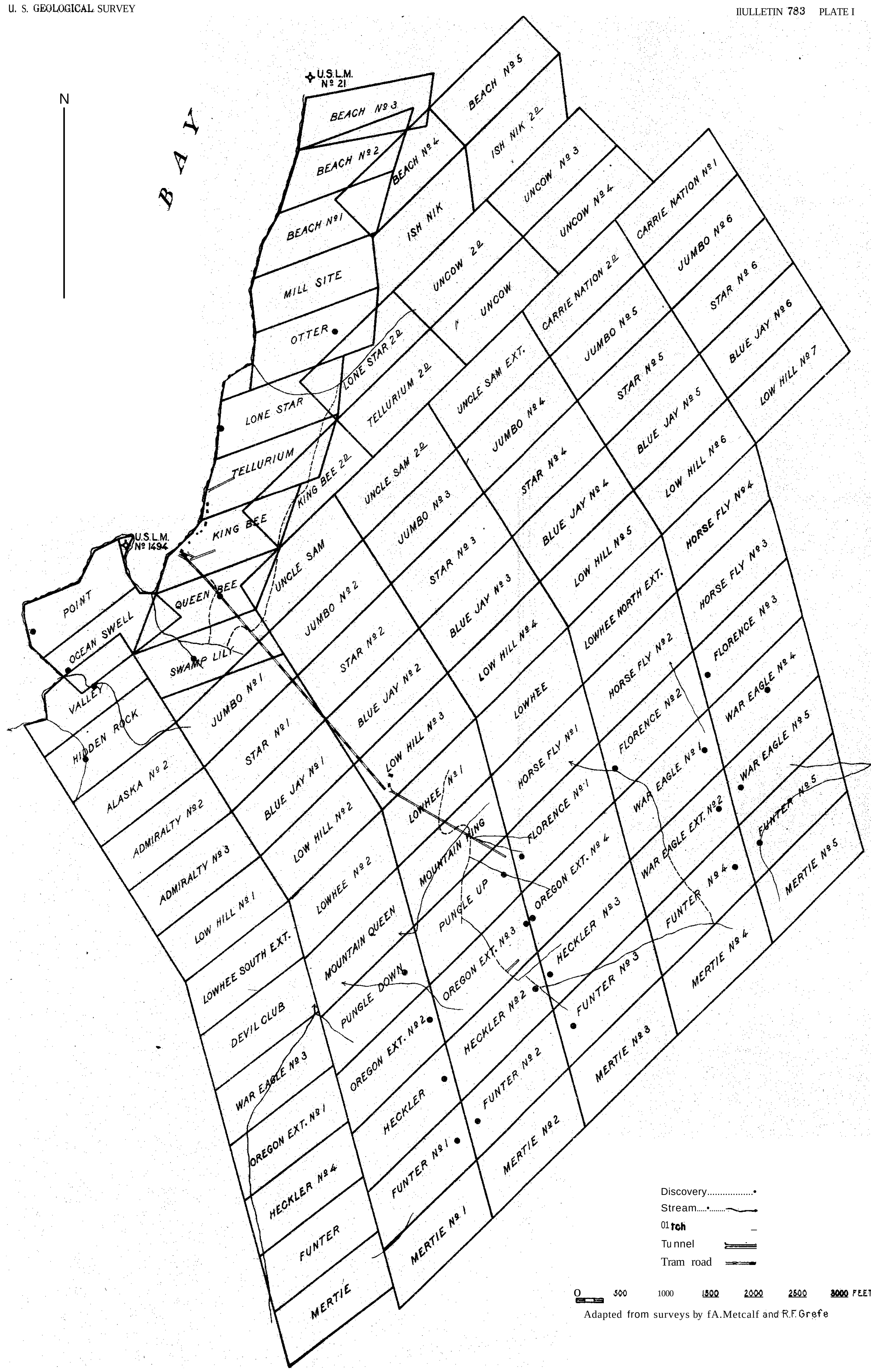
There are abundant quartz veins in this belt, and some of them are very large. Mertie[8] states that the Big Thing lode, on the Nowell-Otterson group, has been traced for a length of 2,300 feet and at one point is 20 feet wide. On the Williams property at the summit ridge there is also a vein which has been traced for over 2,000 feet and which has a width of 20 to 50 feet. Eakin[9] refers to a vein on the Heckler claims of the Admiralty-Alaska property, which has a width of 57 feet and is said to consist of ore.

Some of the large quartz veins have been proved to carry gold ore shoots of low or medium to high grade, and some to carry large quantities of quartz that assays low in gold.

In general the quartz is white, milky, and massive, but locally it shows comb or drusy structure and is associated with masses of iron-bearing carbonate (ankerite) or at the surface with limonite resulting from the weathering of the carbonate and sulphides. The auriferous quartz is commonly iron stained or sparsely metallized with one or more of the minerals pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, specular hematite, and native gold. Extensive, thorough, systematic assaying is necessary at present to distinguish the ore shoots from the barren or relatively barren portions of the vein.

Admiralty-Alaska property.-A claim map of the property of the Admiralty-Alaska Gold Mining Co., comprising some 100 claims, is shown in Plate 1. Since 1919, the time of Mertie's visit, the crosscut tunnel designed to intersect several big quartz veins has been extended to a point 2,200 feet from the portal. Probably it will be necessary to continue the tunnel for several hundred feet farther

[7] Op. cit., p. 85. [8] Op. cit., p. 117. [9] Op. cit., p. 91.



MAP SHOWING CLAIMS IN THE VICINITY OF FUNTER BAY, ALASKA to cut the veins. About 200 feet of exploratory drifts have been driven from the tunnel. The rock in which the tunnel is driven consists of several varieties of greenstone schist, with an intercalated zone of quartz and graphitic schists. The quartz and graphitic schists are full of small quartz seams and stringers parallel to the bedding and occur between 500 to 700 feet from the portal. The beds in general strike about at right angles to the tunnel (S. 60° E.) and dip gently southeastward, but they are cross folded and warped, with axes pitching southeastward, so that locally the schists strike parallel to the tUnnel and dip steeply. The country rock with small quartz stringers parallel to the cleavage is reported to carry only a very small amount of gold.

About 1,250 feet from the tunnel portal the Lowhee vein was cut and drifted upon for 100 feet N. 60° E. This vein is 2 to 3 feet thick throughout the drift but pinches to a thin facing of the fracture in the breast of the drift. In the roof of the tunnel the vein pinches, and its extension to the southwest appears to be indicated by bunches of quartz which are exposed in a short drift. The vein matter shows very sparse sulphides, including pyrite, pyrrhotite, chalcopyrite, and galena in a gangue of quartz. The vein is reported to average $4 to the ton in gold.

At about 2,100 feet from the portal there is a seam of almost solid pyrrhotite, which ranges from a fraction of an inch to 3 inches in width and has been traced for 100 feet. It passes into a quartz stringer and is itself associated with quartz. A specimen of this sulphide was examined for the nickel mineral pentlandite, but none was found.

At an altitude of about 1,200 feet a large open cut has been made on the Heckler blanket vein. At the top of the cut this vein is 6 inches to a foot wide, but it widens downward and is reported to be 20 feet wide at the bottom of the cut. Quartz veins make offshoots into the footwall. The vein strikes northeastward and dips 50°-90° E. Aplite is reported to form the footwall and schist the hanging wall. The vein is of the fissure type and lies at an angle to the dip of the schist. The upper, narrow portion of the vein is reported to have given assays of $200 to $300 to the ton in gold, and specimens very rich in free gold have been obtained here. At the base of the open cut 5 feet of the vein, consisting of quartz and ankerite with many inclusions of the country rock that forms the hanging-wall portion of the vein, is reported to have averaged $10 in gold to the ton. The rest of the vein gave very low assays. The ankerite has sparse disseminated sulphides, including pyrite, pyrrhotite, chalcopyrite, and sphalerite. The rich vein matter at the top of the open cut is especially associated with sphalerite. Open spaces lined with quartz crystals and films of sericite are common in the quartz. Veinlets of sericite also occur in the ankerite.

On the War Eagle Extension claim No.2, at an altitude of about 1,650 to 1,700 feet, a dike of troctolite, locally containing disseminations of sulphide blebs, has been exposed by trenching. The sulphides consist predominantly of pyrrhotite with a little chalcopyrite and pentlandite, and a brief description of the ore occurrence is given iuan earier bulletin.[10] A somewhat more detailed descriptionis given here.

The dike rock consists of about 55 per cent labradorite, 39 per cent olivine, 4 per cent pyroxene, and 2 per cent magnetite. The magnetite occurs both as minute crystals disseminated in the olivine and as grains interstitial to the pyroxene. The olivine occurs as grains of early crystallization in a groundmass of labradorite with a diabasic texture. The pyroxene is wholly interstitial to the plagioclase. The olivine in places is partly to completely altered to aggregates of serpentine or talc and iron oxides. Carbonate, chlorite, actinolite, and biotite are present locally as secondary minerals. The serpentine and secondary minerals are of later origin than the sulphides. The sulphides form irregular-shaped blebs, locally in irregular veinlike forms for half an inch or so, interstitial to the silicate minerals. Generally the sulphides are molded against idiomorphic crystal faces of the silicates, but in places they corrode and partly replace the silicates. Magnetite of two generations is present, the older occurring as abundant minute euhedral crystals disseminated throughout the silicates and the younger as larger grains interstitial to the silicates or as crystals and grains on the outer borders of the sulphide blebs. Magnetite locally occurs as a group of crystals with perfect borders within the sulphides. In places it shows a little corrosion by the sulphides. Rarely pyrite crystals occur within the sulphide masses but are usually on their outer borders. The magnetite and pyrite were the first metallic minerals to crystallize. A little chalcopyrite is present. It is restricted almost exclusively to the outer borders of the sulphide blebs and assumes elongate narrow shapes, with one side against the silicates and rounded borders against the pyrrhotite. It appears to precede the pyrrhotite and pentlandite. The peIitlandite occurs as stringlike veinlets crossing the pyrrhotite and as fringes bordering the pyrrhotite blebs and has therefore crystallized later than the pyrrhotite. The sulphides, though showing an order of crystallization, are yet essentially contemporaneous and, taken as a whole, belong to a late stage in the consolidation of the dike magma and are themselves of magmatic origin.

[10] Buddington, A. F., Mineral investigations in southeastern Alaska: U. S. Geol. Survey Bull. 773, pp. 71-139, 1925.

Charles Williams property.—The Charles Williams property was located in 1919 and has been systematically prospected to the present time. Ninety-six claims have been located and surveyed and are shown on the claim map that forms Plate 2. They extend in a north-northwesterly direction 3½ miles from the cove west of the basin at the head of Hawk Inlet. At the beach there are two cabins and a floating wharf. A pack road runs from this place 1½ miles north-northwest to another camp at an altitude of about 1,000 feet, where there is a large bunk house, a well-equipped assay office, and a blacksmith shop. Trails lead from this place to the other prospects.

A great number of large, well-defined quartz fissure veins are being prospected.. Several open cuts have been made on each of 10 veins, and each has thus been traced for 500 feet or more. There are many other bodies of quartz on the property which have been only slightly prospected if at all. A large shoot of low to medium grade ore has been proved definitely to occur in one of these veins, and other veins are reported to carry shoots of low to medium grade ore or to consist of large volumes of low-grade mineralized rock.

A vein that crosses the boundary between Williams No. 4 claim and Batella No. 1 has been developed by a tunnel driven 353 feet on the vein, a winze sunk 48 feet in the vein on the hanging-wall side at the entrance to the tunnel, and four open cuts at the surface. The vein is in graphitic schistose phyllite. The portal of the tunnel is at an altitude of about 1,000 feet. The relation of the tunnel to the vein is shown in Plate 3. The vein is about 18 feet wide at the entrance to the tunnel. At a point 230 feet from the portal the tunnel and a crosscut expose both the hanging wall and footwall, giving a thickness of about 14 feet. At 80 feet beyond this point the vein consists of quartz, with leaves and horses of schist on the footwall side, and is about 10 feet thick. At about 325 feet from the portal the vein gives place abruptly to a zone of highly crumpled graphitic schist with sparse quartz stringers. The distribution of gold in the vein is variable, both lengthwise and across it.

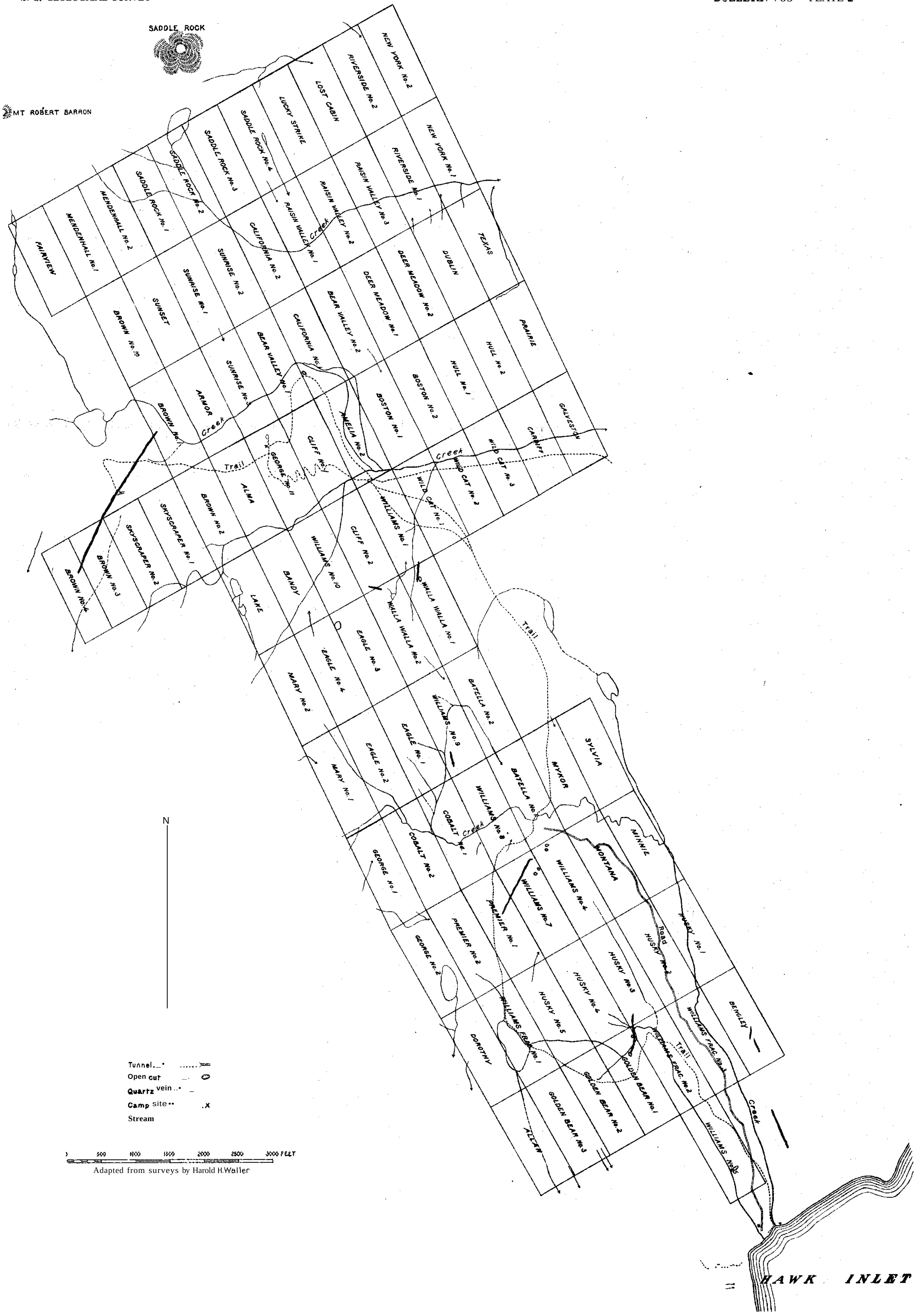
The vein in the tunnel was systematically sampled by H. E. Linney for R. K. Neill. The assay values plotted on the chart shown in Plate 3 are a few taken from his assay chart to illustrate in a representative manner the distribution of the gold. The samples were taken across the working face of the tunnel on successive dates. Harry Townsend, a representative of the United States Bureau of Mines, took samples the full width of the tunnel and both crosscuts, and the values obtained by him are also plotted on the chart. They agree with results obtained by the assayer for Neill. The average of 235 samples taken systematically from the face of the tunnel and from the muck of cars trammed to the dump is reported to be

$12 a ton for the first 172 feet. The average of the assays for the next 90 feet is a little over $7, and that for the last 55 feet of the vein only a little over $1. An open cut about 40 feet above the level of the tunnel exposes about 31 feet of quartz that is reported to average $20 to the ton.

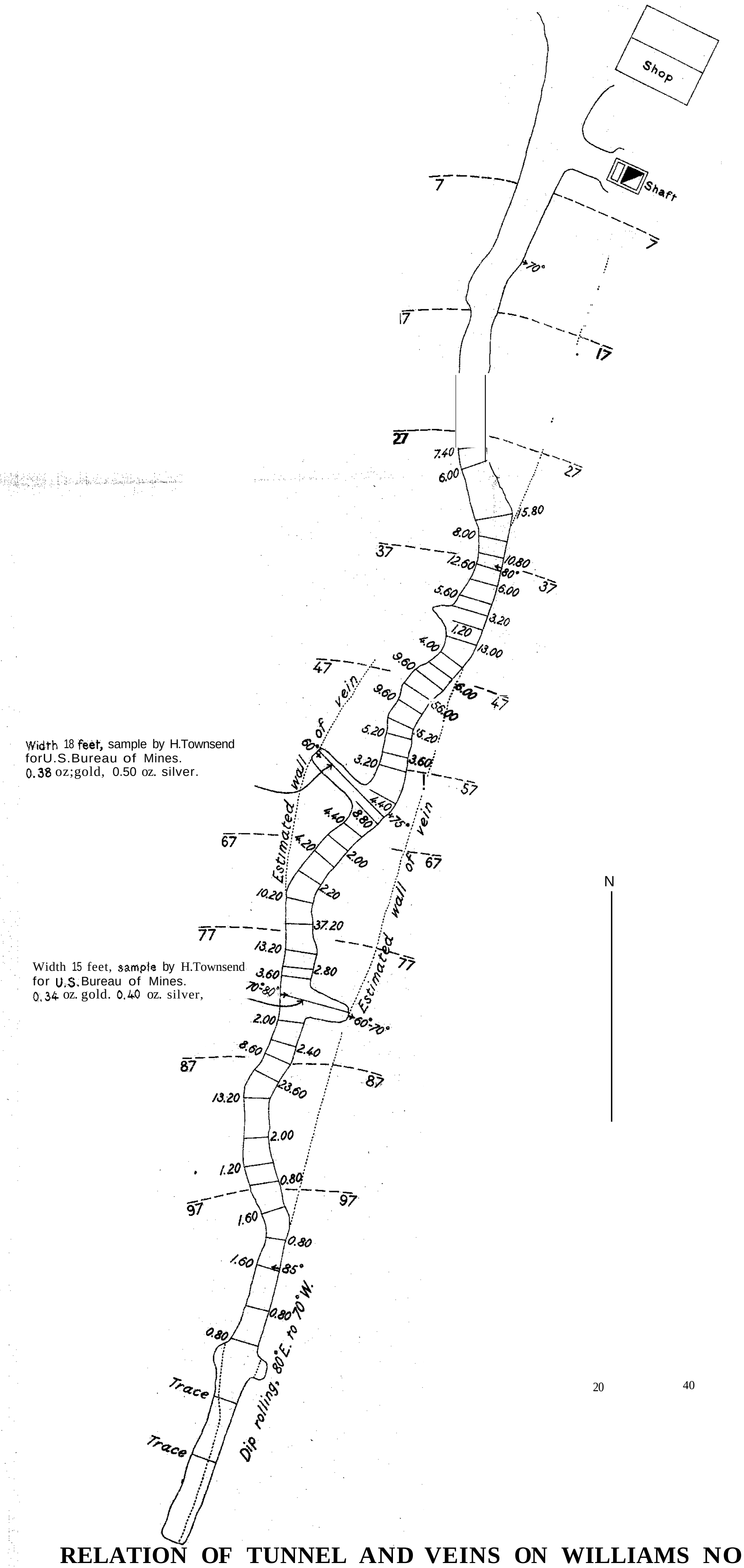
North of the tunnel portal quartz has been found in a series of open cuts aligned along the projected extension of the vein for about 500 feet. To the south, up the hill slope, along the line of strike of the vein, several open cuts expose stringers of quartz from 4 inches to 1 foot wide along joint planes in the phyllites, but no well-defined vein. Southwest of this line of open cuts another series of open cuts on Williams No. 7 and Premier *No.* 1 claims has been made on a quartz vein that has been traced for more than 800 feet. The general strike of this vein at the higher altitudes (about 1,500 feet) is north-northeast. About 160 feet below this place the vein is either faulted or else takes an abrupt turn to the east and is traceable to a point within 300 feet of the southwest end of the vein on which the tunnel has been driven. This fact suggests that this vein may be the continuation of the vein in the tunnel offset by faulting, or possibly the same vein which has come in along two fractures with essentially parallel strikes and a connecting fracture. The manner of termination of the vein in the tunnel does not resemble faulting. Only further work can fully reveal the relations of these two veins. At an altitude of about 1,500 feet an open cut exposed 2½ feet of quartz with slickensided walls. This material is reported to average $14 to the ton in gold. About 30 feet below this place another open cut exposes 16 feet of quartz that is reported to average about $4. Where the vein takes an abrupt turn to the east there is a width of about 10 feet exposed.

Between altitudes of about 875 and 1,050 feet a quartz vein is exposed on Golden Bear No. 1 claim and Husky No. 3. This vein, which is known as the Iron Swamp lead, is reached by a trail from the cabin at the beach, a distance of about three-fourths of a mile. The vein is well exposed for part of its length along a canyon and has been prospected by open cuts and traced for a length of 600 feet. At the north end the vein strikes a little north of east, and at the south end north-northeast. About 5 feet of quartz is exposed at the north end, and about 20 feet at the south end. Gold assays are reported by R. W. Moore to range from $1 to $14 to the ton and to average about $4. The quartz is locally iron stained but predominantly milky.

About 300 yards up the canyon back of the house at the beach, at an altitude of about 300 feet on Williams *No. 5* claim, a wide quartz vein with a horse of schist is exposed in an open cut. A tunnel that



MAP SHOWING CLAIMS OF THE CHARLES WILLIAMS PROPERTY, HAWK INLET, ADMIRALTY ISLAND, ALASKA



RELATION OF TUNNEL AND VEINS ON WILLIAMS NO.4 AND BATELLA NO. 1 CLAIMS, HAWK INLET, ALASKA

has been driven near the base of the canyon through the wall rock of schist intersects this vein. It is reported that a 50-foot width of quartz has averaged $3.60 to the ton. In the direction of the strike of this vein, near the northeast end of Williams No. 5 claim, there is an open cut on a vein of milky-white quartz 8 feet in width that is reported to average $3 to the ton. This vein is reported to be traceable for 1,500 feet.

Three quartz veins are also exposed on the east side of the creek that enters the cove east of the cabin, but these were not visited.

On Batella No. 2 claim, about one-third of a mile north-northwest of the main camp, a quartz vein is exposed in blanket-like form along the face of a hill. The vein has not been prospected. It occurs in quartz schist, and its dip and strike are approximately the same as the slope and trend of the hillside. Free gold was observed at one place in oxidized pyrite.

On Walla Walla No. 1 claim another quartz vein has been prospected by open cuts. This vein is at an altitude of about 1,750 feet and is 2 miles in a straight line north-northwest of the cabin at the beach. This vein strikes a little west of true north and is vertical. About 15 feet of quartz is exposed at the north open cut and several feet at the south open cut, and the vein is traceable for several hundred feet. The vein is of milky quartz and contains narrow bands sparsely mineralized with pyrite and numerous films of micaceous schist.

On George No. 11 claim, at an altitude of about 1,900 feet, a little over 3 miles by trail from the beach, is a quartz vein which has been prospected by an open cut. The vein is in quartz schist and on the west side consists of 2½ feet of quartz moderately metallized with pyrite, with many vugs lined with quartz crystals and with bands of comb quartz. A 135-pound specimen very rich in native gold is reported to have come from this vein. Some ankerite is also present in the vein.

At an altitude of about 2,850 feet, 3 miles in a straight line north-northwest of the house at the beach, a tunnel has been driven 36 feet on a quartz vein. This vein is 20 feet wide at this point. To the northwest it widens to 50 feet and includes horses of quartz schist. The vein has been traced for 2,400 feet. It is characterized by the presence of considerable dark-brown ankerite in the central portion, and open spaces lined with quartz crystals are very common. Local narrow shoots metallized with sparse disseminated galena or pyrite were noted. A sample from the tunnel is reported to assay $6 a ton in gold. The quartz vein occurs in quartz schist adjacent to a quartz-albite schist of the Funter Bay type containing accessory chlorite, muscovite, and epidote. There are many strongly defined quartz veins in this vicinity.

A vein about 1,000 feet N. 60° W. of the house at the beach has been prospected by an open cut and adit, which revealed quartz sparsely metallized with pyrite, sphalerite, galena, and chalcopyrite.

On Williams No.8 claim a strongly defined iron-stained quartz vein, with sparsely disseminated pyrite, is exposed in the bed of a creek. An open cut has been made on this vein, and samples are reported to have given only low returns in gold. Further work is contemplated here, as the vein matter seems to be similar to that which gives higher assays elsewhere on the property.

Several other quartz veins are reported to be exposed on this property, but they have not been prospected and were not visited by the writer.

PROPERTY OF DOUGLAS MINING CO.

The claims of the Douglas Mining Co. are on Douglas Island, about 1¼ miles southwest of Douglas at an altitude of about 650 feet. The property is reached by a trail.

A sheet of highly altered diorite in black slate is being prospected. A tunnel 120 feet long starts in slate and completely crosscuts the diorite sheet, which shows a thickness of about 70 feet. The slate is .almost vertical and strikes northwest. The diorite strikes northwest and dips slightly to the southwest, crosscutting the slate. There are many slickensided surfaces within the dike. The diorite at and near the footwall is fresh. Above the tunnel it is exposed by a trench, and it has been traced along the strike by several trenches along the beds of gulches.

Locally a few small, narrow, irregular stringers of quartz occur along fractures in the diorite. These stringers consist of glassy material containing considerable calcite and sparse grains of disseminated chalcopyrite, pyrite, and sphalerite. The diorite is metallized locally with abundant disseminated fine cubes of pyrite.

The diorite in the tunnel is reported to give an average assay value for the full width of $1.50 to $2 to the ton. One zone 4 feet wide is reported to average $3 to the ton, and another 3 feet wide about $3.50 to the ton.

CLARK PROSPECT

The Clark prospect, staked in 1911,- is about 6½ miles a trifle north of trne east of Juneau, on Gold Branch of Carlson Creek. It is about the same distance a little west of true north of Sunny Cove. It may be reached either by way of the valley of Carlson Creek from Sunny Cove or by road from Juneau up Gold Creek to Granite Creek, by trail up Granite Creek, and thence over the divide at 3,100 feet to the valley of Gold Branch at an altitude of about 1,200 feet.

The property comprises six claims. Four of these claims (Hulda A, Cheechako; Yellow Hornet, and Isaiah R) extend parallel to the valley of Gold Branch on the north side and reach the west side of the valley of Carlson Creek. A crosscut tunnel 150 feet long. has been driven on the Cheechako claim. The John W. and William N. claims extend up the mountain.

The country rock consists of schist and pegmatitic injection gneiss with rare sheets of quartz diorite and sparse dikes of basalt.

The mineral deposits are quartz veins, which for the most part cut across the strike of the cleavage of the formation and fill highly brecciated fissure zones. The vein material consists of milky quartz with sparse to abundant small angular silicified and altered inclusions of the country rock. The quartz usually shows abundant vugs and open spaces lined with quartz crystals. The included fragments of country rock are as a rule full of disseminated small cubes of pyrite. In places the veins consist of highly altered country rock with a reticulating network of quartz veinlets. The sulphides in the vein are small in amount and predominantly pyrite. Stibnite occurs in needle forms in bands and disseminated in the quartz on the John W. and William N. claims at an altitude of about 2,100 feet. Arsenopyrite, sphalerite, and galena are also found.

On the John W. claim a vein striking N. 30° W. and dipping 75° E. stands out boldly in the face of the mountain between altitudes of about 1,600 and 1,850 feet. There is 4 or 5 feet of the vein exposed without either wall being shown.

On the William N. claim an area has been stripped which shows a maximum width of vein of 20 feet. This vein strikes about north. Some of the quartz here is accompanied by stibnite. A specimen of the vein matter with stibnite is reported to have assayed $2.80 in gold and $4.25 in silver to the ton (the silver being computed at $1 an ounce). Another sample from the same vein yielded 0.16 ounce of gold to the ton.

On the Cheechako claim a quartz vein is exposed in the gulch above the tunnel and extends northeastward to the adjoining gulch. The gulch appears to mark the course of a fault. The vein turns and runs lengthwise of the gulch and has been partly exposed by sluicing off the overburden. About 100 yards down the gulch a great width of quartz is again exposed and the vein resumes its northeast strike. On the side of the gulch 20 feet of vein matter is exposed on the uphill side of a basalt dike and 5 feet on the downhill side. On the uphill side the overburden has been sluiced off and the vein exposed for a length of 100 feet. The exposures are inadequate to show the relations certainly, but the basalt appears to intrude the quartz vein. The basalt itself is offset by faults of small displacement. Considerable country rock is included in one zone of the wide part of the vein.

Other bodies of quartz have been exposed by strippings on the other claims.

The writer is indebted to E. F. Clark, of 'Washington, D. C., for the following data on assays made by Ledoux & Co. of samples collected by him from the vein on the Cheechako claim: Sample from vein below basalt dike on Cheechako claim, 1.03 ounces gold ($21.29) to the ton of 2,000 pounds; two samples from vein above basalt dike, 0.23 ounce gold ($4:75) and 0.13 ounce gold ($2.69) to the ton; sample from vein west of falls above tunnel, 0.12 ounce gold ($4.38) to the ton; sample from east end of Cheechako claim, 0.17 ounce gold ($3.51) to the ton.

Considerable bodies of quartz which are exposed on this property apparently yield small amounts of gold.

MARTIN SAXE PROSPECT

A gold prospect comprising four claims is held by Martin Saxe, of Klawak, on the west coast of Prince of Wales Island, Ketchikan district. The prospect is on the south side of the basin, at the head of the valley whose stream enters Klawak Lake at the abandoned hatchery. The vein is exposed in the bed of a small stream at the head of the basin, on the south side, at an altitude of about 1,450 feet. Considerable float occurs in the bed of the stream well below the outcrop. The prospect is reached from Klawak by lY2 miles of trail to Klawak Lake, by rowboat on the lake 4 miles to a point about a mile beyond the hatchery, and then by blazed trail to the prospect. It may also be reached by going up the stream valley which comes out at the hatchery. The prospect is about 2 miles back from the lake. Klawak is served by mail boat from Ketchikan. The property has timber and also a waterfall adequate to develop all necessary water power for mining use.

The vein is in a massive green andesite porphyry breccia. Dikes of diorite cut the greenstone in the mountain above the prospect. The ore deposit is a sheeted quartz fissure vein. At an altitude of about 1,450 feet a small open cut has been made. The vein zone thus exposed is about 10 feet wide and carries half a dozen quartz stringers, the largest 6 inches wide, and on the south side a quartz vein 2 feet wide. The vein zone is exposed in the bed of the stream for a difference in altitude of about 250 feet above the open cut. least one quartz vein 1 to 2 feet wide is exposed throughout this height, and usually one or more additional stringers are present. The extension above and below is covered.

The quartz in some of the stringers is mineralized with disseminated pyrite. In the wide vein of the open cut the quartz is heavily metallized with galena, pyrite, sphalerite, and a trace of chalcopyrite. The gangue consists of colorless to milky and rose-colored quartz, associated with considerable carbonate. Some of the quartz shows comb structure.

A grab sample from the heavily metallized vein in the open cut was submitted to the Geological Survey for analysis. E. T. Erickson reports the gold as 0.07 ounce and silver 1.96 ounces to the ton. A grab sample from a sparsely metallized stringer consisting of rose quartz and carbonate gave 0.24 ounce silver and 0.07 ounce gold. Higher assays in gold and silver are also reported.

The country rock between the quartz stringers is impregnated with pyrite, and in many places the fractured surfaces of the greenstone are coated with quartz carrying pyrrhotite.

HYDER DISTRICT

In 1924 development work in excess of that required to satisfy assessment requirements was carried on at the Riverside, Daly-Alaska, ahd Ibex properties, in the Hyder district. Developments at the Riverside have been previously described.[11] The Daly-Alaska property was not visited by the writer, but large ore shoots are reported to have been cut in underground workings.

On the Ibex *No.* 1 claim a vein is exposed in bedded argillite and quartzite for about 100 feet in length and 75 feet in altitude. It pinches and swells, but considerable portions of it are 15 to 24 inches in width. The sulphides consist almost wholly of interbanded sphalerite and galena. A little tetrahedrite is present locally. The vein is cut by a granite dike and offset by faulting. A half interest in this property was sold to Day Bros., of Idaho, who drove a crosscut adit tunnel 131 feet in length about 100 feet below the top of the open cut and failed to find the ore body. Work was then abandoned.

A crosscut adit is reported to have been driven by Carlson & Hewitt to the Homestake vein 35 feet below the outcrop and to have cut the vein.

Dominick Bevacque located five claims on a vein on the east side of Ferguson Glacier, about a quarter of a mile above its terminus. The vein is reported to have been traced for several hundred feet and to have a maximum width of 3½ feet. Heavily metallized ore shoots yielding good assays in gold, silver, and lead are reported to be present in this vein.

In May, 1924, Carlson & Hewitt located a new vein on the west fork of Texas Creek, in the vicinity of the Ibex group of claims and staked a new claim under the name Ibex *No. 7.* The vein is at an altitude. of about 1,300 feet above the cabin and is exposed in the

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[11] Buddington, A. F., Mineral investigations in southeastern. Alaska: U. S. Geol. Survey Bull. 773, pp. 71-139. 1925.

bed of Ibex Creek. The vein has been traced for several hundred feet and ranges from 5 inches to 3 feet in width. At the north end, where it passes beneath snow lying in a gulch, the vein consists of a fissure zone of granodiorite with stringers of qnartz for a width of 3 feet. Heavily metallized shoots of sulphides, comprising galena with a little pyrite, occur along the vein. The vein is in granodiorite, strikes about N. 10° W., dips east, and is locally broken by faults of slight displacement.

MOUNTAIN VIEW GROUP

The Mountain View group comprises eight claims and a fraction and lies mainly between Skookum and Fish creeks, just above their junction hut in part below it. Five of the claims are patented by John Hovland. The property is under bond to a group of Ketchikan business men and has been undergoing active development since June in charge of Arthur Moa.

Most of the work to date on this property has been done on three veins, though several other quartz veins and stringers have been found on the property.

On Fish Creek No. 3 claim a quartz fissure vein with mineralized shoots has been prospected by several open cuts and stripping, and a tunnel is now being driven along it. The vein is in granodiorite and has been traced for 400 feet. Its strike is about N. 7° E. and its dip 45°-50° E. The southern 250 feet of the vein ranges £rom3 to 4 feet in width. North of this the vein splits into two branches about 10 feet apart. The upper one is several inches thick and carries shoots of ore. The lower vein is the main branch and for 75 feet ranges from 6 inches t02 feet in width, averaging about a foot, but for the next 75 feet it ranges between 5 and 9 inches in width. The vein throughout shows many moderately to heavily mineralized shoots of ore. The sulphides consist of pyrite, galena, pyrrhotite, chalcopyrite, sphalerite, and sparse tetrahedrite.

On Fish Creek No. 2 claim a vein has been traced by five open cuts for a leng,th of 300 feet. It strikes N. 50° W. and dips 40° NE. The southeastern portion of the vein, as shown by two open cuts and a crosscut tunel, is pyritic quartz. In the open cut above the tunnel the vein zone is 6 to 8 feet thick with 5 to 6 feet of mineralized quartz, and the remainder consists of included bands and fragments of country rock, which here is granodiorite. The quartz is heavily mineralized with bands and disseminations of coarsely crystalline pyrite, which may form as much as half the vein by volume. About 20 feet below the open cut a 40-foot crosscut tunnel has been driven to cut the vein. At the end of the tunnel there is a 1½-foot vein of quartz heavily mineralized with pyrite. Small quartz stringers are present above this vein, and it is not certain that the hanging wall of the vein zone has been reached. Another open cut has been made 15 feet west of the open cut above the tunnel. On the east wall of this cut the vein consists predominantly of two mineralized shoots. One of these shoots is a quartz vein 2 feet thick, very heavy mineralized with pyrite, which pinches to a narrow stringer in the face of the open cut. The other shoot consists of fine crystalline barite and carbonate with seams and disseminations of tetrahedrite, pyrite, and an unidentified yellow mineral. This shoot is 12 to 18 inches thick in the east wall of the open cut and 15 feet or more long. To the northwest it passes into a 10-inch quartz vein with a few bands of baritic rock in the hanging wall. A specimen from this vein, about half of which was composed of tetrahedrite, is reported to have assayed an ounce in gold and 225 ounces in silver. The western open cuts on this vein show a fissure zone 5 to 6 feet thick with the main lead and many narrow quartz stringers. The sulphide mineralization includes pyrrhotite, pyrite, galena, chalcopyrite, and a little tetrahedrite.

On Fish Creek No. 1 claim a mineralized quartz vein striking N. 60° W. and dipping northeast has been prospected by a series of small pits, a stripping, and two tunnels and has thus been traced for 450 feet. The country rock of the vein at the northwest is granodiorite, but for most of the length it is a brown contact-metamorphosed sedimentary rock with dikes of aplite and a light-colored facies of the granodioritic intrusive rock. The vein cuts these older dikes but itself is cut by a 75-foot dike of massive granodiorite, which is probably genetically connected with a mass of granodiorite which forms the region north of Hyder. Locally shoots mineralized with pyrite, galena, and sphalerite occur. On the bank of Fish Creek a small vein above that just described occurs in an aplite dike. It ranges from a couple of inches to 9 inches in thickness and is exposed for a vertical distance of 35 feet. It is heavily to moderately mineralized. On the bank of Fish Creek a tunnel 90 feet in length has been driven. The rock at the entrance appears to be a sheared altered rocklike aplite, but at the end of the tunnel it is a brown contact-metamorphosed slate or tuffaceous rock. An 8-foot crosscut at the end of the tunnel exposes a gently dipping stringer of quartz 4 to 6 inches thick containing a shoot mineralized with native gold.

MOLYBDENITE ON LEMESURIER ISLAND

Lemesurier Island lies in Cross Sound near the entrance to Glacier Bay. Two patented claims, the Christmas and Enterprise lodes, held by George JI. Whitney, of Juneau, are located near the center of the headland between Iceberg and Willoughby coves, on the south side of the island. The developments consist of a 7s-foot tunnel and a 25-foot crosscut, about 50 feet above sea level.

A landslide has exposed at the contact zone between the diorite and the limestone about 30 feet of massive "contact" rock with associated banded hornstone. The "contact" rock consists predominantly of red-brown garnet, but some green pyroxene. is associated with it. The tunnel starts at a point on the contact between the limestone and the garnet rock. The last 25. feet of the tunnel is in banded hornstone and quartzitic beds. At the breast of the crosscut diorite is exposed. Several pockets of garnet rock are exposed along the walls of the tunnel, but the best exposures are at the surface. Molybdenite occurs as facings along small gash fractures in the contact rock and to a lesser extent in disseminated form. In most of the rock the molybdenite is sparse, but small pockets are found in which molybdenite forms several per cent of the rock.

Mr. J. P. Ibach states that on the southwest headland of Willoughby Cove there are small vein stringers with variable metallization in the limestone. The stringers consist of quartz with garnet and molybdenite; epidote with bornite along fractures; pyroxene with molybdenite; and quartz heavily metallized with chalcopyrite.

FRANCIS ISLAND, GLACIER BAY

Two claims have been staked on Francis Island, in Glacier Bay, by M. V. Manville and T. P. Smith. These claims lie along a dike of diorite which cuts across the island from the southwest end to the north end. The island is composed of marble. At the southwest end the dike is about 50 yards wide and is bordered by 5 feet or so of green contact garnet rock. A few lenses of serpentine and veins of tremolite occur in the adjacent marble. Near the southwest end of the dike, on the westside, at the top of a cliff, a small pocket of bornite yielding gold and silver assays was found in the contact garnet rock. The dike at the north end is impregnated with pyrite and pyrrhotite.

DALTON HOT SPRINGS

In 1923 a group of hot springs was discovered on Baker Island in the Ketchikan district by Maxfield Dalton, of Klawak. The writer is indebted to Mr. Dalton for guidance to the locality. The springs are on the east side of the cove at the south end of Veta Bay, on the west coast of Baker Island (fig. 1). They are in a narrow niche in the coast, about 50 yards across, which trends due east and lies a little north of a position in line with two rocks off the west headland of the cove. This niche is also just north of the place where there is a slight change in the direction of the shore line and is on the south side of the scar of an old overgrown landslide. It is in a relatively exposed position, and a landing can not be made if a heavy swell is rolling. It can be reached, however, by walking, with some difficulty, along the beach from the head of the cove.

Several small springs issue from cracks in the face of the cliff 25 feet or so above the base. Another hot spring rises in the next

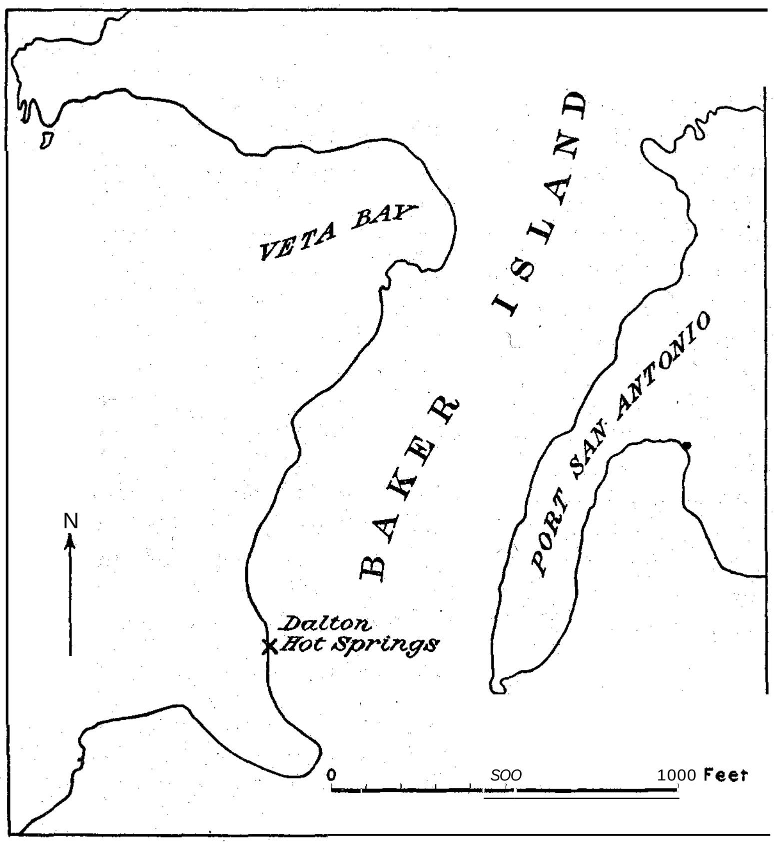

FIGURE I.-Map showing location of Dalton Hot Springs, on west coast of Baker Island

gulch to the north. This spring was flooded with water from recent rains at the time of the writer's visit.

The country rock is quartzose diorite near a contact with sediments. Many fissure zones occur in the diorite, and the springs issue from cracks in the diorite. It was raining at the time of examination, and there had been a heavy precipitation for several days. The springs may therefore have been somewhat diluted and cooled with rain water. Their temperature was about 110° F. The accompanying table gives a chemical analysis of a sample of the water.

Analysis of water from Dalton Hot Springs, Baker Island, Alaska, collected August 18, 1924

Silica (SiO_2)	57
Iron (Fe)	.02
Calcium (Ca)	3.9
Magnesium (Mg)	1.5
Sodium and potassium (Na+K)	30
Carbonate radicle (CO_3)	16
Bicarbonate radicle (HCO_3)	24
Sulphate radicle (SO_4)	20
Chloride radicle (Cl)	8.4
Nitrate radicle (NO_3)	0
Total dissolved solids at 180° C	156
Total hardness as $CaCO_3$ (calculated)	16

The composition of the water as shown by this analysis is very similar to that of the Baranof Hot Springs,[12] on the east side of Baranof Island, or the hot springs near Fish Bay, at the north end of Baranof Island. The water is of a sodium carbonate type with relatively high silica. The mineral content of the Dalton Hot Springs is relatively low, but this may be due in part to dilution from the heavy rain which had been falling for several days before the sample was collected. A pocket of siliceous tufa has been deposited where the springs issue from the cracks in the diorite.

The temperature of the Dalton Hot Springs (110° F.) is similar to that of the Baranof Hot Springs (118° F.), the Fish Bay Hot Springs (117° F.), and the Tenakee Hot Springs (106° F.).

The springs would be accessible to the people of the towns of Craig, Klawak, and Hydaberg if a trail were cut from the head of the south arm of Port San Antonio, a distance of about 1½ miles.

LIMESTONE AND MARBLE

With the development of a pulp and paper industry in southeastern Alaska, there will probably come a demand for limestone for use in the manufacturing processes. Possibly other uses also may create a demand for it.

A general summary of the occurrence of marble has been given by E. F. Burchard,[13] but he makes only incidental references to the many available areas of limestone in southeastern Alaska. Some of these limestone areas are described here, as well as several occurrences of marble on the mainland.

The largest areas and thickest beds of uniformly pure, very high calcite limestone occur in the islands off the west coast and at the north end of Prince of Wales Island, and are of Silurian age.

[12] Waring, G. A., Mineral springs of Alaska: U. S. Geol. Survey Water-Supply Paper 418, pp. 26-27, 32, 1917.

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

Silurian limestone forms many of the islands in the Kashevarof group in Clarence Straits. On the north end of Prince of Wales Islands it forms the marble beds at Calder and El Capitan, in Dry Pass, and in the northwestern part of the Mount Calder range it extends northwest from Calder Bay to Labouchere Bay and along the shore north of the Barrier Islands. Other areas are on the east side of Port Protection; along several miles of coast 1½ miles east of Point Baker; on the coast in the vicinity of Red Bay nearly as far east as Point Colpoys; and on El Capitan Passage in a belt north of Sarheen Cove and west of Aneskett Point. The largest area in which this limestone is exposed lies in the vicinity of Davidson Inlet and Sea Otter Sound and includes most of Kosciusko, Marble, Orr, Tuxekan, Eagle, White Cliff, Owl, Hoot, and Heceta islands, the east side of Tuxekan Passage in the vicinity of Tuxekan, and the southern part of Staney Island. The limestone is exposed also on Dall Island and forms a belt that strikes northwest from Breezy Bay to the Diver Islands and from View Cove to Sea Otter Harbor. It forms Beauclerc Peak on Kuiu Island and is exposed on the passage south of Edwards Island. A fine belt of limestone forms the range of mountains along the southwest side of Saginaw Bay, on Kuiu Island. On Chichagof Island limestone is found at Basket Bay, Tenakee Inlet, and Freshwater Bay. In Glacier Bay a great range of coarsely crystalline limestone of late Silurian age runs through Willoughby and Drake islands and the east side of Rendu Inlet.

The Silurian limestones are in part of a dense texture and massive, in few places, if anywhere, showing any evidence of bedding, and in part interbedded massive limestone, thin-layered limestone, nodular and shaly limestones, calcareous shaly argillite, green-gray shale, and sparse buff-weathering sandstone. The massive limestone occurs in uniform beds as much as 2,000 feet thick. The fresh rock is white, but the usual weathered surface color is a pallid brown. The rock is usually intensely fractured, and the fracture surfaces are coated with a thin facing of calcite or rarely dolomite, which in many places weathers out in relief as a network of veinlets. Conglomerate beds are commonly associated with the thin-layered zones. Where the limestones are intruded by igneous rocks they are recrystallized and form fine to coarsely crystalline limestone, some of which afford fine marble, as at Tokeen, on Marble Island, and Calder and El Capitan, on Dry Pass, Prince of Wales Island. The Silurian limestones of Glacier Bay and Chichagof Island are likewise recrystallized by the contact-metamorphic action of intrusive igneous masses.

The Silurian limestones are prevailingly high-calcite limestones, carrying from 95 to 99 per cent of calcium carbonate. Of the 10 analyses given in the table on page 61, 7 show about 96 per cent or more of calcium carbonate.. It is certain that large quantities of very high grade calcite limestone are available in this formation.

Limestones of pre-Silurian age in beds from 100 to several hundred or even a thousand feet thick, together with a great many thinner ones, occur within a series of schists and greenstones in the vicinity of Sulzer and Copper Mountain and at the head of Cholmondeley Sound, on Prince of Wales Island. They also form the east side of Long Island, in Cordova Bay, and a belt that strikes southeast through Howkan and northwest to Waterfall Bay, though the rocks in this belt may not be of pre-Silurian age but may represent the high-calcite beds of the Silurian system. The limestone ranges from a white, coarsely crystalline marble to a dark-blue to nearly black, in places finely crystalline to granular though locally thin-bedded and slaty limestone. Only two analyses of these limestones are available. One represents a very high calcite limestone (No. 19) and the other a pure magnesian or dolomitic limestone (No. 20).

Limestones of Devonian age in beds as much as 600 feet thick are exposed on Long and Round islands in Kasaan Bay, Prince of 'Wales Island, and on the islands in San Alberto Bay opposite KIawak. On Kupreanof Island they are found at the head of Duncan Canal, along the center and west arms, and at the head and along the east side of Emily Island Arm. No chemical analyses of these limestones are available. Some of the limestones on San Alberto Bay seem to be fairly pure, and all are worthy of investigation if their geographic location should make it desirable.

Limestones of Permian age form much of the KeIrn group of islands and the adjacent shore of Kuiu Island. They also form the line of conspicuous bluffs along the northeast side of Saginaw Bay on Kuiu Island. They are also found in a narrow belt on the mainland in the Juneau district, outcropping along the shore at Point Anmer, at the entrance to Port Snettisham, and striking inland to the southeast. Permian limestones are also exposed in Pybus and Gambier bays, on Admiralty Island. The Permian limestones (about 1,000 feet thick) usually have intercalated layers of chert. Locally, however, thick clean beds are present. On the island opposite the cannery on the east side of Saginaw Bay, Kuiu Island, there is a steep, high bluff of clean limestone. Analysis No. 13, which represents a typical specimen, shows the rock to be a high-calcite limestone.

Limestones of Triassic age crop out east of Point Cornwallis, on Kuiu Island, and probably form much of the peninsula inland. Analysis No. 14, which represents the composition of a specimen from a locality about 3 miles southwest of Point Cornwallis, on Keku Straits, shows the rock to be an impure calcite limestone containing about 11 per cent insoluble matter. Upper Triassic limestones are exposed on the islands in Hamilton Bay, Kupreanof Island; on the Screen Islands, in Clarence Straits; on the west side of Gravina Island; and in Pybus and Gambier bays, Admiralty Island. These limestones are usually medium to thin bedded and commonly have intercalated layers of black slate. They are probably predominantly impure argillaceous and siliceous calcite limestones.

Analyses of limestones from southeastern Alaska

	Locality	Calcium carbonate ($CaCO_3$)	Magnesium carbonate ($MgCO_3$)	Insoluble
	BEDS OF SILURIAN AGE			
1	White marble, Tokeen, Marble Island, Ketchikan district	99.51	0.94	0.01
2	Veined marble, Tokeen, Marble Island, Ketchikan district	81.90	14.93	.20
3	Dark-veined marble, Orr Island, Ketchikan district	95.90	1.40	3.50
4	Mottled dark marble, Orr Island, Ketchikan district	95.35	2.04	2.95
5	Limestone, north side Beceta Island, Ketchikan district	84.46	13.18	13.18
6	Limestone, southwest end Orr Island, Ketchikan district	98.99	1.01	.12
7	Limestone, north side Beceta Island, Ketchikan district	99.12	.63	.37
8	Marble, head of Red Bay, Prince of Wales Island	96.90	2.59	1.70
9	Marble, Marble Creek, north of Shakan; Prince of Wales Island	99.26	.63	Trace.
10	Mottled marble, south of Sandy Cove, Glacier Bay	96.16	.89	2.56
	BEDS OF MISCELLANEOUS AGE			
11	Marble, Dickman Bay, Prince of Wales Island	74.61	3.25	22.84
12	Dark-green marble, Dickman Bay, Prince of Wales Island	58.40	6.61	37.32
13	Bluff of Permian limestone at southwest end of island opposite the cannery on the east side of Saginaw Bay, Kuiu Island	96.82	.63	2.79
14	Triassic limestone, about 3 miles southwest of Point Cornwallis on Keku Straits, Kuiu Island	87.19	.84	11.32
15	Talcose marble, Lake Virginia, mainland, east of Wrangell	53.69	26.10	19.06
16	Graphite marble, Basket Bay, Chichagof Island	63.68	8.90	28.19
17	White marble, north side of Marble Cove, Admiralty Island	61.11	39.10	.91
18	White marble, south of Marble Cove, Admiralty Island	95.44	1.45	3.61
19	Marble, near Waterfall Bay, Dall Island	99.59	1.03	.32
20	Limestone, near Jumbo mine, Copper Mountain region, Prince of Wales Island	82.75	15.62	1.84

Analyses 1-5, 8, 10-12, and 15-19 made by R. K. Bailey for E. F. Burchard; 6, 7, 13, and 14 by J. G. Fairchild for A. F. Buddington; 9 by E. F. Lass for the Alaska Marble Co.; 20 by George Steiger for C. W. Wright.

Beds of clean, sound marble are found at several places on the mainland, but the grain is usually medium to coarse, and some of the rock is inaccessible. The clean beds are associated with or intercalated between beds that carry silicate material disseminated or in pockets or veins. Narrow beds of fine-grained marble occur locally, and some very fine specimens occur in the terminal moraine of the North Dawes Glacier, at the head of Endicott Arm.

On the mainland, about 3 miles east of the landslides on Thomas' Bay, marble forms a conspicuous mountain peak and probably a belt that extends almost to the valley of Scenery Cove, for many boulders are found in the bed of the stream draining into that arm of the bay.

Two brooks enter at the head of the west arm of Fords Terror. Beds of limestone are exposed in the bed of the eastern brook at an altitude of about 500 feet. A knoll about 1,000 feet high, just visible from the head of the arm, consists predominantly of marble that weathers to a buff color. The beds strike about N. 60° W. and can be plainly seen to strike into the mountains to the southeast and northwest. The marble occurs in part in thick beds and is prevalently coarse grained. Thin seams with disseminated fine scaly phlogopite and grains of yellow chondrodite are common. Locally minute crystals of lavender-colored spinel are associated with them. Beds and thin layers of dark biotite schist and injection gneiss are intercalated in the marble. Boulders of marble several feet in diameter litter the bed of the brook all the way to the shore.

About 8 miles from the head of Tracy Arm, on the south side, Eugene Owens has staked claims on coarse-grained marble. Just east of the mouth of a large brook a bed of marble about 25 yards wide is exposed between injection gneiss and nonbedded schistose rock that weathers yellowish brown. The marble is quite clear in the central portion but is banded with quartz veinings on the edges.

The widest, clearest bed of marble seen by the writer is that which forms the mountain at the Whiting River silver prospect, about 7½ miles a little north of east of Whiting Point. Bands containing disseminated chondrodite and tremolite were noted, but much of the rock appears to be pure. Several specimens taken here consist of medium-grained dolomite, and one of coarse-grained calcite marble. The dolomite appears to be the predominant rock.

A belt of marble much disrupted and brecciated by quartz diorite is found at Bride Point, on the north arm of Port Snettisham.

At the extreme head of Saginaw Bay, on the southwest side, dikes of diorite occur in limestone. The limestones strike inland to the southeast. If the dikes at the shore are offshoots from a larger intrusive mass lying inland there would be a chance of finding marble at the contact. The actual conditions are not known.

GEOLOGY AND OIL DEVELOPMENT OF THE COLD BAY DISTRICT

By WALTER R. SMITH

INTRODUCTION

During the field season of 1924 the United States Geological Survey continued its investigation of the areal and structural geology in the Cold Bay district, Alaska Peninsula. Topographic and geologic mapping of the Cold Bay and adjacent districts was begun in the spring of 1921, and progress has been made each year since that time. The results of the first three field seasons have been published in several Survey bulletins,[1] to which the reader is referred for a general description of the country northeast and southwest of the Cold Bay district. In 1924 a geologic party in charge of the writer, who was assisted by E. C. Roschen, was sent into the field to make a more detailed study of some of the most promising areas which had been previously visited by members of the Geological Survey during hasty reconnaissance trips. The areas studied include Cape Kekurnoi, the Salmon Creek-Bear Creek anticline, the Ugashik Creek anticline, the shores of Wide Bay, and an area along the north side of Becharof Lake.

The Cold Bay district includes an indefinite area lying west of Cold, Portage, and Wide Bays on the northwest side of Shelikof Strait west of Kodiak Island. The term "Cold Bay district" has survived from the days of the oil excitement in 1902–1904, when Cold Bay was the center of activity and the place of landing for the machinery and supplies used in drilling several wells near the head of Trail Creek. At present a much larger area is generally referred to as the Cold Bay district, and in the more recent oil development, which began in 1922, the town of Kanatak, at the head of Portage Bay, 30 miles southwest of Cold Bay, has been the port of landing. Wide Bay affords greater protection from easterly storms than Portage and Cold Bays and will probably be used as a harbor in the near

[1] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 77-116, 1922.
Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district, Alaska: U. S. Geol. Survey Bull. 755, pp. 151-218, 1924.
Mather, K. F., Smith, W. R., and Martin, G. C., Petroleum on Alaska Peninsula: U. S. Geol. Survey Bull. 773, pp. 159-213, 1925.

future. Local areas in the Cold Bay district are referred to as the "east field," which lies between the Pacific coast and Becharof Lake, and the" west field," which lies south and west of Becharof Lake, in the vicinity of Mount Peulik.

GEOGRAPHY

The relief, drainage, climate, vegetation, and routes of travel in the Cold Bay district have been described in some detail in several recent publications of the Geological Survey. Only a brief summary of the most striking geographic features is given in this report.

The Alaska Peninsula is about 550 miles long and is in the form of a slightly arched wedge whose greatest width is toward the northeast or landward end, from which it tapers toward the southwest. In the latitude of Cold Bay the peninsula has a width of about 90 miles. The Aleutian Range extends the entire length of the peninsula and as far southwest as Stepovak Bay is much closer to the Pacific Ocean than to Bering Sea. The Pacific coast is indented by many bays separated by capes that present bold headlands. The north side of the peninsula bordering Bristol Bay consists of a broad lowland less than 100 feet above sea level that contains many lakes and swamps.

In the Cold Bay district the Aleutian Range extends about 20 miles inland from the Pacific coast or one-fourth the distance across the peninsula. The crests of many of the mountains are rounded and rise to altitudes of 1,500 to 2,500 feet, although a few sharp peaks, especially those southwest of Wide Bay, attain altitudes of nearly 4,000 feet. Mount Peulik, which is the most conspicuous topographic feature in the district, is an extinct volcano that stands south of the main arm of Becharof Lake and has an altitude of 4,800 feet.

The larger streams of the Cold Bay district rise along the northwest side of the range and flow either directly into Bristol Bay or into Becharof and Ugashik Lakes, which lie west of the mountains. The Pacific drainage consists of short turbulent streams, most of which are less than 8 miles in length.

GEOLOGY

PRINCIPAL FEATURES

During a reconnaissance geologic survey[2] of the Cold Bay district in 1921 it was found that all the sedimentary rocks with the exception of the unconsolidated sand and gravel are Mesozoic, ranging in age from Upper Triassic to Upper Jurassic. Additional information regarding the areal extent of the different formations

[2] Capps, S. R. The Cold Bay district: U. S. Geol. Survey Bull. 739. PP. 77-147. 1922.

and several areas of igneous rocks was obtained in 1922, and 1923. Reports, including maps, on, the geology of the district have been published by the Geological Survey. A brief review is here given of the general geologic features with the details of structure and areal extent of the formations mapped during the field season of 1924.

The oldest beds exposed in the area outlined above occur on Cape Kekurnoi, on the east entrance of Cold Bay, and consist of massive and thin-bedded limestones of Upper Triassic age overlain conformably by Lower Jurassic limestone, sandstone, and shale. Beds of probable Middle Jurassic age, the Kialagvik formation, are exposed along both sides of the southwest end of Wide Bay and also in a small area near the head of Alinchak Bay, the next indentation of the coast northeast of Cold Bay. With the exception of these localities and several small areas of igneous rocks, the entire Cold Bay district is covered by thick and extensive beds of Upper Jurassic age, which have been divided into a lower part, the Shelikof formation, consisting chiefly of sandstone and shale, and an upper part, the Naknek formation, consisting of thick beds of conglomerate, arkosic sandstone, and shale. The Shelikof formation is exposed north of Cold Bay and east of a line drawn from the head of Cold Bay to the head of Portage Bay and also in the mountains just west of Wide Bay. Within the large drainage areas of Becharof and Ugashik Lakes the sedimentary rocks belong mostly to the Naknek formation, but wide areas are covered with alluvial deposits that conceal the underlying bedrock.

The igneous rocks of the district consist of dikes and interbedded basalt flows on Cape Kekurnoi and rather large masses of quartz diorite on Cape Igvak, between Portage and Wide Bays, and in the mountains southwest of Wide Bay. Lava and several kinds of crystalline rocks occur on the flanks and near the base of Mount Peulik. A few small dikes cut the sedimentary beds at several other localities.

The sedimentary beds of the district have been folded along two roughly parallel lines into well-defined anticlinal folds with an intervening syncline. The southeast line of folding lies close to the Pacific coast and extends about 40 miles northeastward from the valley at the southwest end of Wide Bay to the forks of Rex Creek. A saddle on Cape Igvak divides the eastern fold into a southwestern part, the Wide Bay anticline and a northeastern part known as the east field or the Salmon Creek-Bear Creek anticline. A second line of folding, the Ugashik Creek anticline, begins 6 miles west of the upper arm of Becharof Lake; near the head of Featherby Creek, northwest of which it dies out in a mon.?cline. Pearl Creek dome, where drills are now in operation, forms the northeastern part of the Ugashik Creek anticline. In the vicinity of Moore Creek, 10 miles southwest of Pearl Creek and west of Wide Bay, a rise of the beds along the anticline is locally known as the Hubbell dome, but is not so well defined as the Pearl Creek dome and does not close toward the southwest. Between the two anticlinal folds a synclinal trough extends southwestward through the upper arm of BecharoT Lake and gradually rises and flattens until it merges into the monocline west of Wide Bay near Deer Mountain.

CAPE KEKURNOI

The primary source of oil in the Cold Bay district is unknown. The oldest sedimentary rocks exposed in the district and, so far as known, on the Alaska Peninsula crop out in a small area on the cape between the north shore of Cold Bay and Alinchak Bay. A careful study of the beds in this area was made with the purpose of learning the character of the beds that probably underlie other parts of the district, as well as to ascertain whether the rocks are porous enough to contain oil in commercial quantities or whether they contain enough organic material to have been the primary source of the oil. Cursory examinations of these beds, the oldest of which are of Upper Triassic age, had been made during several reconnaissance trips,s but the contacts of the different formations had not been followed across the cape and time had not been available for a systematic search for fossils.

Although the work done back of Cape Kekurnoi in 1924 was not so detailed as would have been desirable, the sections obtained on the shores of Cold and Alinchak Bays (fig. 2) give an idea of the character of the rocks that may be encountered at depth beneath the Salmon Creek-Bear Creek and Wide Bay anticlines. The beds were not all carefully measured, and the sections are intended only to show the approximate thickness and relative position of the rocks.

The lowest beds examined prior to 1924 consist of thin-bedded hard bluish limestone containing very many impressions of the bivalve *Pseudomonotis subcircularis*, a widely distributed Upper Triassic fossil. The coast line between Cold and Alinchak Bays, a distance of about 5 miles, is very irregular and is bordered by nearly vertical cliffs that rise to heights of 60 to 80 feet above the water's edge. The limestone beds exposed in these cliffs include 85 feet of very massive buff limestone overlain by 30 feet of blue nodular limestone. Both members lie below the thin-bedded limestone that

• Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, p. 58, 1921.
Capps, S. R., The Cold Bay district: U. S. Gool. Survey Bull. 793, p. 92, 1922.
Mather, K. F., Smith, W. R, and Martin, G. C., Petroleum in Alaska Peninsula: U. S. Geol. Survey Bull. 773, pp. 159-213, 1925.

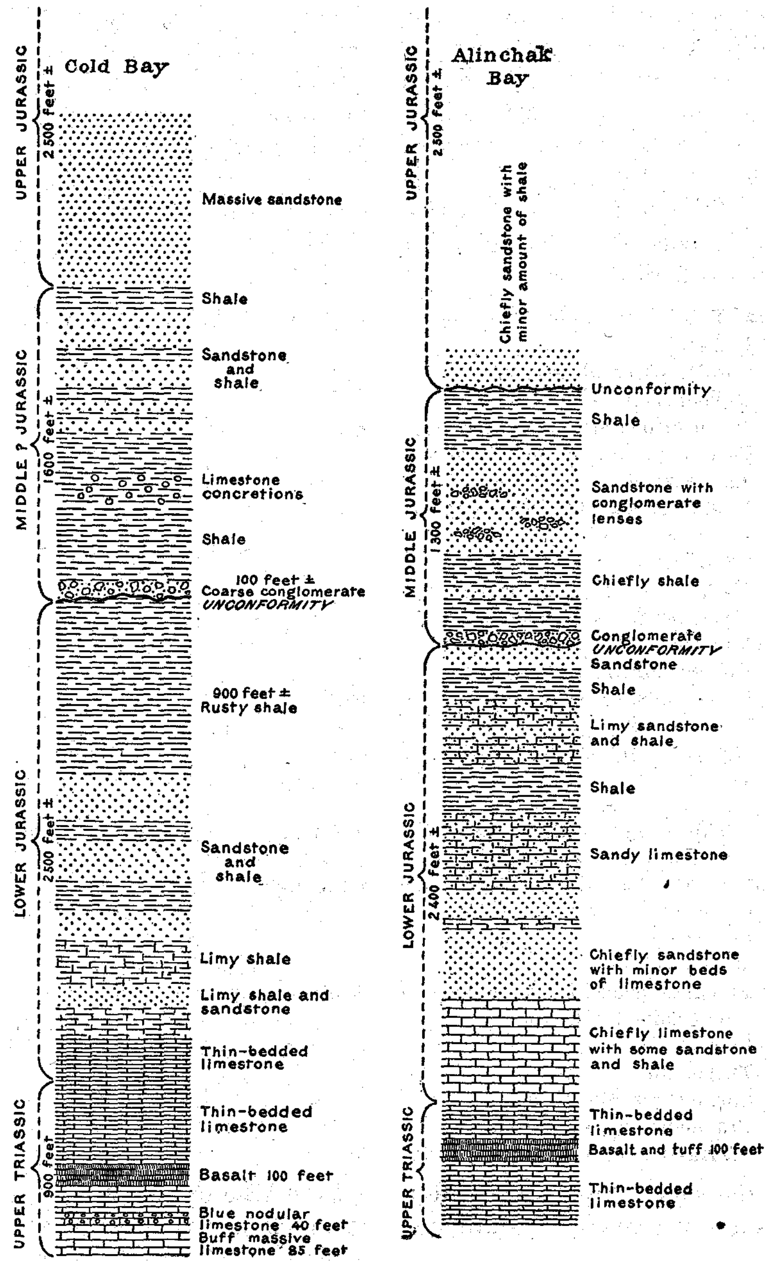

FIGURE 2.-Columnar sections of rocks exposed .at Cold and Alinchak Bays, Alaska Peninsula

yields *Pseudomonotis*. The base of the massive limestone is not exposed. The lowest beds strike in general northeast and dip rather steeply southwest, although there are many variations in the strike and dip. Only a few bedding planes are visible in the massive limestone. The overlying limestone is made up almost entirely of rounded nodules from 3 to 6 inches in diamete,r. Both the massive and the nodular limestone members are abundantly fossiliferous and yielded an interesting and varied marine fauna. The following Upper Triassic fossils and all the Jurassic fossils subsequently listed in this report were determined by T. W. Stanton, of the United States Geological Survey:

12393. F. 15. Cape Kekurnoi, along beach between Cold and Alinchak Bays, below F. 14:

Corals. Several genera.
Rhynchonella sp.
Terebratula? sp. Abundant large form.
Pecten sp. Small smooth form.
Amusium sp.
Pinnigena sp. Large, well preserved.
Pinna sp.
Cassianella sp.
Myophoria? sp. Several ribbed forms.
Myophoria? sp. Smooth form.
Pleuroll1ya sp. Large form.
Undetermined pelecypods.
Gastropods. Several genera represented.
Nautilus sp.
Halorites sp. Catenati group.
Trachyceras? sp. Two or more species represented by imperfect specimens.

This is an Upper Triassic (Noric) fauna not previously recorded in America.

12395. F. 17. Cape Kekurnoi. Boulder in lava flow of Triassic age:

Ostrea? sp. Oval ribbed form.
Pecten sp.
Myophoria sp.
Elongate pelecypod with very broad hinge plate and other small undetermined pelecypods.
Pleurotomaria sp.
Turbo? sp.
Slender gastropod cast.
Fragment of a crustacean.

Triassic, presumably Upper Triassic.

In the surf a few hundred feet from the base of the cliff several exposures of coarsely crystalline granitic rocks were seen at low tide, but whether they are huge boulders, dikes, or parts of a larger intrusion could not be determined.

At places the hard thin-bedded limestone appears to rest conformably upon the nodular limestone, but near Alinchak Bay the two members are separated by a basalt flow. The basalt is about 20 feet thick and is columnar. On the Cold Bay side of the cape a greenish tuff containing many fragments of basalt rests upon the nodular limestone. The thin-bedded blue limestone containing beds of *Pseudomonotis* is slightly over 700 feet thick and is exposed on both sides of the cape and in the islands south of the cape. Locally the beds are sharply folded as a result of basaltic intrusions. On the mainland the general dip is toward the northwest, but on the islands the rocks dip steeply toward the southeast and are on the southeast flank of a sharply folded anticline, the crest of which is concealed beneath the waters of Shelikof Strait.

The fauna of the thin-bedded limestone consists almost entirely of *Pseudomonotis*. The fossils listed below were collected in these beds.

12392. F. 14. Cape Kekurnoi:
- Stoliczkaria sp.
- Pseudomonotis subcircularis (Gabb).
- Cassianella? sp.
- Upper Triassic.

At least 100 feet of basalt and tuffaceous material is interbedded in the thin-bedded limestone. The basalt is columnar and forms overhanging cliffs and arches near the southwest entrance of Alinchak Bay. Numerous veinlets of calcite and pyrite occur in the basalt. The upper part of the limestone grades into a massive sandstone. About 200 feet below the upper horizon at which limestone predominates fossils, believed to be Jurassic, have been collected. At this horizon the rocks differ very little from the limestone beneath and there is no evidence of an unconformity. Hence the assignment of the rocks to Upper Triassic and Lower Jurassic is based entirely on paleontologic evidence, and the point of division is arbitrarily drawn. The fossils that have been assigned to the Lower Jurassic were collected within a stratigraphic distance of 200 feet above those that were determined to be of Upper Triassic age: Sedimentation apparently continued from Upper Triassic time into Lower Jurassic time without interruption in this locality. Higher in the section, where the limestone becomes more arenaceous and is intercalated with thin beds of shale, an unconformity was noted. However, the fossils on both sides of the unconformity are similar and indicate that they are about the same geologic age. Several collections of fossils made from the first series of rocks above the known Triassic beds are as follows:

12389. F. 11. Mountain 1½ miles southwest of Alinchak Bay:
- Rhynchonella sp.
- Pecten sp.
- Pteria? sp.

Cardinia? sp. Abundant.
Turbo? sp. Two or more.
Ammonite fragments. A discoid strongly ribbed form.
Probably Lower Jurassic.

12391. F. 13. Mountain three-fourths of a mile south of Alinchak Bay:
Pecten sp. Small smooth form.
Pecten sp. Small form with coarse angular ribs.
Pecten sp. Large form with coarse rounded ribs.
Undetermined pelecypod.
Similar types are common in the Lower Jurassic, but they can not be called distinctive.

12394. F. 16. South side of Alinchak Bay:
Small undetermined pelecypod.
Several species of ammonites apparently belonging to Lower Jurassic types.
This is the same fauna as 10820 Capps No. 1-127. Probably Lower Jurassic.

12396. F.18. North shore of Cold Bay, 2 miles west of Cape Kekurnoi:
Rhynchonella sp.
Leda sp.
Pleuromya? sp.
Arietites? sp.
Other ammonites of undetermined genera.
Probably Lower Jurassic and same fauna as F. 16.

This series of rocks is approximately 2,500 feet thick. At the base is limestone that becomes progressively more sandy higher in the section until a massive fine to coarse pebbly sandstone with lenses of conglomerate is encountered. The pebbles in the sandstone and conglomerate are rarely more than an inch in diameter but are Characteristic, as they consist almost entirely of fragments of brightly colored greenstone and red jasper. Thin beds of limy shale occur irregularly in the lower part of the sapdstone. Above the sandstone, on the Cold Bay side of the cape, lies a thick deposit of iron-stained shale cut by basaltic dikes, which form the upper member of the beds included in this series. The exposures across the cape are rather poor on account of the covering of vegetation over a large part of the surface and of the alluvial filling in the valleys. The beds exposed along the beach at Cold Bay and Alinchak Bay differ considerably both in character and thickness, so that lateral changes in the sediments must occur within short distances. The section as measured is thicker and contains more shale on the Cold Bay side.

The thick shale member of the lower series of Jurassic rocks is overlain unconformably by a coarse conglomerate 50 to 100 feet thick. The pebbles and boulders of the conglomerate consist of many types of igneous rocks. They are well rounded, and some of the larger boulders are over a foot in diameter. This conglomerate is considered to be the base of the second series of Jurassic rocks above the Triassic limestone. The exposures of conglomerate west of Alinchak Bay and on the beach of Cold Bay seem to occur at a slightly different horizon. This condition may be due to the unconformity, or the different exposures may represent outcrops of local lenses. The conglomerate was not traced across the cape. On the Cold Bay side shale carrying layers of large limestone concretions predominates in this series of rocks, whereas on the northeast side of the cape sandstone containing minor amounts of shale and conglomerate is exposed, The sandstone is dark and coarse and contains many small lenses of fine conglomerate. A collection of marine fossils that was made from this sandstone is the only one obtained from this series of rocks. As determined by Mr. Stanton, the fossils indicate Middle Jurassic age, but the sediments between the horizon at which the fossils were collected and the massive conglomerate may be only in part Middle Jurassic. A list of the fossils is given here:

12390. F. 12. Half a mile south of head of Alinchak Bay:
Pecten sp. Small smooth form.
Pecten sp. Small ribbed form.
Pteria sp.
Inoceramus lucifer Eichwald?
Inoceramus ambiguus Eichwald? Loose specimen.
Grammatodon sp.
Astarte sp.
Trigonia sp. Costatae group.
Trigonia sp. Clavellatae group.
Protocardia sp.
Pleuromya dalli (White)?
Several undetermined pelecypods.
Phylloceras sp. Small fragment.
This assemblage suggests the fauna of the Kialagvik formation at locality 10807.

The upper part of this series of Jurassic rocks consists of thick beds of yellow shale, which is overlain by a thick massive sandstone, unconformably west of Alinchak Bay but apparently conformably at Cold Bay. The sandstone is coarse, usually dark in color, and contains fossils which indicate that it belongs to the Shelikof formation, of Upper Jurassic age. A collection of fossils made by Capps from this sandstone on the east side of Cold Bay in 1921 and several collections made by the writer from beds higher in the section on the west side of the bay in 1924 are listed below:

10818. No. 1-126. North shore of Cold Bay, 4 miles northwest of mouth of bay; collected by S. R. Capps, 1921:
Cadoceras doroschini Eichwald.
Chinitna shale fauna.

12386. F. 8. Southwest side of Cold Bay; same as Capps C. 10824:
Pecten sp. Small smooth form.
Grammatodon sp.
Nucula sp.

Astarte sp.
Thracia? sp.
Pleuromya sp.
Amberleya sp.
Cadoceras petelini Pompeckj.
Cadoceras stenoloboide Pompeckj?
Belemnites sp.
Shelikof (Chinitna) fauna.

12387. F. 9. Near summit of bill 1½ miles soutbwest of store, Cold Bay:
Pecten sp. Small smooth form.
Pteria sp. Small with strong ribs.
Pinna sp.
Grammatodon sp.
Nucula sp.
Isocardia? sp.
Goniomya sp.
Pleuromya? sp.
Other small undetermined pelecypods.
Amberleya sp.
Tornatellaea? sp.
Cadoceras grewingki Pompeckj.
Cadoceras stenoloboide Pompeckj.
Cadoceras petelini Pompeckj.
Shelikof (Chinitna) fauna.

Along the northeast side of Cold Bay the Shelikof formation consists chiefly of massive brown to dark-gray sandstone with minor beds of blue to dark-yellow shale. At this locality the Shelikof formation is nearly 5,000 feet thick. The upper part of the series of beds now considered to be Middle Jurassic was formerly included in the Shelikof formation. All the beds exposed along the northeast shore of Cold Bay are monoclinal; they dip 8°-40° NW. and strike prevailingly northeast. The steeper dips occur at the head of the bay, near the top of the Shelikof formation and the base of the overlying Naknek formation. Northeast of Cold Bay the Shelikof formation flattens out and is apparently not so thick. At Kashvik Bay it is concealed beneath the Naknek formation, which consists of thick beds of shale, sandstone, and conglomerate.

Two faults that are nearly parallel along the opposite sides of the lower valley of Portage Creek show a displacement of about 2,000 feet, with the downthrow toward the southeast. One of the faults crosses the head of Cold Bay, and shows a greater displacement on the west side, where it is known as the Dry Creek fault. A multitude of minor faults and at least one great fault of unknown extent and displacement were noted along the southwest shore of Alinchak Bay. These faults are probably the cause of the apparent difference in the thickness of the strata exposed along Alinchak and Cold Bays.

No seepages or evidences of oil in the rocks were found on Cape Kekurnoi or in the country immediately northwest. The lowest rocks exposed, the Upper Triassic limestone, are in most places too compact to contain oil in large quantities. However, thick beds within the limestone contain impressions of countless millions of organisms that might have been the source of some of the oil in the district. The series of overlying Lower and Middle Jurassic rocks consists chiefly of alternating beds of coarse porous sandstone and impervious shale, a condition which is favorable for the retention of oil if the structural position of the beds is favorable. The Shelikof formation also contains porous sandstone members and thick beds of shale. It is from these beds that most of the seepages farther southwest issue, but whether the oil has actually accumulated in quantity in these beds or whether it is brought to the surface from greater depths by faults and fissures is uncertain. Oil is known to occur as low in the section as the lower part of the Middle (?) Jurassic rocks, or the Kialagvik formation, at Wide Bay.

SALMON CREEK-BEAR CREEK ANTICLINE

The structure contour map (pl. 4) gives a general idea of the anticlinal fold that crosses the headwaters of Salmon and Bear Creeks. The contours are drawn at intervals of 100 feet on a horizon low in the Shelikof formation. Broken lines represent the probable continuations of faults and the approximate positions of some of the contours.

All the rocks exposed along the anticline belong to the Shelikof formation, except the conglomerate and sandstone of the Naknek formation that crop out about 3 miles from the crest along the northwest flank. The lowest bed exposed at the crest of the anticline is a coarse gray sandstone the greater part of which is massive, although at several horizons the rock is thin bedded and weathers into flat boulders that form talus slopes. A thickness of about 400 feet of this sandstone is exposed on both sides of the divide between Salmon and Bear Creeks. The dips are toward the valleys in opposite directions. On the Bear Creek side the sandstone is broken at places by faults. A few fossils collected from this sandstone were determined as follows:

12384. F. 6. Large draw east of Salmon Creek. Lowest collection:
Ostrea sp.
Grammatodon? sp. Small cast.
Cadoceras? sp. Fragment.
Apparently these belong to the Shelikof (Chinitna) fauna.

An upward transition from coarse sandstone to pebbly sandstone, conglomerate lenses, and finally to a very massive conglomerate takes place near the top of the sandstone. The conglomerate differs greatly in thickness from place to place. It is best exposed in a large draw eroded on the crest of the anticline by a tributary of Salmon Creek. Here the conglomerate, with some thin interbedded lenses of sandstone, attains a maximum observed thickness of nearly 300 feet. Only 60 feet of the upper part of this conglomerate is exposed along the crest of the anticline on the south side of Salmon Creek. In Bear Creek it is apparently less than 50 feet thick, but part of it may be concealed by talus and vegetation. The conglomerate consists of exceptionally smooth, rounded pebbles and of boulders, some of which are 2 feet in diameter. The boulders are chiefly quartz diorite and granite, and the matrix is a coarse iron-stained sandstone that forms about one-third of the mass. Several limestone nodules that may have weathered from an older formation were seen in the conglomerate. The following fossils were collected from the limestone nodules:

12411. F. 33. Large draw near crest of dome on Salmon Creek. Float from conglomerate.:

Terebratula? sp.
Pecten sp. Smooth form.
Inoceramus sp.
Astarte? sp.
Grammatodon sp.
Pleuromya sp.
Undetermined pelecypods. Several small forms.
Amberleya sp.
Undetermined small slender gastropod.
Phylloceras sp. Numerous young shells.
Cadoceras sp. Numerous young shells.
Undetermined small keeled ammonite.
Belemnites sp.

These fossils apparently belong to the Shelikof (Chinitna) fauna.

The massive conglomerate is overlain by a thin bed of sandstone and fine conglomerate. Above the sandstone a thick and extensive bed of sandy light-colored shale occurs over a considerable area along the crest of the anticline, especially on the north side of the valleys of Bear Creek and the South Fork of Rex Creek. The shale is predominantly light brown, but at several localities it is dark and somewhat carbonaceous. Above the light-colored shale the greater part of the Shelikof formation consists of thick alternating members of sandstone and shale. Three sandstone members separated by varying amounts of shale were recognized in the upper part of the formation on Salmon Creek. The interbedded shale members decrease in thickness toward the northeast until on the north side of Cold Bay the formation is predominantly sandstone, although the uppermost member consists of 600 to 1,000 feet of blue to black

STRUCTURE CONTOUR MAP OF SALMON CREEK-BEAR CREEK ANTICLINE, ALASKA PENINSULA.

78644°-26. (Face p. 74.)

shale. Although variable in thickness the uppermost dark shale occurs throughout the district at the top of the Shelikof formation. The contact of the dark shale with the overlying basal conglomerate of the Naknek formation marks a horizon which is easily recognized. Locally the conglomerate rests unconformably upon the shale. Irregular nodules of blue limestone which weather to a conspicuous light-yellow color occur as lenses in the shale. Concretions composed of the shale itself and without definite boundaries are common at many horizons. The massive sandstone members of the upper part of the Shelikof formation are dark gray and very coarse and porous. In many outcrops hard spherical bodies of sandstone ranging from an inch to a foot or more in diameter form a considerable part of the upper two members of sandstone. These concretions are composed of the same material as the rock in which they occur and are very little harder than it. They do not contain nuclei and do not show concentric structure. The cause and manner of their formation are not known to the writer. The coarse sandstone members of the upper part of the Shelikof formation with the included beds of shale are of especial economic significance, particularly in the western part of the Cold Bay district, for under favorable structural conditions the sandstone and interbedded shale would form excellent reservoirs for oil and gas. However, over a large part of the Salmon Creek-Bear Creek anticline these sandstone beds have been deeply eroded, and any oil which they may once have contained in this locality has had ample opportunity to escape.

Accurate measurements of the brown shale and the overlying members of the Shelikof formation were not made in the vicinity of Salmon and Bear Creeks, but calculations of thickness made by pace traverse and careful estimates from available data give a thickness of more than 5,000 feet for the Shelikof formation exposed on Salmon Creek.

The structure map shows the position of several faults that cross the anticline in different directions. One of the most extensive is the Island Bay fault, along the east side of Island Bay, which strikes across the mountains N. 40° W. and probably continues parallel to the valley of Bear Creek for about 1½ miles on the northwest flank of the anticline. On the southwest flank of the anticline the greatest displacement along the Island Bay fault is apparently over 500 feet, but the exact amount of displacement is not known. Prominent scarps and small rifts can be seen along the strike of the fault. The relative displacement has been downward on the northeast side. Another fault of considerable extent and displacement, which is here called the Bear Creek fault, occurs along the upper valley of Bear

Creek and strikes N. 80° W. across the mountains between Bear Creek and Salmon Creek. In the upper valley of Bear Creek the displacement along this fault is apparently very great, for the apex of a large triangular block of sedimentary rock between this fault and the Island Bay fault has been tilted downward toward the crest of the anticline and also toward the southeast. A definite horizon in the tilted block is rather difficult to locate, and hence on the map the contour lines are dotted across this area, but they show approximately the relative position of these beds. A displacement of less than 100 feet was noted along the Bear Creek fault on the west flank of the anticline between Bear Creek and Salmon Creek. A fault strikes S. 30° W. from Jute Mountain along the base of the triangular block, but its displacement is not great.

From a point near the confluence of South Fork and Rex Creek a fault trends S.400 W. nearly parallel to and just southeast of the crest of the anticline. This fault, which 'for convenience is called the Anticline fault, was traced to Salmon Creek, a distance of nearly 5 miles. On the divide between Bear Creek and Salmon Creek the displacement is at least 250 feet and the relative downward throw is on the southeast side. This fault would have considerable influence on the concentration of any oil that may occur beneath the Salmon Creek-Bear Creek anticline, and its position and amount of displacement should be accurately known by those engaged in the development of the field. The Anticline fault was not traced across the high mountains northeast of Rex Creek, but a prolongation in that direction would be almost in alinement with the great Dry Creek fault, which crosses the head of Cold Bay and extends up the valley of Dry Creek. If a slight curve is postulated in the direction of the Dry Creek fault from the head of Dry Creek through the large patch of residue at the head of Oil Creek and thence straight to Rex Creek the two faults would coincide.

From the west side of the pass between Bear Creek and South Fork a fault trends N. 50° E. down the valley of South Fork and intersects the Anticline fault at an acute angle in the valley of Rex Creek. The rocks in the narrow area between the South Fork fault and Anticline fault have been tilted from a normal dip of about 5° N. to 18°-22° E. (See pI. 4.) A large part of the area between the two faults would normally have been along the plunging crest of the anticline. The South Fork fault apparently dies out in the shale that is locally folded and broken on the northwest side of the Bear Creek valley. Besides the faults above mentioned several minor faults were noted, and their position has been indicated on the map. Huge blocks of sandstone and shale have slumped toward the Salmon Creek valley from the side of the mountain northeast of the head of Salmon Creek.

Four oil seepages besides those near the head of Oil Creek are known on the Salmon Creek-Bear Creek anticline. Two of the seepages are on Salmon Creek, one is on Bear Creek, and one on South Fork. The lowest seepage stratigraphically occurs very near the highest point on the anticline on the divide between Salmon and Bear Creeks, in a large draw eroded by a tributary to Salmon Creek. (See pl. 4.) The oil issues frbm small fissures along joint planes in the lowermost sandstone exposed on the anticline. The seepage is about 150 feet stratigraphically above the lowest beds exposed. Only a few gallons of oil was seen, but the seepage is near a small stream, and the greater part of the oil is carried away as it emerges from the rock. Whether the oil originated in the rock from which it issues or whether it came from some bed at a lower horizon could not be determined. No indication of oil was seen, however, in other outcrops of the same sandstone. Although this seepage is small it is much nearer the crest of the anticline than the previously known seepages and is of considerable significance in as much as it proves that oil occurs much lower in the Shelikof formation than the other seepages indicate. This seepage is at least 5,000 feet lower stratigraphically than those that issue from the Naknek formation on the Pearl Creek dome, in the west field.

A larger seepage issues through the alluvium in the main valley of Salmon Creek about 1½ miles southwest of the axis of the anticline and over 1,000 feet higher stratigraphically than the small seepage in the draw. The rocks exposed close to the seepage in the main valley consist of sandstone, fine conglomerate, and thin beds of shale. The largest seepage on the Salmon Creek-Bear Creek anticline occurs in the valley of Bear Creek. A considerable quantity of oil and residue has collected in a circular pool about 50 feet in diameter with a narrOw outlet 120 feet long to Bear Creek. This seepage appears to beat least 100 feet lower in the section than the larger seepage on Salmon Creek. Thick beds of shale crop out on the south side of the valley opposite the Bear Creek seepage. The seepage in the South Fork of Rex Creek occurs along the South Fork fault in about the central part of the valley and issues from sandstone and shale fora distance of 100 feet along the bank of the stream. This seepage is much lower in the section than the seepage on Bear Creek, which is very close to the Island Bay fault, and probably the oil escapes through a fissure connected with that fault. Although a fault was not observed in and Parallel to the main valley of Salmon Creek near the seepage, it is quite probable that such a fault exists. A consideration of the position and cause of the seepages is useful. If the oil is migrating up the dip of the beds that contain it and flows out of the upturned edges of the beds on the flanks of the anticline the condition is not favorable for concentration and retention of the oil in commercial quantities. As the seepages in the valley of Bear Creek and the main valley of Salmon Creek are a considerable distance down the northwest flank of the anticline and are perhaps within 100 feet of the same horizon it might be suggested that the oil is migrating up a bedding plane and entirely escaping. However, if this is the actual condition of these two seepages there is undoubtedly more than one oil-bearing bed in the east field, for the seepage on South Fork is much lower in the section and is known to occur on a fault through which the oil might migrate vertically from a still lower horizon. The small seepage on a tributary to Salmon Creek is at least 1,000 feet lower in the section than the seepage in the main valley. The oil of the small seepage and of the South Fork seepage could by no means be derived from the beds exposed near the seepages on the flank of the anticline in the valleys of Bear and Salmon Creeks, but if the Bear Creek and Salmon Creek seepages occur along faults, a condition that is strongly suspected, all the oil may be escaping from one horizon beneath the crest of the anticline.

The character of the beds immediately beneath the crest of the anticline is not known, but quite probably the beds belonging to the Kialagvik formation that are exposed at Wide Bay and Alinchak Bay would be reached by drilling a few hundred feet. The Kialagvik formation is known to contain oil at Wide Bay, and all the seepages near Iniskin Bay, on the west side of Cook Inlet, occur in rocks of nearly the same age. At Wide Bay, however, an angular unconformity exists between the Kialagvik and Shelikof formations, so that the strike and dip of the lower beds do not everywhere conform to those of the beds higher in the section. A similar condition may exist beneath the Salmon Creek-Bear Creek anticline and cause the seepages far down on its flanks.

The seepages near the head of Oil Creek issue from a porous sandstone high in the Shelikof formation, which crops out on Trail Creek and which lies about 1,000 feet below the base of the Naknek formation. The principal seepage issues at the base of a low knoll near a large residue patch, and the oil is brought to the surface by a strong spring. A considerable quantity of gas escapes with the water and oil. This seepage is nearly in alignment with the great Dry Creek fault, which suggests that the oil may be coming from beds much lower than the sandstone on Trail Creek. Smaller seepages close to the residue patch appear to issue from fractures in the sandstone, which is somewhat shattered in the immediate vicinity. The beds are in general nearly horizontal in the area near the Oil Creek seepages, but gradually merge into a monocline that dips 12°-15° NW., toward Becharof Lake. Five wells were drilled near the divide between Becharo£, Trail; and Oil Creeks in 1902-1904 to depths of 500 to 1,500 feet. Some of these wells were reported to have found a small amount of oil and to have penetrated sand containing residue. The area near the Oil Creek seepages is not structurally as favorable for containing large oil pools as the Salmon Creek-Bear Creek anticline. Should an oil-bearing bed be encountered by drilling on the anticline, an. estimate of the additional depth to this bed in the Oil Creek area could be made.

The chances of obtaining oil in commercial quantities on the Salmon Creek-Bear Creek anticline appear favorable. Although the anticlme is faulted, this condition should not be considered a serious disadvantage, as the faults may have stopped the migration of oil at places and thus formed separate pools and widened the productive area. Many highly productive oil fields are extensively faulted. The position of the faults should be known, and sites for test wells should be carefully chosen. The drills would explore beds that in the west field are beyond reach of the drill; and if the stratigraphic conditions beneath the anticline are as favorable as those, to be seen at Wide Bay and Cape Kekurnoi, the prospect of obtaining oil at a moderate depth is good; A road can be built to Salmon Creek without great expense, either from Kanatak or across a very low divide from the head of Island Bay. The valley' of Bear Creek can also be entered from Island Bay.

WIDE BAY ANTICLINE

The Wide Bay anticline forms the southwestern part of the same general line of folding to which the Salmon Creek-Bear Creek anticline belongs, The anticlinal fold is not continuous across Portage Bay and Cape Igvak but is interrupted by a large intrusionoI quartz diorite. The Salmon Creek-BearCreek anticline plunges steeply toward the southwest. at Portage Bay. On the southwest side of Cape Igvak the Wide Bay anticline rises very gradually toward the lower end of the bay. This anticline is over 20 miles in length. The crest is not accessible for observation, as it lies beneath the waters of Wide Bay. The bay is about 5 miles wide, and the position of the highest part of the anticline Can only be estimated from observations made along the shore, which at places appears to be. a considerable distance from the crest. Along the northeast side of the bay the beds are nearly horizontal and the axis of the anticline is probably not far offshore. Toward the lower .end of the bay, liowever, the anticline rises and apparently swings toward the southeast side. The beds on the group of islands across. the bay and on the cape projecting toward the islands dip 6°_24° SE. and form the southeast flank of the anticline. The prevailing dips on the mainland are to the northwest.

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Rocks of Middle (?) Jurassic age, belonging to the Kialagvik formation, are exposed along the shores of both sides of the southwest end of Wide Bay. With the exception of a small area on Cape Kekurnoi, the Kialagvik formation is known on the Alaska Peninsula only at Wide Bay. This formation is of especial interest, because it probably underlies the Salmon Creek-Bear Creek anticline within moderate drilling depth. About 1,400 feet of the Kialagvik formation is exposed at the southwest end of Wide Bay. The entire thickness of the formation is not known, as the base is not exposed. At a point just west of Cape Kekurnoi a thickness of 1,300 to 1,600 feet of sediments is tentatively regarded as of Middle Jurassic age. Near Iniskin Bay, on the west side of Cook Inlet, the Tuxedni formation, part of which is equivalent in age to the Kialagvik formation, is approximately 8,000 feet thick. On the northwest side of Wide Bay the Kialagvik formation occurs in a narrow strip about a mile wide, extending from a point near the mouth of Des Moines Creek to a point nearly 3 miles up the broad glacial valley at the southwest end of the bay. The formation is exposed in the cliffs along the bay and in the valleys of small streams. The intervalley areas west of the bay are covered by glacial drift and by a dense growth of vegetation, so that the contact with the overlying Shelikof formation is difficult to follow. The exposures along the northwest side of the bay contain chiefly sandstone, sandy shale, and minor beds of conglomerate. The lowest bed exposed at low tide opposite Pass Creek consists of fine grit and is overlain by several hundred feet of thin beds of alternating sandstone and sandy shale. These beds are overlain by a massive sandstone. In the creek just north of the large sand spit the section is roughly as follows:

Section on northwest side of Wide Bay

	Feet
Thin-bedded bluish-gray sandstone (lowest beds)	200±
Rusty shale with some sandstone and limy lenses	60
Massive dark-gray sandstone	100±
Thin-bedded pink sandstone	80
Massive dark-gray sandstone	150±
Rusty shale with thin bands of limestone	800±

The pink sandstone between beds of gray sandstone forms an excellent horizon marker and can be recognized in several localities. The color is not due to weathering or iron stains.

Along the southwest side of the bay the Kialagvik formation crops out at the base of the high mountains and has been traced from a point near the cape projecting toward the island to the first small glacier at the head of the bay. The formation is probably exposed farther southwest. Near the glacier and for a distance of about 1½ miles northeast of it the sedimentary rocks are somewhat metamorphosed by a large quartz diorite intrusion. Dikes and sills cut the sedimentary rocks in this locality. At places the rocks are stained dark brown and red by iron oxide derived from the decomposition of pyrite.

Section of Kialagvik formation on southwest side of Wide Bay

	Feet
Coarse pebbly sandstone	150
Unexposed	100?
Pink sandstone	80
Unexposed	150?
Fine to coarse sandstone	200±
Bluish shale with limestone bands and concretions	400±
Coarse massive dark sandstone	100-200
Massive light-colored sandstone	80±

The sections on the opposite sides of the bay can not be correlated satisfactorily, in part because of an unconformity at the top of the formation. The unconformity is most pronounced in the bluffs north of Lee's store, where the shale beds of the Kialagvik strike S. 45° E. and the overlying beds strike southwest. Deformation and erosion occurred in this locality before the sediments of Upper Jurassic age were deposited. At the southwest end of the bay, where locally the beds are nearly horizontal, the unconformity was not observed. Numerous faults were noted in the cliffs along the shore of the bay, but none of them appeared to have a displacement of more than 100 feet.

The Kialagvik formation is abundantly fossiliferous and contains a peculiar fauna somewhat similar to the lower Tuxedni fauna. Lenses of sandstone, 20 feet thick, that occur in the Kialagvik formation west of Wide Bay are made up almost entirely of casts of *Inoceramus.* The collections that were made during 1924 are listed below.

12399.F. 21. Cliff southwest of Pass Creek, Wide Bay (Capps 104):

Nutlike fruit?
Ostrea sp.
Pecten sp. Smooth form.
Pecten sp. Ribbed form.
Lima sp. Related to L. gigantea Sowerby.
Inoceramus sp.
Mytilus sp.
Cucullaea increbescens White?
Trigonia sp. Costatae group.
Venerid?
Pleuromya dalli (White).
Natica sp.
Hammatoceras howelli White.
Harpoceras whiteavesi White.
Belemnites sp.

Kialagvik fauna.

12400. F. 22. Rocks exposed at low tide opposite Pass Creek, Wide Bay:
Mytilus sp.
Eumicrotis? sp.
Presumably Jurassic, but exact horizon not determined by these fossils.

12401. F. 23. Cliff southwest of Short Creek, Wide Bay:
Nutlike fruit?
Rhynchonella sp.
Ostrea sp.
Pecten sp. Smooth form.
Pecten sp. Ribbed form.
Pteria sp.
Eumicrotis? sp.
Trigonia sp., Costatae group.
Trigonia sp., Glabrae group.
Trigonia sp., Clavellatae group.
Tancredia? sp.
Protocardia sp.
Goniomya sp.
Pleuromya dalli (White).
Natica? sp. ' Two or more.
Hammatoceras? kialagvikense (White).
Harpoceras whiteavesi (White).
Kialagvik fauna.

12402. F.24. Half a mile up Quail Creek, Wide Bay:
Pecten sp. Small smooth form.
Pecten sp. Ribbed form.
Lima sp. Related to L. gigantea Sowerby.
Lima sp. Small ribbed form.
pteria sp.
Inoceramus lucifer Eichwald?
Pleuromya sp.
Pholadomya sp.
Undetermined pelecypod.'
Harpoceras whiteavesi (White)? •
Phylloceras sp.
Stephanoceras? sp.
Ammonite. Genus undeterLlined.
Belemnites sp.
Kialagvik fauna.

12404. F. 26. Southeast side at head of Wide Bay:
Pecten sp. Small smooth form.
Lima sp. Related to L. gigantea Sowerby.
Inoceramus lucifer Eichwald.
Trigonia sp. Clavellatae group.
Stephanoceras? sp.
Kialagvik fauna.

12405. F. 27. Southeast side of Wide Bay, 1½ miles from cape near the islands:
Pteria sp.
Inoceramus lucifer Eichwald?
Harpoceras whiteavesi (White)?
Harpoceras? sp.

Hammatoceras? Several species distinct from H. howelli (White).
Sonninia? sp.
Stephanoceras sp. Related to a species in the Tuxedni sandstone.
Stephanoceras? Two other species.
Phylloceras sp. Fragment of a large individual.
These fossils apparently belong to the Kialagvik fauna, though they include several species not before collected.

12410. F. 32. Cliffs at southwest end of Wide Bay, west side below sand spit:
Pecten sp. Smooth form.
Grammatodon sp.
Trigonia sp. Glabrae group.
Isocardia? sp.
Goniomya sp.
Homomya sp.
Sonninia? sp.
Hammatoceras? sp.
Kialagvik fauna.

The Shelikof formation, which overlies the Kialagvik unconformably, is nearly 6,000 feet thick west of Wide Bay. The beds are composed of thick members of shale and sandstone, but in this area shale predominates and occurs in much thicker beds than in the area farther northeast. Locally the lowermost bed is a coarse conglomerate, although in general the lower 1,500 feet consists of rusty and dark-blue massive shale with minor amounts of sandstone. The uppermost member also consists of about 1,000 feet of shale with limy concretions and some sandstone. The coarse massive sandstone members are similar in character to their equivalents on Salmon Creek, although they are not as thick. The rocks exposed on the islands in the bay presumably belong to the Shelikof formation, although no fossils have been found on the islands. The individual beds are not so thick as on the mainland and probably represent a different phase of deposition. A few collections of fossils were made on the mainland just above the contact of the Kialagvik formation.

12398. F. 20. 1½ miles up west branch of Lee Creek, Wide Bay:
Cadoceras? sp.
Probably Shelikof (Chinitna) fauna.

12406. F. 28. Southwest of Wide Bay (Johnson Hill). Highest collection:
pteria sp.
Inoceramus sp.
Grammatodon sp.
Cardium? sp.
Pleuromya sp.
Other pelecypod casts.
Shelikof (Chinitna) fauna.

12407. F. 29. Southwest of Wide Bay, near summit of Johnson Hill:
Rhynchonella sp.
pteria sp.

Grammatodon sp.
Goniomya sp.
Amberleya sp.
Cadoceras sp.
Shelikof (Chinitna) fauna.

12408. F. 30. Southwest of Wide Bay, south side of Johnson Hill:
Pteria sp.
Phylloceras sp.
Cadoceras doroschini (Eichwald).
Cadoceras stenoloboide Pompeckj.
Shelikof (Chinitna) fauna.

12409. F. 31. Southwest of Wide Bay. Lowest collection in section on Johnson Bill:
Pecten sp. Small smooth form.
Trigonia? sp. Small cast.
Pleuromya sp.
Probably Shelikof (Chinitna) fauna.

A small oil seepage was found in the rocks exposed at low tide opposite the mouth of Pass Creek. These rocks consist of light-colored grit and pebbly sandstone that strike S. 45° W. and dip 8°_10° NW. and are probably the lowest beds exposed at Wide Bay. The oil issues from cracks in the sandstone. A thin coating of residue adhered to the walls of the cracks. Bubbles of gas escaped continuously through the water close to the oil seepage. The gas was not ignited. Only a small amount of oil was seen, but the seepage was active. This is the only seepage known at Wide Bay and is significant in that it proves that oil occurs in Middle Jurassic beds on the Alaska Peninsula as well as near Iniskin Bay, Cook Inlet. Stratigraphically the Wide Bay seepage is perhaps 1,800 feet below the lowest seepage on Salmon Creek, but the unconformity in the section between the two seepages makes any estimate very uncertain.

At several localities on both sides of the bay and in the rocks at the oil seepages a solid hydrocarbon occurs in thin irregular stringers along vertical fault planes and small fissures. In a cliff along the beach about half a mile northeast of Lee's store the stringers had a maximum observed width of 2 inches. Crystals of calcite generally occur along the. fissures with the hydrocarbon. No evidence of lateral migration from the fissures was noted. The material ignites easily and emits an odor similar to that of burning residue. An analysis of a sample of the hydrocarbon, made in the chemIcal laboratory,of the United States Geological Survey by E. T. Erickson, is given below. The sample was previously dried at 105° C.

Specific gravity at 25°	1.026
Fixed carbon --per cent__	28.5
Ash ----do----	7.6
Solubility in carbon disulphide at room temperature__do___	90.0

Organic matter insoluble in carbon disulphide at room temperature__ per cent__	2.4
Solubility in 88° naphtha at room temperature ---do----	58.0
Per cent of sample soluble in 88° naphtha found to be chemically saturated -------------per cent__	16.7

Specimens of the sample showed homogeneous structure and subconchoidal fracture with brilliant black luster. The powdered sample was dark brown. The ash content appeared to be largely due to extraneous mineral matter. The hydrocarbon (pure basis) showed considerable resemblance to Utah gilsonite, the principal differences being that the sample was a little higher in gravity and contained a higher percentage of chemically saturated material soluble in 88° naphtha than gilsonite.

Probably the oil and the hydrocarbon have a common origin. Two viewpoints regarding the origin of the hydrocarbon may be taken-that it is a residue left after the oil has migrated; or that material which represents an earlier stage in the metamorphism of the petroleum has entered the fault plane.

The possibility of obtaining oil at Wide Bay is not known, as the character of the underlying beds may be quite different from that of the Lower Jurassic and Upper Triassic beds at Cape Kekurnoi, the only locality where lower beds are exposed in the district. However, if the organisms whose remains are found in the Triassic limestone contributed some of the oil in the district, and if the Lower Jurassic is present beneath Wide Bay and is composed of thick beds of sandstone and shale as at Cape Kekurnoi, the occurrence and concentration of oil at Wide Bay could be expected. The structural conditions are favorable, and the dimensions of the Wide Bay anticline are such that if a test well is successful the productive area might be very large. The construction of roads and the expense of transporting equipment over the mountains would not be necessary at Wide Bay, which is more favorably located than any other promising area in the district.

UGASHIK CREEK ANTICLINE

The Ugashik Creek anticline roughly parallels the Salmon Creek-Bear Creek and Wide Bay line of folding but lies 8 to 14 miles inland and extends from Mount Burls, between the upper arm of Becharof Lake and Mount Peulik, southwestward to Deer Creek. The maximum development of the fold occurs near its northeast end, where the beds are arched into a large and well-defined dome that is referred to as the Pearl Creek dome. Southwestward from Crooked Creek, where both flanks of the anticline dip about *12°;* the fold gradually rises and flattens out until at Deer Creek it merges into a monocline with northwest dips. The Becharof Lake syncline separates the eastern line of folding from the Ugashik anticline. The axis of the syncline occurs along the upper arm of Becharof Lake and extends southwestward to the vicinity of Deer Mountain, where it flattens out and becomes a westward-dipping monocline.

All the consolidated rocks exposed on the Ugashik Creek anticline belong to the Naknek formation with the exception of a small area at its northwest end, where lava from Mount Peulik, a volcano, has concealed the sedimentary beds. The Naknek formation overlies the Shelikof and is the highest Upper Jurassic formation in the district. At least 6,000 feet of shale, arkosic sandstone, and conglomerate has been assigned to the Naknek. The several members of the formation show a great lateral variation in thickness, but in general the lower 1,000 to 3,000 feet consists of coarse conglomerate and light-gray pebbly and arkosic sandstone. Light to dark brown shale predominates throughout the upper 3,000 feet of the formation. The Naknek and Shelikof formations are locally unconformable. West of Wide Bay the basal part of the Naknek includes two heavy conglomerates separated by more than 1,000 feet of gray arkosic and pebbly sandstone. The lower conglomerate ranges in thickness from 70 feet at Cold Bay to 900 feet west of Wide Bay. The upper conglomerate is about 1,000 feet thick in the mountains at the head of the South Fork of Crooked Creek and in Burls Ridge. The conglomerate exposed on the Pearl Creek dome rises toward the southwest and occurs near the summit of the mountain on the north side of the upper valley of Moore Creek. The lower conglomerate crops out about 1,500 feet lower on the east side of Des Moines Creek Pass, where it is about 200 feet thick. The log of a well 3,000 feet deep does not show the presence of the lower conglomerate on the Pearl Creek dome.

Several oil seepages and two patches of residue occur on Pearl Creek dome. The largest seepage and patch of residue is about 1 mile upstream from the mouth of Barbara Creek. The residue has been successfully used as fuel for drilling. A pit 12 feet deep does not reach the bottom of the deposit. Analysis by E. T. Erickson of a sample of oil from Barbara Creek is given below:

Specific gravity at 15° C., 0.952, 17.1° Baumé, modulus 140.
Color, dark brown.
Water, 1.5 per cent.
Distillation in Bureau of Mines Hempel flask: First drop, 170° C.

Distillation with Bureau Of Mines fractionating column

[Barometer 759 millimeters]

Temperature (°O.)	Fractions (per cent by volume)	Total (per cent by volume)	Specific gravity	Oloud test
170-200	1.2	1.2	0.826	
200-225	2.2	3.4	.849	
225-250	5.3	8.7	.862	
250-275	7.7	16.4	.876	
165-200	7.0	23.4	.904	
200-225	12.1	35.5	.914	
225-250	7.4	42.9	.936	
250-275	6.7	49.6	.945	
275-300	6.3	55.9	.955	Below-5° O.
300-325	11.3	67.2	.960	Do.
Residue (undecomposed oil)	32.0	99.2		

The fraction 300°-325° C. (40 minutes) ·gave indications of a slightquantity of paraffin by the use. of Holde's test.

At ordinary temperature the oil seems to have high viscosity together with high gravity, which also characterize the high-boiling fractions. These properties, together with the presence of not more than a small proportion of the paraffin series·of hydrocarbons in the higher boiling-point fractions (shown by Holde's test for paraffin and also by the low temperature given by the cloud test) indicate that the sample of oil is a naphthene-base petroleum. This type of petroleum is known to some oil men as "asphaltic base," a term which introduces confusion, for the sample contains but a small proportion of material (1.2 percent found to be insoluble in 88° naphtha) that may be the chemical equivalent of asphalt.

A sample of the natural residue from the seepage on the Pearl Creek dome, which has been called" paraffin residue," yielded 63½ per cent of bitumen of specific gravity 1.021 upon extraction with carbon disulphide and drying at 105° C.,'leaving 29 per cent of insoluble matter consisting almost entirely of dried vegetable material. The bitumen, which was highly viscous at ordinary temperatures, was found to be 87 per cent soluble in naphtha of 88° Baumé. The extract soluble in naphtha yielded 44 per cent of the original bitumen taken as chemicallY' saturated, which was found by Holde's' paraffin test to contain only a small amount of paraffin.

The opposite sides of the valley of Barbara Creek have been displaced at least 200 feet by a fault that strikes through the saddle between Mount, Demian and Mount Lee. The seepage near the mouth of the creek. is in alinement· with this fault. Several minor faults nearly parallel to the large fault were noted near the head of Barbara Creek. Faults were not observed near the seepages on PearI Creek.

A rise in the beds along the crest of the Ugashik Creek anticline in the vicinity of Moore Creek is locally called the Hubbell dome, but the structure does not close toward the southwest.

As a result of the gradual rise of the anticline southwest of Crooked Creek, the surface rocks at Moore Creek are perhaps 600 feet lower in the section than the lowest beds exposed on Pearl Creek dome. The axes of the Becharof Lake syncline and the Ugashik Creek anticline, which are about 5 miles apart between upper. Becharof Lake and Pearl Creek dome, converge in the vicinity of Moore Creek until they are only 3,000 feet apart. Where the synclinal axis approaches the anticline a thrust fault occurs along the crest of the anticline and parallel·to the axis of the syncline. The overthrust beds are composed of arkosic sandstone and conglomerate and dip 19°_35° SE. The beds on the northwest flank of the fold are normal and dip 4° NW. A small amount of residue occurs in several fissures near the thrust fault in the canyons west of the sharp bend in Moore Creek. An active seepage is reported near this locality. The beds beneath the Moore Creek area should be somewhat similar to those beneath Pearl Creek dome.

The possibilities of obtaining oil in commercial quantities on Pearl Creek dome have been considered favorable by many geologists, and the dome has been generally regarded as more promising than any other structural feature in the Cold Bay district. The presence of large seepages, the well-developed dome structure, and the underlying Shelikof formation, consisting of a thick series of sandstone and interbedded shale, are favorable features. However, the question arises whether the oil has been concentrated in the sandstones of the Shelikof or in lower formations. Some of the oil in the district issues through beds low in the Shelikof and Kialagvik formations and beyond the reach of the drill at the Pearl Creek dome. The presence of more than one oil-bearing bed is probable, and under favorable structural conditions, such as those at the Pearl Creek dome, the coarse sandstone of the Shelikof would form an excellent reservoir if the oil had access to it. The stratigraphic conditions of the east and west parts of the district are quite different, and the success or failure of drilling oil in one area does not necessarily mean that similar results would be obtained elsewhere.

AREA NORTH OF BECHAROF LAKE

In a reconnaissance trip along the north shore of Becharof Lake, west of the Kejulik Mountains, the Tocks exposed in the southwest end of these mountains were found to consist chiefly of lava beds, which have been elevated and slightly folded since their extension over the sedimentary rocks. The lava is somewhat scoriaceous and rudely stratified. At a few exposures sedimentary rocks beneath the lava consist of shale within beds of sandstone and limestone concretions. The characteristic upper Naknek fossil *A uoella* occurs abundantly in the shale. All the beds observed strike northwest and dip northeast.

The isolated mountain north of the central part of the lake shore is made up of coarsely crystalline granite, gabbro, and igneous rocks of intermediate types. These rocks are similar in character to a large granitic mass 30 miles farther northeast and probably represent a southwestern extension of the same intrusion. The area immediately north of Becharof Lake and west of the Kejulik Mountains, in so far as it has been studied, is not believed to be favorable for the occurrence of oil.

A RUBY SILVER PROSPECT IN ALASKA

By S. R. CAPPS and M. N. SHORT

INTRODUCTION

In Jruly, 1922, a silver prospect of unusual type was discovered in the upper Susitna Basin. This prospect, named the Mint mine by the owners, is the property of Arthur Moose Johnson, the discoverer, and of his partner, Harry A. Wertz. It is about 9 miles east of Chulitna station on the Alaska Railroad, 274 miles by rail north of Seward, and lies on the west bluff of Portage Creek, about 3 miles above the junction of that creek with Susitna River. At that place Portage Creek has an altitude of about 1,100 feet above sea level. The Mint mine can be reached on foot over a fair trail of moderate grades in about three hours' travel from the railroad. The trail has been improved by a bridge across In.dian River, by some cutting of brush, and by numerous notices of direction. In 1924 it was wet and soft in places, but by some relocation and grading it couid without serious difficulty and without much heavy construction be developed into a good wagon road. A .comfortable cabin has been built on Bear Lake, about 2 miles west of the lode.

The present description of the Mint mine is the result of a visit in September, 1924, by S. R. Capps, who spent about two days on this and adjacent properties. At the same time Mr. Harry Townsend, of the Bureau of Mines, visited the property and made a sketch survey of the lode and the developments and took some samples_of the ore body. Thew-riters wish to acknowledge their indebtedness to Mr. Townsend for furnishing copies of his surveys and the results of his sampling. The laboratory study of the specimens of the rock and, the ore in thin section or in polished section was made by M. *N.* Short.

GEOLOGIC RELATIONS

The outcrop of the Mint ore body is on the west bluff of Portage Creek, at a place where the creek makes a sharp U-shaped bend eastward. The creek valley in this stretch lies in a steep-sided canyon cut several hundred feet below the level of the upland, and a prominent narrow point extends eastward into the U-shaped bend. This point rises about 300 feet above the creek, and its walls are in many places sheer cliffs, so that except in one place, where some ladders have been placed along a steep drainage line, the canyon walls are scalable only with difficulty. The ore body was first discovered at a narrow place on the crest of this projecting point of the canyon wall and has since been traced down nearly to the creek on both sides. Developments on this property at the time of visit included a lower tunnel 15 feet long, 10 feet above Portage Creek and on the footwall side of the lode, which had been started to cut the lode at a low level but had not yet reached it; a second tunnel 17 feet long and an open cut on the lode about 100 feet above Portage Creek; and a small open cut about 230 feet above Portage Creek and on the south side of the point, about 30 feet below its crest. The country rock in this vicinity consists of dark-gray to black slate, generally blocky but locally fissile, with a well-developed cleavage. It has yielded no fossils in this vicinity but is believed to be of Mesozoic age. No detailed geologic mapping has been done in this immediate vicinity, but within a few miles to the north of the Mint property there are considerable areas of greenstone associated with the slate, and both slate and greenstone are cut by stocks of granitic rock, probably also of Mesozoic age, from which acidic dikes radiate into the slate. Two such dikes were observed on lower Portage Creek—one at the Mint prospect, which though much altered was probably originally an andesite dike, and another on the Ella B. prospect, about a mile south of the Mint, which is a much fresher and less altered andesite. The Mint lode is believed to be genetically related to these dikes, which have supplied the mineralized solution from which the vein quartz and sulphides of the lodes were deposited. The ore at the Mint mine consists of quartz carrying sulphides, the most valuable of which is pyrargyrite. The ore occurs as the interstitial filling of a slate breccia on the west side of the dike, as veinlets in the dike itself, and as stockworks of quartz veinlets in the slate on both sides of the dike.

At the Mint prospect the blocky slate, which strikes north to N. 30° E. and dips 20°–80° west to northwest, is cut at a low angle by an andesite dike from 5 to 12 feet wide that strikes about N. 20° W. and dips 75° southwest. The freshest obtainable specimens of rock from this dike, when studied in thin section, are found to be composed predominantly of feldspathic materials, consisting of phenocrysts of somewhat sericitized orthoclase in a groundmass of badly altered feldspar laths that suggest that the rock is an andesite. Ferromagnesian minerals are notably absent. The dike rock is crushed and traversed by minute veinlets of quartz, which are accompanied by a few small grains of sulphide.

Other thin sections of a rock which in the field appeared to be identical with the dike rock described above prove under the microscope to consist of closely spaced parallel seams of quartz, in the midst of which are small clusters of ruby silver and arsenopyrite. The arsenopyrite preserves its crystal outlines against both quartz and ruby silver, but the sulphides and quartz were undoubtedly introduced together. The rock shows no signs of igneous origin, but consists of a fine-grained aggregate of quartz and biotite low in iron, with the biotite plates approximately parallel. The field evidence suggests that this material is a portion of the dike that has been almost completely replaced by secondary quartz, but the microscopic evidence suggests that it is a highly silicified mass of the slate country rock.

The accompanying sketch (fig. 3) shows the relations of slate, dike, and ore body at the upper tunnel, about 100 feet above Portage Creek. At the upper tunnel workings the evidence indicates strong movement on the west side of the dike, which resulted in the brecciation of the slate and the formation of some gouge. The interstices between the fragments of slate have been partly or wholly filled with solution quartz. In thin section this quartz exhibits a mosaic pattern. The quartz grains adjoining the fragments of slate have tended to orient themselves with their optic axes perpendicular to the fragments. There are many irregular vugs in which the quartz filling is incomplete and the cavities are lined with crusts of quartz prisms with which sulphide minerals are associated. Many of these crystals are now stained a rusty red on the surface. The fragments of slate are generally sharp and angular, though there is evidence of some replacement by quartz. As has been stated, the dike itself has been largely replaced by silica and is cut by quartz veinlets containing sulphides.

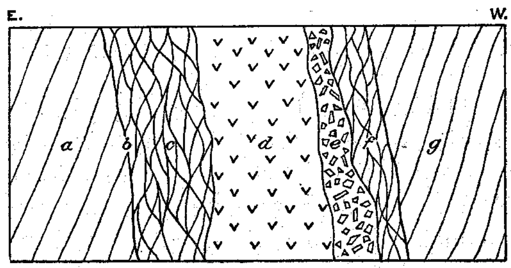

FIGURE 3.-Sketch of geologic relations at upper tunnel, mint mine, looking south. Scale, 1 inch=20 feet. *a*, Blocky slate; *b*, slip zone with gouge; *c*, slate, with quartz veinlets and sulphides; *d*, badly altered and silicified andesite dike with quartz veinlets and sulphides; *e*, breccia of slate fragments with quartz filling that carries sulphides; *f*, slate with gouge and quartz veinlets that carry sulphides; *g*, blocky slate

On the footwall or east side of the dike and adjoining it is an area of slate, about 8 feet wide, which is intimately cut by sulphide-bearing quartz veinlets. This area of slate is bounded on the east side by a slip zone with gouge. This slip zone has been somewhat mineralized as well as the slate for some distance east of it.

At the place where the original discovery was made, .about 230 feet above Portage Creek, on the south side of the narrow ridge where the ore body occurs, a continuation of the mineralized zone is seen. At that place a shallow open cut reveals much the same conditions as those already described, though the expOsures are imperfect. Blocky slate on the east adjoins the altered dike, which is here about 10 feet thick, is almost completely silicified, and is cut by quartz veinlets carrying sulphide minerals. Westof the dike lies a zone 18 inches wide composed mainly of quartz, which carries some sulphides. This zone is succeeded to the west by about 8 feet of slate carrying more or less vein quartz and sulphides. Still farther west lies a zone 1 to 3 feet wide composed of slate breccia with quartz and sulphides in the interstices. This breccia lies below a hanging wall of blocky slate that shows only scattered specks of sulphide minerals and little quarti.

THE ORE

The ore samples that are described below were examined in thin section or in polished section under the metallographic microscope and are believed to be typical of the slate-breccia portion of the ore body. Much of the highest-grade silver ore, however, occurs as veinlets of quartz carrying ruby silver which cut either the dike rock or the adjoining slate.

Sample la.-Slate breccia from open cut near top of ridge on south side. Fragments of slate cemented by solution quartz. The slate consists mainly of a very fine aggregate of biotite and quartz. The fragments have sharp boundaries with the quartz, and there has been almost no replacement of slate.· Veinlets of quartz break across the fragments in places, b'ut the boundaries of the veinlets are sharp and indicate a filling of cracks rather than replacement. However, locally there has been some replacement of slate by quartz, as in the midst of some areas of slate there are perfectly formed quartz prisms, some as much as 1 millimeter in diameter. It is hardly possible that cavities of the proper size and shape could have existed prior to the advent of the quartz. Sulphides occur in both quartz and slate. Some sericite accompanied the solution quartz and replaced it along the boundaries between the individual grams.

Sample lb.-From same locality as sample la. The replacement of slate by quartz is more apparent in sample lb, and rounded areas of slate surrounded by quartz are common. The solution quartz in places forms a fan-shaped mosaic around fragments of slate. The quartz contains tiny dark inclusions whose exact nature could not be determined. They are transparent and dark-brown and may be rutile.

One veinlet of sulphides crosses the entire section. mainly in the slate area. It is bounded on both sides by seams of quartz, the quartz grains being oriented more or less perpendicularly to the sUlphide veinlet. The quartz at this place is later than the sulphides.

Ore minerals.—The following ore minerals were identified in polished sections:

Pyrargyrite (Ag,SbS.).
Miargyrite (Ag SbS2).
Arsenopyrite (FeAsS).
Chalcopyrite (CuFeS2).
Galena (PbS),
Tennantite (?) ($Cu_8As_2S_7$).
Pyrite (FeS,).

These sulphides are very closely associated with one another and form intergrowths which appear as simple patterns in the polished section. Arsenopyrite and pyrite usually show some crystal outlines and may be a little earlier than the remaining sulphides, which form mutual boundaries owing to simultaneous deposition, indicating that they are all of the same age. The boundaries are smooth and rounded, with few prominent projections of one mineral in the other. All the minerals are believed to be hypogene. No oxidized minerals were observed, and there are no microscopic structural features indicative of s'upergene enrichment.

The sulphide minerals are intimately associated with the vein quartz that cements the breccia, and the evidence is clear that the quartz and ore minerals were deposited by the same solutions.

Pyrargyrite is the predominating ore mineral present. It is readily identifie.d in the hand specimen and forms dark-reddish crusts and coatings on quartz. No crystals were observed in the material studied microscopically, though a few fine prisms as much as 17 millimeters in length by 12 millimeters in diameter have been found. The laboratory examination which polarized light showed only small individual grains, none more than 0.1 millimeter in diameter. An open-tube test indicates that arsenic is entirely absent or forms only a small percentage of the mineral.

Miargyrite is closely intergrown with pyrargyrite and forms approximately 10 per cent of the sulphides present. It is recognized only in the polished section and was identified by microchemical tests, by the color of its powder, which is darker than that of pyrargyrite but lighter than that of polybasite, by its color in reflected light, and by its strong anisotropism. No isolated areas of miargyrite were observed, and it occurs only as small rounded areas in pyrargyrite.

Arsenopyrite occurs for the most part as scattered crystals and small clusters of grains well distributed through the specimen. The total amount of arsenopyrite in the specimens observed is about the same as that of pyrargyrite. Although most of the arsenopyrite is disseminated, a veinlet of arsenopyrite entirely traverses one of the polished sections and is an open-space filling. Most of the arsenopyrite occurs in quartz, but a relatively small percentage replaces fragments of slate.

Pyrite is relatively rare and waspnly observed along the margins of the veinlet of arsenopyrite described in the preceding paragraph. The comparative absence of pyrite is noteworthy and indicates that the ore solutions were poor in sulphur.

Chalcopyrite is found only in microscopic quantities and does not form more than 1 per cent of the total sulphides. On the polished surface it appears as small isolated areas in pyrargyrite.

Galena is almost invariably found adjacent to chalcopyrite but is also found as isolated patches in pyrargyrite. In places it forms well-defined graphic intergrowths with pyrargyrite; elsewhere the two minerals form mutual boundaries. The total amount of galena is about the same as that of chalcopyrite.

Closely associated with the galena and chalcopyrite is a mineral which has a brownish-gray tint in reflected light. The total amount of this mineral is too small to permit positive identification. It is inert to all the chemical reagents used and is apparently isotropic in polarized reflected light, hence presumably isometric. Its properties check fairly well with those of tennantite.

SUMMARY

The country rock of the Mint mine is composed of a series of slates into which are intruded one or more dikes of andesite. The dikes apparently follow a zone of shearing. The intrusion was accompanied by extensive brecciation and the introduction of large quantities of silica. Quartz was deposited in and around the fragments of slate and as veinlets traversing them, and there was more or less replacement of these fragments. Where the replacement was most thorough the rock has a bleached appearance and in the hand specimen is indistinguishable from the andesite dike.

The silica in the open-space fillings has many vugs into which project small slender prisms of quartz.

The association of silica with the sulphides is very close, and the conclusion is warranted that quartz and sulphides were deposited by the same solutions. Some of the sulphides occur as coatings on the quartz prisms of the vugs, but for the most part they occur as isolated bunches in the midst of quartz. There has been very little replacement of quartz by sulphides or sulphides by quartz.

The sulphides are intergrown in patterns which indicate that they are essentially contemporaneous. There is no evidence that any minerals are due to supergene enrichment, and all are believed to owe their origin to hypogene deposition. The area in which the ore body occurs was overridden, in Pleistocene time, by a great glacier that doubtless eroded away any oxidized zone in this deposit and left only the hypogene unoxidized portion of the lode.

Too little work had been done at the time of visit to determine the size or the value of the ore body. A 40-pound picked sample tested by the Bureau of Mines shows a silver content of 117.90 ounces to the ton. A series of samples taken at the mine by Harry Townsend, of the Bureau of Mines, ranged in value from a trace of gold and 1.20 ounces of silver to 0.14 ounce of gold and 32.2 ounces of silver to the ton.

The mineral association resembles that at the Premier and Mayo mines, Yukon Territory. The sharp boundaries of the fragments of slate and the fine-grained character of the quartz, as well as the presence of numerous vugs, indicate conditions of relatively low temperature and pressure. The mineral association is that of the shallow-seated type and will probably not extend to gr'eat depth.

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THE NIXON FORK COUNTRY

By JOHN S. BROWN

INTRODUCTION

FIELD WORK

Nixon Fork, from which the region here described is named, is a river that unites with the Takotna a few miles above McGrath, where the Takotna joins the Kuskokwim. In addition to the Nixon Fork basin the region includes a considerable area that drains directly to North Fork of Kuskokwim River and a large part of the upper Nowitna basin, tributary to the Yukon, as shown in Figure 4. This region previously constituted all unsurveyed wedge of land lying between surveyed areas. As the region was known to contain some valuable mineral deposits it was thought desirable to fill this break, and in 1924 a United States Geological Survey party, in charge of R. H. Sargent, topographic engineer, was sent into the region to cover as much of it as possible. The writer accompanied this party as geologist. Four other men were taken as assistants and camp hands. The party used 16 pack horses and 6 saddle horses. Field work began on July 4 and ended the last of August. Owing to nearly continuous rain with heavy fogs after July 20, progress was slow.

GEOGRAPHY

Routes of travel.—The Nixon Fork country is remote from any large ports or mining centers. In winter it is reached from almost any direction by dog team, but the principal route, the one used by the mail service, runs from Nenana by way of Lake MinChumina down the valley of the North Fork of the Kuskokwim. Almost all outside freight comes in summer by ocean steamer to Bethel and thence is carried by river boats up the Kuskokwim to McGrath or Berry's Landing (Medfra post office), but service is irregular and uncertain. There is some summer travel between the Kuskokwim and the Yukon by way of Ophir and Iditarod and also by Lake Minchumina and the Kantishna to Nenana, but any of these routes involves many miles of foot travel.

The Alaska Treadwell Gold Mining Co. for a few years maintained a wagon road between Berry's Landing and its mines, about 12 miles to the north, but this road is now unused and scarcely

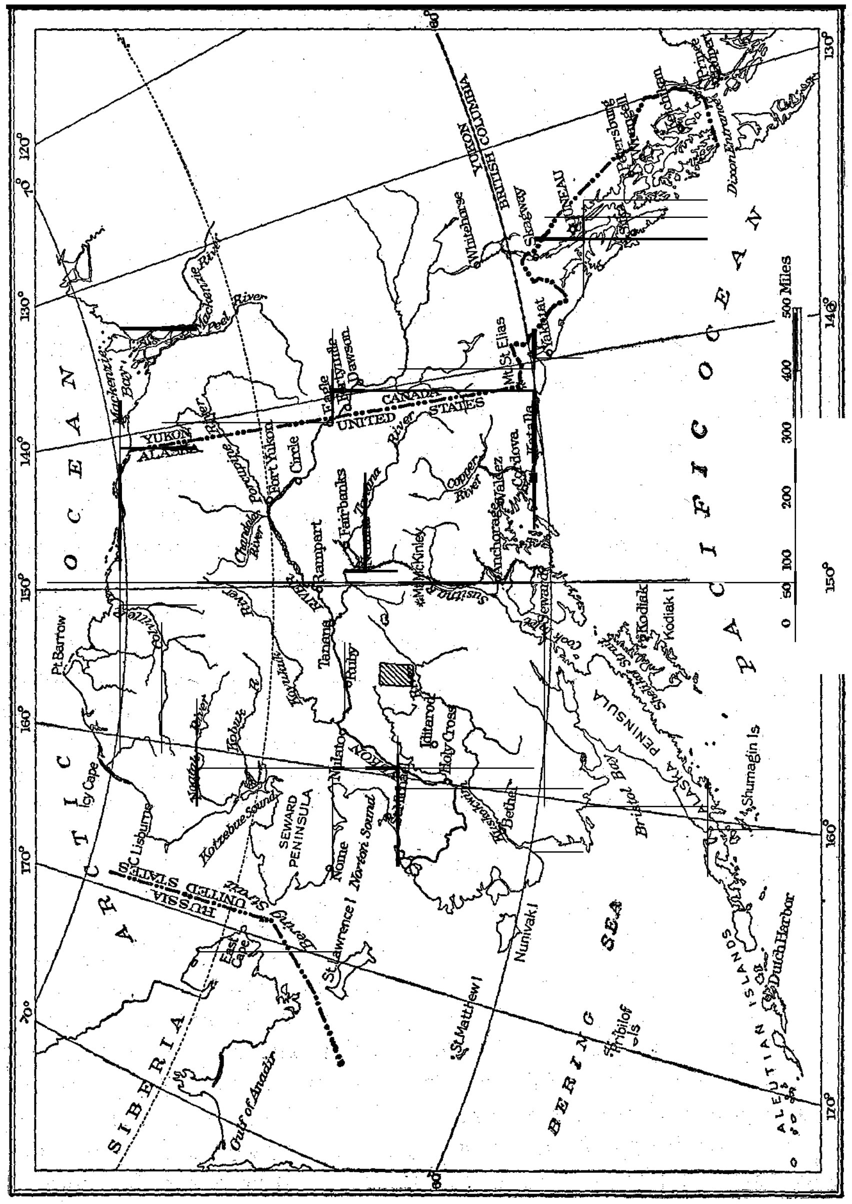


FIGURE 4.—Index map showing location of the Nixon Fork country (shaded rectangle)

passable in summer. There are no other roads in the region except the winter trails of trappers and prospectors, a few of which have been blazed and lightly bridged at bad crossings. In summer poling boats may be used for considerable distances on Nixon Fork, Nowitna River, Susulatna River, locally called Agate Fork, and possibly a few other streams.

The Survey party entered the region from Ruby, on the Yukon, using the Government road that is maintained in good condition to Long and is being gradually extended toward Poorman. The return was made by the same route.

Inhabitants.—At present there are no natives and very few permanent inhabitants in the Nixon Fork country. In 1924 there were about 20 white men at the Nixon Fork mines, possibly half as many more scattered over the rest of the region, and one or two families at Berry's Landing. A few trappers occupy isolated cabins here and there in winter.

Climate.—As a rule the rivers run free of ice in May and freeze in October, and this period represents the growing season. Frosts may occur during every month of the year. In summer the temperature rises above 80°, F. and in winter it falls to 60° below zero. The annual precipitation probably averages about 20 inches but is erratic from year to year. Slow and long-continued rains with much fog seem to be the rule in July and August, at least along the higher ranges, but months of fair weather are common at other seasons.

Vegetation.—The vegetation is subarctic. The greater part of the region is at least thinly forested, although numerous peaks and ridges rise above timber line, which ranges from 1,000 to 2,000 feet above sea level. Most of the forest is composed of small spruce less than 6 inches in diameter, of little value except for fuel but indispensable for this purpose to trapper, prospector, and miner. Small patches of larger spruce, some of the trees 2 feet in diameter and useful for lumber, grow in favored places near the big streams or on southern slopes. The aspen, commonly called cottonwood, and the birch also form local patches of forest and reach diameters of more than a foot. Tamarack grows sparingly with the spruce. ALder is common is many places, dominating the upper fringe of forest near timber line. Willows of several species form thickets along the streams.

Small brush, berries, flowers, and grasses grow profusely in the long summer days. Blueberry and cranberry usually are abundant. Wild roses, bluebells, fireweed, and other flowers in turn brighten the landscape. Several species of grass make valuable forage; the best is the wild redtop that is usually found on the flood plains of the larger streams and here and there on hill sides, especially in thin birch forests. Upland grasses in the spruce timber are, also valuable. Grass was the sole subsistence of the horses of the Survey party. As a rule it is available from early in June until about the middle of September.

Mosses of numerous kinds are present almost everywhere, growing with other vegetation and also mounting well above timber line, although commonly replaced at higher altitudes by the lichens or "caribou moss."

Many of the peaks of the higher ranges, especially of the limestone ranges, seem almost entirely devoid of vegetation.

Animal life.-Game is moderately plentiful in much of the region and includes the black bear, moose, caribou, and small animals, such as rabbits, grouse, and ptarmigan. Beaver are abundant, and their numerous dams create swampy areas that are a great nuisance in crossing the smaller streams. Grayling is the only common fish and inhabits only favored parts of certain streams.

Topography.-In the basin of Nowitna River most of the interstream areas are of moderate altitude and have a rolling surface, but farther southeast, on either flank of Nixon Fork, the region is dominated by irregular groups of rugged mountains which for considerable distances rise more than 3,000 feet and in some places more than 4,000 feet above sea level. Along the larger streams broad alluvial flats scarred by oxbows and meanders are common.

Geographic names.—In an area so thinly inhabited many features, even notable ones, bear no names, or the names that have been used are unobtainable. Again, the prospectors of one period use a set of names which are forgotten or ignored by their successors, who apply new names to the same features. The large river formerly mapped as the Susulatna is now more generally known as Agate Fork. Duplication of well-worn names is excessive. Thus many small areas have several streams called "Flat Creek" and "Bonanza Creek." So far as possible names in local usage have been adopted; for other features names have been invented as convenient handles for description. The Sunshine Mountains in particular bear no local name, although Mertie and Harrington[1] have referred to them casually as the Nixon Fork Mountains, a name that seems ill chosen because it is not now in use and because the name Nixon Fork is more closely identified with the mining district in a different mountain range.

ACKNOWLEDGMENTS

The Geological Survey party is deeply indebted for hospitality and assistance to many citizens from Ruby to Poorman and at the Nixon Fork mines. J. B. Mertie, jr., of the Survey, made the determinative study of thin sections of the rocks from the Nixon Fork country and has assisted the writer in their interpretation. He has also carefully criticized the report as a whole.

[1] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, p. 28, 1924.

AREAL GEOLOGY

PREVIOUS WORK

The United States Geological Survey has published several reports that deal mainly with the geology of regions adjacent to the Nixon Fork country. Of these reports the bulletins by Eakin[2] and by Mertie and Harrington[3] are most detailed. A brief report by Martin covers the Nixon Fork mining district.[4] Spurr's account of his traverse down Kuskokwim River in 1898 is also still of value.[5] A few other papers of incidental interest are mentioned in their appropriate connections.

GEOLOGIC MAP

The accompanying geologic map (pl. 5) shows the distribution of the different subdivisions of rocks within the area and gives their ages and relations as well as could be determined.

METAMORPHIC ROCKS

Metamorphic rocks of unknown age but chiefly pre-Ordovician constitute the oldest recognized subdivision in the region. They occur mainly in a large area between Nowitna and Sulukna Rivers, where they are seemingly continuous with similar rocks to the northeast mapped by Eakin.[6] They are also correlated in a general way with the metamorphic rocks to the northwest described by Mertie and Harrington.[7] The description is based mainly on observations in a small area northwest of Nowitna River and in the basins of Bridge and Harding Creeks.

The metamorphic rocks embrace a great variety of schistose rocks, many of which must originally have been sandstone, shale, and limestone. Others, however, are greenstones and gneissoid diorites of igneous origin. The sedimentary rocks now constitute quartzite, quartz-sericite schist, slaty schist or phyllite, mica schist, at places garnetiferous, and yellow to white recrystallized limestone. Quartz-sericite schist and phyllite are very common. Greenstone, or green schist rich in chlorite and green hornblende, is fairly common, and gneissoid hornblende diorite is well developed. The greenstone prob-

[2] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, 1918.

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

[4] Martin, G. C., Gold lodes in the upper Kuskokwim region: U. S. Geol. Survey Bull. 722, pp. 149–161, 1921.

[5] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31–264, 1900.

[6] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, 1918.

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

amy represents basic lava flows and the hornblende diorite was doubtless intrusive. Quartz veins injected along the cleavage are abundant in these rocks at most places. No evidence of extensive mineralization was found related to these veins.

The structure of the metamorphic rocks is very complex. The cleavage trends north and south rather than east and west but varies greatly both in strike and dip. True bedding is evident in few places. The erratic distribution of different rock types suggests complex folding, probably accompanied by faulting and complicated by unconformity.

Limestone beds seem as a rule not to exceed a few hundred feet in thickness. Some small limestone masses show true bedding. These are very likely later Paleozoic rocks infolded into the schists, but no fossils were found in them.

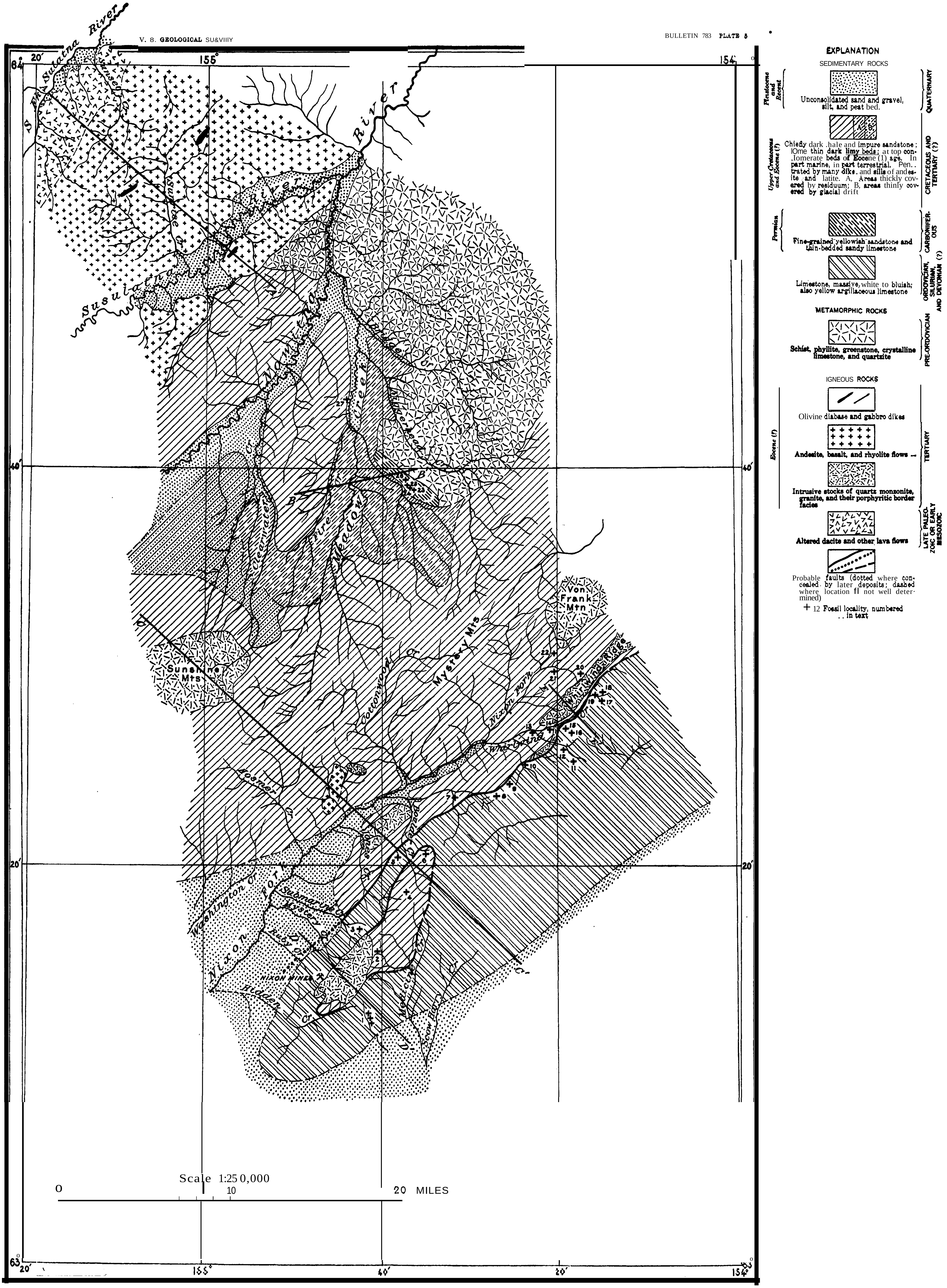
The oldest sedimentary rocks overlying this complex group within the region are of Ordovician age. The Ordovician limestones show much less metamorphism than the schists, a fact which suggests that they are younger, although in Alaska this criterion must be used with great caution. Evidence from other areas also indicates that the schist series is mainly pre-Ordovician.

PALEOZOIC LIMESTONE

Limestone forms the greater part of the ranges that lie between Nixon Fork and the North Fork of the Kuskokwim. Several types of limestone are common. One is dull white or gray on weathered surfaces, blue-gray on a fresh fracture, and commonly seamed by many calcite veinlets. The beds usually range from 2 to 6 inches in thickness, but a few very massive beds 20 to 200 feet thick are found, at some places forming huge ridges crossing hills and valleys. This massive type is well developed just south of upper Whirlwind Creek and less so near the Nixon mines. It forms the most rugged of the limestone peaks. At places it is highly fossiliferous, and most of the collections listed were obtained from rocks of this type.

Another type of limestone is very thin bedded, the layers ranging from one-eighth inch to 1 inch in thickness. It is conspicuously buff or yellow on weathered surfaces but dark blue or black inside. Outside it commonly looks sandy, and cross-bedding is suggested. Shaly layers and blue-black chert were noted in this limestone. Small worm trails are abundant, but no fossils of diagnostic value were found. Its topographic forms are of subdued character. Near the head of Canyon Creek it forms a lowland.

A third and very common type of limestone is almost dead white on weathered surfaces, has a sandy or granular texture, and is white to gray in the interior. It seems to be moderately thin bedded, but bedding is visible in but few places, as the surface slumps readily.



GEOLOGIC SKETCH MAP OF THE NIXON FORK COUNTRY

Only molds of fossils of no determinative value were found. The peaks and ridges formed by this third type of limestone are intermediate in ruggedness between those formed by the first two types.

The structure of the limestone is complex. Nearly everywhere the beds are sharply folded, although the details could not be determined in the time available. The area around the Nixon Fork mines is believed to be irregularly anticlinal. Steep or vertical dips are not uncommon. The major trend of folding is to the north of east along the general elongation of the ranges. Observation along the northern border, however, showed variable dips locally, and on Whirlwind Creek at the two observed localities the limestone is overturned near the Cretaceous contact and dips about 80° SE. The writer believes that the limestone has been thrust forward along a great fault over beds of Upper Cretaceous age.

The thickness of the limestone series is unknown but must be at least 5,000 to 7,000 feet and may be much more.

Sharp-crested divides, cliffed peaks and slopes, and in the higher mountains great barren areas wholly devoid of vegetation make the limestone ranges the most picturesque feature of this region. On many ridges vegetation occupies the southward-facing slopes but terminates abruptly at the crest. Grass is scarce and forage very hard to find over much of the limestone country.

Many stream beds in the limestone are paved with loose cobbles and traversed by dry flood channels, as much of the drainage both here and on the slopes is subterranean. Typical sink-hole topography, however, is lacking, although there are a few sinks.

Fossils from these limestones, some in place and some from float, were obtained at numerous localities, as numbered on Plate 5. These collections were examined by Edwin Kirk, of the United States Geological Survey, who has made the following determinations. Key numbers are those given on Plate 5. Numbers in parentheses are those of the Geological Survey locality records. N. B. indicates the number in the author's notebooks.

1 (1963, 1964, 1965). N. B. 75a, 75b, 75c. Collected along a mile or more of road about halfway between the monzonite contact and the flats from boulders washed bare in roadbed and creek. About midway of this distance some of the species can be found poorly preserved in a parent ledge. Beds estimated to be at least in part from 1,500 to 2,500 feet stratigraphically above the base of the limestone.

Silurian: Pentameroid brachiopod.

In part Silurian, in part possibly Devonian:

- Favosites sp.
- Alveolites sp.
- Favosites sp. (same as No. 9).
- Cyathophyllum sp.

3 (1962). N.B. 69; From loose blocky talus of broken moss-covered ledges on north slope of ridge east of Submarine Creek and about 1½ miles north

of Strand Peak. Beds estimated to be not over 500 feet above the adjacent shale and porphyry, nearly in place.

Probably same as No. 8 and probably Ordovician:

Leperditia sp.
Zygospira sp.

5 (1966). N. B. 88. Just south of Boulder Creek near northern contact of limestone. Slump, nearly in place.

Ordovician (Richmond): Liospira sp.

7 (1960). N. B. 63. Limestone float in creek bed a mile or more from contact.

Ordovician (Richmond) :

Cyrtolites? sp.
Lophospira sp.

S (1959). N. B. 62. Crest of the first (northern) limestone ridge. In place.

Probably Ordovician (compare No.3) : Leperditia sp.

9 (1958). N. B. 61. From loose material thrown out of a prospect pit. Very near northern border of limestone.

Silurian or possibly Devonian: Favosites sp.

10 (1957). N. B. 60. Limestone float in a small creek bed.

Probably Silurian but might be Devonian: Sieberella sp.

11 (1955). N. B. 55. In place. Thin-bedded limestone.

Age indeterminable: Annelid trails.

12 (1954). N. B. 54. Float, bed of Canyon Creek.

Age doubtful: Poorly preserved corals and crinoid stems.

14 (1953). N. B. 51. Limestone float, bed of Whirlwind Creek.

Probably Silurian: Favosites sp.

15 (1953). N. B. 51. Hillside float between 14 and 16.

Ordovician: Poorly preserved cephalopod and Hormotoma sp.

16 (1952). N. B. 50. From subsidiary peak north of impressive high peak (station 39). Crest of anticline. Virtually in place.

Silurian or possibly Devonian:

Stromatopora sp.
Favosites sp.
Cladopora sp.

17 (1950). N. B. 46.

Ordovician (Richmond) : Liospira? sp.

18 (1951). N. B. 47.

Ordovician (Richmond):

Paleophyllum sp.
Halysites sp.
Paleofavosites sp.
Calapoecia canadensis Billings.
Liospira sp.
Hormotoma sp.
Illaenus sp.

19 (1949). N. B. 48. Localities 17–19 are close together and all represent very massive beds described on page 102, about half a mile south of Whirlwind Creek. Nos. 17 and 18 represent material substantially in place in massive reefs; No. 19, stream float below and between these two localities.

Ordovician (Richmond):

Stromatopora sp.
Favosites sp.
Columnaria sp.
Halysites sp.

With reference to No. 19 Mr. Kirk states that the greater part is Ordovician, but that one Or two specimens may be Silurian.

It seems from these determinations that the limestones constitute a terrane which comprises. sections of both Ordovician' and Silurian beds and possibly Devonian. The separation of these systems isa problem for further study, but one which the general features of the region indicate might well be done.

These limestones seem' to beat least in part the same as those to the n9rtheast described by Eakin,[8] for the indications are that the rocks are continuous through the areas, and similar fossils (Richmond) have been found in them. The writer also suspects that they are closely related to the limestone of the Takotna ("Tachatna") "series"[9] to the southwest, which has been considered Middle Devonian.

PERMIAN ROCKS

A small area of Permian rocks was found along the crest of the low, elongate, asymmetric ridge west of Harding Creek. 'This discovery is interesting because Permian rocks are not known in the adjoining areas. The exposures were studied only for about affiile along a group Qf small knobs that occupy the summit of this ridge. The lower portion of the beds, in the southern part of the area seemS to consist elltirely. of brown to yellowish sandstone, generally weathered soft and porous, containing a few poorly preserved fossils. This sandstone seems at one place to rest on green chloritic schist. The thickness of sandstone here probably does not exceed a few hundred feet.

On a group of several small knobs midway of the exposures the sandstone grades into thin-bedded, impure yellowish sandy' limestone, which is exposed in place dipping gently southwestward. Certain beds are abundantly fossiliferous.

Farther north, and therefore seemingly beneath these beds, is a band about 1,000 feet wide of very thinly laminated black slate, whose cleavage strikes N. 60° W. and dips 45° SW. This slate separates the first sandy and limy beds from a little ridge on which similar but more indurated sandy and quartzitic rock is found, at one place in a small, rather massively jointed cliff. The slump from this exposure is partly dense ql1artzite, partly leached porous sandstone. The sandstone phase is :full of poor fossil molds rather similar to those farther south. This sandstone is succeeded to the northwest hy blocky semimetamorphic dark crystalline limestone, which is assumed to belong ,to the metamorphic complex.

[8] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, 1918.
[9] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31–264, 1900.

The Permian beds probably continue at least 2 or 3 miles to the southeast and very likely some distance to the northwest. Certain thin-bedded limestones and siliceous limestones only mildly metamorphosed just south of the head of the north fork of Bridge Creek may perhaps also belong to this series. The Permian beds are doubtless overlain unconformably by the Upper Cretaceous beds if the two series are anywhere in contact.

George H. Girty, of the United States GeologIcal Survey, reports on these fossils as follows:

23 (5456). N. B. 32. Small knob showing low bluff of sandy limestone at Survey station 28. The most southerly collection.

Stenopora aff. carbonaria.	Rhyncopora aff. R. nikitina.
Chonetes aff. C. ostiolatus.	Spiriferella arctica.
Chonetes sp.	Spirifer aff. S. nikitina.
Productus aff. P. mamm.atus.	Spirifer aff. S. triplicatus.
Productus n. sp.	Martinia aff. M. triquetra.
Margfnifera aagardi?	Squamularia sp.
Pustula aff. P. montpelierensis.	Aviculopecten n. sp.
Pustula n. sp.	Aviculopecten sp.
Pustula sp.	Euchondria? sp.
Pustula sp.	Pseudomonotis? sp.
Aulosteges? sp.	Griffithides.
Camarophoria margaritovi?	

24 (5455). N. B. 31. Small knob similar to No. 23 and about 300 feet to the northwest.

Batostomella? sp.	Spirifer aff.S. triplicatus.
Chonetes sp.	Squamularia sp.
Productus aff. P. mammatus.	Aviculopecten n. sp.
Marginifera aff. M. splendens.	Euchondria? sp.
Marginifera aagardi.	Pleurotomaria sp.
Rhyncopora sp.	Griffithides sp.
Camarophoria aff. C. crumena.	

25 (5454). N. B. 30. Very thin limestone beds on little ridge 400 feet northwest of No. 24.

Fistulipora sp.
Stenopora sp.
Rhombopora sp.
Spirifer uff. S. triplicatus.

26 (5453). N. B. 29. Talus just west of small cliffy exposure of massively jointed quartzite. About a quarter of a mile northwest of station 29 and perhaps half a mile north of No. 23.

Marginifera aagardi.
Phanerotrema? sp.

These four collections all contain the same fauna, though that from lot 25 is almost too meager for satisfactory interpretation. The fauna is obviously that which has been identified in Alaska as Permian (A.rtinskian) and which is best known from exposures on

Kuiu Island and on Yukon River opposite the mouth of Nation River.

A smaller collection of the same fauna was obtained by A. G. Maddren, of the Geological Survey, a few hundred miles to the southwest, on Kuskokwim River at about longitude 160° W. This is the nearest known occurrence of Permian beds. The beds there, according to unpublished information, consist of 50 feet of limestone overlain by several hundred feet of tuffs and volcanic rocks. The upper part of the llmestone is tuffaceous and contains the fossils. No similar tuffaceous rocks were noted in the Nixon Fork country.

UPPER CRETACEOUS AND EOCENE (i') ROCKS

Rocks of Upper Cretaceous and perhaps in. part of Eocene age cover extensive tracts in the heart of the area and are particularly well exposed along the Nixon Fork-Nowitna divide, where they form the Mystery Mountains and the border about the Sunshine Mountains. Here they are well exposed along numerous creeks and canyonsbut have been strongly affected by the abundant intrusions. In the tongues of land between Nowitna River and Meadow Creek to the south and Agate Fork to the north they are present in more normal condition but much less satisfactorily exposed. On the west they are continuous directly·or beneath alluvial flats. with similar rocks that have been mapped over wide areas by Mertie and Harrington.[10] On the east they are cut off over most of their extent by the schists and metamorphic rocks but continue an undetermined distance eastward in the region at the head of Nixon Fork and Sulukna River, although they were not recognized by Eakin[11] in the Cosna-Nowitna area. If present there they must oCCur in only small areas and must bemuch modified bymetamorphisIU.

The Upper Cretac.eous rocks are of highly variable character but cdnsistdo|||inantly of dark, more or less slaty shale and of impure grayish arkosicsandstone or graywacke, with gradations between the two. Thin beds of impure dark limestone as much as 2 feet thick are. notuncOlnmon, and impure chert is interbedded with. the slate. on lower Whirlwind Creek. Pebbly or conglomeratic sandstone is fairly C?1ll1ll0l1, and thick beds of very coarse conglomerate occur in the upperpal't'of the series in the generalregion of Hosmer Creek. This part of the section, if any, is believed to be of Eocene age.

The thickness of the Upper Cretaceous and Eocene (?) rocks is unknown but must be at least .5,000 feet .andpossibly. considerably more. .On the south slopes of the Mystery Mountains oppositethe head of Cottonwood Creek anunbrbken section about 1,500 feet

[10] Mertie, J. B., jr.; and Harrington, G; L., op. cit.
[11] Eakin, H. M., Oll'. cit.

thick was examined. Possibly 10 per cent of this thicknessis made up of intrusive matter in the form of sills. The beds grade from slaty sandstone at the lowest exposures into coarse arkosic sandstone and pebbly beds above. These rocks are thin bedded, well indurated; and cross-bedded and contain imperfect plant markings. Thin sections show the sandstone to contain a little quartz, more feldspar, and abundant fragments of a dark lava, with a little slate. Similar arkosic sandstone or graywacke is abundant south of Nixon Fork from Whirlwind Creek to Jones Creek and occurs also, mainly as loose fragments, on nearly all the ridges northwest of Meadow Creek. A thin section from station 20 consists dominantly of quartz but contains much dark chert, some feldspar, and, traces of slate or schist, with considerable secondary carbonate.

The conglomerate occurs in thick beds forming very prominent ridges between Cottonwood and Hosmer Creeks. The pebbles are as much as 6 inches in diameter, are very perfectly rounded, and consist of dark micaceous quartzite, varicolored chert, and vein quartz in the relative order of decreasing abundance named. Some of the conglomerate beds are a few hundred feet thick.

The shale as a rule is black and fissile, and at many places it is impossible to determine true bedding, owing to the secondary cleavage and jointing. Small nodules of pyrite and large calcareous concretions are common in some exposures.

Included with these rocks in the region of fossil station 20 is a small area of much shattered grayish chert, which may possibly be a remnant of an older series of chert and argillite described by Mertie and Harrington.[12]

Around the Sunshine Mountains, in the Mystery Range, at Von Frank Mountain and about the monzonite at the Nixon Fork mines, the Upper Cretaceous rocks, especially the shale, have been strongly indurated by the intrusive igneous rocks which cut them everywhere as bosses, sills, and dikes. Near the larger intrusive masses the shale is changed to a dense black structureless rock which forms coarse talus blocks, many of them several feet in diameter, called locally "block slate." In a general way metamorphism is notably gradational and is much more severe in the southern part of the Upper Cretaceous area than in the area northwest of Meadow Creek, where igneous rocks are absent and folding is less intense. Veining in the slate is fairly common, quartz veins being abundant south of the Sunshine Mountains and calcite veins fairly common near Meadow Creek.

Structurally the rocks occupy a series of open folds closely related to the intrusive rocks, as described on page 114-120. They must rest,

[12] Mertie, J. B., jr., and Harrington, G. L., op. cit., pp. 22-23.

unconformably on the metamorphic rocks, fragments of which they contain in some places, and doubtless they are also unconformable with the Permian beds. With the Paleozoic limestones they seem to be in fault contact throughout the Nixon Fork area, as described on pages 120-123.

The rare limy beds in the series very commonly yield imperfect fossils, usually broken fragments of *Inoceramus*. Collections obtained at several localities described as follows have been examined by T. W. Stanton, of the United States Geological Survey, who reports on them as follows:

6 (12564). N. B. 64. Slopes east of head of east fork of Boulder Creek and about 1½ miles southwest of Survey station 46.

Fragments of small undetermined pelecypods, one of which has angular ribs. Presumably from the same Mesozoic formation as lots 13, 22, and 27.

13 (12563). N. B. 53. Low bluffs on south bank of Whirlwind Creek just below mouth of Canyon Creek.

Inoceramus sp.

Fragments of shell like those in lots 22 and 27.

22 (12562). N. B. 41. Headwaters of Nixon Fork, about 3 miles southwest of Von Frank Peak.

Inoceramus sp. Fragments of shell. Belemnites or Belemnitella sp. The fossils are like those in lot 27.

27 (12561). N. B. 23. Bluff on northwest bank of Meadow Creek about 10 miles above its mouth and about 2 miles below mouth of Fire Creek.

Rhynchonella? sp. Fragmentary imprints.

Inoceramus sp. Numerous fragments of a rather large, thick-shelled species.

Belemnites or Belemnitella sp. Several fragments and cross sections of a slender species.

The thick fibrous shell and the apparently large size of the *Inoceramus* in this lot suggest Upper Cretaceous age. On the other hand, belemnites are common in the Lower Cretaceous and especially in the Jurassic, whereas belemnoids of any kind are very rarely if ever present in the Upper Cretaceous of Alaska. The horizon is not older than Middle Jurassic and not younger than Cretaceous. I think it most likely Upper Cretaceous, but additional species or better preserved specimens, or both, must be obtained before it will be possible to make a more definite age determination. Previous collections from presumably the same formation in this region have been no better than this one.

All the collections are fragmentary, but the last (No. 27) is best.

In addition to the above collections four others of indeterminate character were obtained from what appear to be the same (Upper Cretaceous) beds, as follows:

2 (1948b). N. B. 68. About 1½ miles east of Strand Peak, Survey station 47.

4 (1961). N. B. 66. Divide at head of Jones and Boulder creeks.

Fragment of a bivalve; indeterminable.

20 (1948a). N. B. 44. Slope of Whirlwind Ridge near porphyry contact, about 1½ miles northeast of summit.

21 (1948). N. B. 43. South bank Flat Creek, about 1 mile north of No. 20. Algae. Age indeterminable.

Mr. Stanton says that lots 2 and 20 "may well come from the same formation," but they contain nothing positively determinable.

The greater part of the shales and sandstones are evidently of Upper Cretaceous age. The higher conglomeratic beds, from evidence obtained in other areas, probably range into the Eocene, although no fossils were obtained from them.

The topography of the Upper Cretaceous rocks differs in different areas. They form very bold jagged and asymmetric peaks on the borders of the Sunshine Mountains, in the Mystery Range, and on Von Frank Mountain, where the shale is so indurated as to be very resistant. At other places there is a succession of curved asymmetric ridges of sandstone or of intrusive sheets, harder than the shale. Northwest of Meadow Creek a very low, subdued rolling topography is the rule. Most of the area of outcrop is well wooded.

UNCONSOLIDATED SAND AND GRAVEL DEPOSITS

Flat lowlands underlain by unconsolidated gravel, sand, and silt are extensive along the larger streams. The "flats" along the North Fork of the Kuskokwim and the lower part of Nixon Fork are several miles in width. Others are generally less than a mile wide.

Information about these deposits is meager, as they are in few places well exposed, and the Survey party traversed none of the larger flats or stream courses. Spurr has described very well the exposures in bluffs along the Kuskokwim.[13] They consist of yellow silt, blue clay, and local layers of peat and of buried logs. There seems to be imperfect terracing in the deposits, and small terraces were noted on some streams, such as Whirlwind Creek.

Fossil bones of extinct Pleistocene mammals are found in these deposits, very often during placer mining. C. W. Gilmore, in 1907, ascended Nowitna River for about 180 miles by water and collected bones of *Elephas primigenius*, *Bison*, *Equus* (horse), *Ursus* (bear), *Alce* (moose), and *Castor* (beaver) on the gravel bars, which had been uncovered by erosion from the stratified silts.[14] Shells of invertebrate land animals are also common in the silt at many places.

In addition to the true alluvium there are large areas of residuum consisting of a mantle of decayed vegetation, soil, and ground ice,

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[13] Spurr, J. E., op. cit., p. 122.

[14] Gilmore, C. W., Smithsonian exploration in Alaska in 1907 in search of Pleistocene fossil vertebrates: Smithsonian Misc. Coll., vol. 51, No. 1807, p. 23, 1908.

generally less than 50 feet thick. Most of these areas are not shown on Plate 5. The most extensive area is southeast of the strip of alluvium along Meadow Creek and on the low saddles connecting with Nowitna River. Most of this area is probably underlain by soft Upper Cretaceous shale.

The alluvium and residuum exhibit a number of peculiar topographic forms which are due mainly to the subarctic climate. These forms include small benches, probably formed by creep and the action of landslides and lakes or muskegs on slopes or even hilltops, possibly due, at least partly, to irregular thawing of ground ice. Only along the largest streams are features of normal stream erosion, such as oxbows and gravel bars, to be found.

Nearly all the higher portion of the Sunshine Mountains was rather severely glaciated in Pleistocene time. The north slopes were most strongly affected, and the area occupied by slate on the southeast seems to have escaped. Characteristic U-profiles can be seen on many valleys, as at the head of Clearwater Creek; high benches and hanging valleys are common along minor streams; imperfect cirques are numerous, and one very beautiful example has a lake several hundred feet long and a great steep granite cliff behind. Morainal deposits are common, and at the north and west the ice seems to have spread out in a sheet that rode indiscriminately over ridges and valleys, smoothing off much of the area into flat spurs of gentle slope covered with thin ground moraine. This moraine consists mainly of fine fragments of slate but includes a few large boulders of granite and spotted slate even several miles from their nearest possible source. The area of glacial deposits, as shown on the map (pl. 5), occupies mainly the slopes between Clearwater Creek and Nowitna River.

Glacial deposits probably occur in similar development on the north and west slopes of Von Frank Mountain but were not examined. Cirquelike forms were seen from a distance, and broad flat spurs, probably covered with moraines, were noted at the base of the mountains. Slight glaciation may also have occurred in the Mystery Range on the north, which was not examined. Even the highest peaks of limestone show no sign of glaciation, and in general the glaciers seem to have been restricted in this region to areas in which the highest peaks reach 4,000 feet or more in altitude.

IGNEOUS ROCKS

EXTRUSIVE FLOWS, AND TUFFS

Extrusive igneous rocks occur mainly in the narrow northern part of the Nixon Fork country (pl. 5) a snort distance south of Agate Fork. The rocks of this belt extend into the region on both sides, where they occupy large areas and have been described by Mertie and Harrington,[15] who separate them into two groups of different age.

OLDER EXTRUSIVE ROCKS

The older volcanic series occupies only a very narrow strip of the Nixon Fork country just south of the South Fork of Sulatna River. The writer had little opportunity to study this area, but his observations accord with those of Mertie and Harrington.[16] These authors classify the rocks as soda rhyolite and oligoclase dacite. They are fine-grained volcanic lavas, porphyritic in thin section but thoroughly impregnated with secondary chalcedonic silica. Imperfect feldspar laths and magnetite dust are abundant, and flow structure is suggested.

In the field the rocks are red, brown, or green, very commonly green in the interior. They break persistently along minute, invisible joint planes, which show black stains of iron or manganese. Amygdaloidal beds containing almond-shaped cavities filled with calcite or chalcedony or both are common.

Mertie and Harrington found that these rocks were interbedded with cherty and gritty rocks that they considered doubtfully to be of Mesozoic age but older than Upper Cretaceous. The structure of the series is complex, owing to folding and faulting.

YOUNGER EXTRUSIVE ROCKS

Mertie and Harrington[17] classify the younger extrusive rocks as pyroxene andesite and basalt. The series as studied by the writer fits this description fairly well but seems also to contain a large amount of material of rhyolitic appearance, some of it distinctly quartz-bearing. In this respect it accords more closely with the volcanic series in the Cosna-Nowitna area described by Eakin.[18] In the thin sections examined by Mertie and Harrington and in those from the Nixon Fork country the feldspar of the andesite is chiefly labradorite, partly oligoclase. The labradorite forms striking phenocrysts and also small laths in an oligoclase matrix. Some sections contain a dark-brown glassy matrix, more or less devitrified. Augite and magnetite are common. The basalt closely resembles the andesite but is darker, contains no oligoclase, and may contain olivine. The more acidic lavas seem to consist mainly of oligoclase, with orthoclase phenocrysts and with quartz phenocrysts also common in some sections. They should be classed as rhyolite.

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[15] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 55 et seq., 1924.

[16] Idem, pp. 60–62.

[17] Idem, pp. 62–66.

[18] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, pp. 33–34, 1918.

In the field the more basaltic types are black and may be either dense and vitreous or scoriaceous. Some of the cavities seem to have contained fillings of calcite or chalcedony. These rocks are clearly interbedded in the andesite but form only a small part of the series. Separate flows probably in few places exceed 50 feet in thickness.

The most abundant and best exposed lava, where found in place, is rather solid and blocky. Steeply dipping joints are more pronounced than the obscure flow banding. Weathered faces generally are brown or reddish, and fresh surfaces are commonly dark green. The prominent feldspar phenocrysts in many places give the rock a spotted appearance. This rock ranges from andesite to basalt.

The rhyolite was not found in place but yields abundant float blocks at many localities and forms almost the whole of Stone Mountain (Survey station 14). It is generally white, except for abundant brown iron stains. Striking flow structures are common. Many of the fragments are platy. The rocks seem to be interbedded with the andesite and basalt.

Tuffs either are not abundant in the series or else are very poorly exposed. A thin bed was noted about 6 miles southwest of the junction of Agate Fork and Nowitna River. It forms a narrow band about 800 feet long and 12 feet wide, offset 20 feet at the northeast end by faulting. The rock is porous and light colored and seems to correspond in composition to the rhyolite. The largest fragments are about an inch across.

Some portions of the lava contain abundant cavity fillings of chalcedonic quartz, locally called agates. These agates are very resistant and have become so concentrated on the gravel bars of Agate Fork as to give the name to that stream. They range in diameter from a quarter of an inch to 6 inches. As a rule there is an outer shell of chalcedony and a drusy center lined with quartz crystals. Impressions of calcite rhombohedrons indicate that this mineral was commonly present but has been broken or dissolved away. Some of the agates are of good quality and might have a slight value as cut stones.

The main source of the agates is uncertain. They were found sparingly on weathered knobs of andesite and basalt, and a piece of andesitic matrix full of small specimens was found on a bar. Mertie and Harrington[19] mention a locality where fillings at most 3 inches in diameter were so abundant as to make the rocks resemble superficially a conglomerate. Some such locality must be the principal source of this material.

The structure of the lavas is rarely visible, but it was seen at several places along the ridge, at the western border of the area

[19] Mertie, J. B., jr., and Harrington, G. L., op. cit., p. 62.

mapped. Here the dip is uniformly southeast at angles of 5° to 20°, flattening toward the northwest. The strike is N. 30°-50° E. Dips of 20°-50° SE. were noted in a bluff northeast of the main western tributary of Sunrise Creek. Southeast of Agate Fork, on the other hand, the few observed dips are all fairly steep to the northwest and the strike is about N. 55° E. It therefore seems that the structure from northwest to southeast is synclinal.

The observations along the ridge at the western border indicate that the total thickness of the lavas must be at least 3,000 feet, unless there is unsuspected repetition by faulting.

Very little was learned concerning the relations of the lavas to the other formations, but nothing was found that did not fit with the conclusions of Mertie and Harrington, who believed that they rested unconformably above the older lavas to the north and more or less conformably above the Upper Cretaceous and Eocene (?) beds. Their age is interpreted as Eocene or post-Eocene.

In addition to the main body of these volcanic rocks a small area of similar andesitic lavas was found between Cottonwood and Hosmer Creeks. These lavas seem to overlie the conglomer'ate and sandstones of probable Eocene age in the trough of a deep syncline and are presUIpably of about the same age as those just described.

INTRUSIVE ROCKS

BASIO ROOKS

Several small bodies of basic intrusive rocks are found within the region. Three of these bodies are within the large area of younger extrusive rocks in the northern part of the region (pI. 5). One locality is on the ridge south of the head of Sunrise Creek, and specimens of similar rock were brought to the writer by Ray Russell, assistant to Mr. Sargent, from a locality about 5 miles to the southwest. The rocks are diabasic and in thin section are seen to consist of labradorite feldspar, olivine, and augite, probably titaniferous, all abundant, with a-green incrusting, radiate product of alteration, probably serpentine, replacing the olivine and feldspar. They may be classified as olivine diabase. At both localities the rock is found only in abundant dark glistening boulders, the largest of them 3 feet in diameter, rather well rounded by weathering. The areas of occurrence are a few hundred feet long and elongated from northeast to southwest.

A very similar rock occurs in much the same way on the slopes just south of Agate Fork on the first bluffs below Sunrise Creek. This rock, however, is, fully crystalline and seems to be a gabbro. This gabbro and the diabase are believed to form dikes or plugs cutting the volcanic rocks.

On the divide east of Mint Creek on the crest of the Sunshine Mountains a dike of basic andesite cuts the granite. It consists of zoned plagioclase of intermediate character in a matrix of devitrified brown glass full of small crystals of magnetite. Secondary carbonate, serpentine, and zeolites are present.

Considerable float of green basic rocks was noted on Whirlwind Creek, but its source was not determined.

Martin[20] describes a basic dike of pyroxenite cutting the limestone on the southeast border of the monzonite at the Nixon Fork mines.

The basic rocks of the Nixon Fork country resemble closely those in the Ruby-Kuskokwim region described by Mertie and Harrington.[21] Those authors state, however, that the basic rocks are older than the monzonite and are cut by it, whereas at the only localities in the Nixon Fork country where they have been definitely recognized the basic rocks cut granite. The basic rocks associated with the lavas probably cut them but are very closely related to them both in age and composition.

ACIDIC ROCKS

Acidic intrusive rocks of the general type called granite by prospectors form a number of irregular stocks and bosses within and bordering the drainage basin of Nixon Fork. Some of these rocks are true granite, and others are more properly classified as quartz monzonite. Associated with the larger intrusive bodies are a multitude of smaller closely related bodies forming dikes and sills, mainly in the Upper Cretaceous shale and sandstone. As the larger intrusive bodies are genetically related to the gold and other mineral deposits in this and adjacent areas, it seems advisable to describe each of the occurrences in some detail.

GRANITE AND QUARTZ MONZONITE

Sunshine Mountains.—The Sunshine Mountains contain a simple core of granite surrounded by a rim of slate, which represents the indurated Upper Cretaceous shale. The highest peaks, on the east and southeast, are composed of slate, but granite forms numerous peaks of nearly equal height in the central and more northerly and westerly areas. These features correspond closely to the descriptions of Mertie and Harrington.[22]

The granite is a gray rock generally of rather coarse and even grain but over considerable areas distinctly a granite porphyry. The granite porphyry, however, seems not to be a border phase.

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[20] Martin, G. C., op. cit., p. 161.
[21] Mertie, J. B., jr., and Harrington, G. L., op. cit., pp. 66–69.
[22] Idem, p. 28.

In thin section dusty orthoclase and large quartz grains are seen to be the chief minerals. Soda orthoclase and acidic plagioclase are subordinate. Green and brown biotite is fairly common, and unimportant accessories, chiefly magnetite and apatite, are present. The rock is a typical granite.

Small porphyritic dikes closely related to the granite in composition are common near the contact in the slate and probably within the granite itself. Small quartz veins occur in the granite but are not abundant. A basic andesite dike was noted at one place, and float of dark fine-grained rocks at several places indicates that related dikes may be fairly common.

The granite forms an irregularly rounded stock whose walls are inclined at angles of 45° to 90°. As a rule this dip is steeper than the bedding of the surrounding slate, which, nevertheless, is sharply domed. The slate is so much metamorphosed that bedding is commonly destroyed and a steeply inclined jointing imposed upon it. Much of it also is spotted with specks composed chiefly of biotite and muscovite.

The topography of the granite has been produced largely by glaciation (p. 111). Sharp arêtes and cirque forms are common. Many jointed and pointed pinnacles of granite, locally called monument rocks, occur along the divides. Below the ridge crests are great slopes covered with coarse blocky talus, and morainal débris of granite covers most of the lower slopes and valley bottoms.

Von Frank Mountain.—The mountain locally called Von Frank is formed of a rock resembling granite but more properly called quartz monzonite. It has the texture and appearance of granite but is darker gray, the feldspars are orthoclase and plagioclase, the latter near oligoclase, in about equal amounts, and both hornblende and augite are present in addition to quartz and biotite. The writer studied this rock only at its most southwesterly exposure and in hand specimens brought by Mr. Sargent from the summit of Von Frank Mountain. It seems to be an intrusive rock of rather uniform character cut by a few small quartz veins.

The extent of the quartz monzonite is unknown, but it probably constitutes the bulk of the higher peaks in the vicinity and may very likely be connected around the head of Nixon Fork with the similar monzonite of Whirwind Ridge.

The slate that borders the intrusive is much indurated and blocky, like that of the Sunshine Mountains, and forms numerous sharp subsidiary peaks. The structure seems to be complex, unlike that of the simple Sunshine Mountain dome.

Topographically the vicinity of Von Frank Mountain is the most rugged area in the Nixon Fork country. Glaciation has probably assisted in carving its features, particularly on the northern slopes.

Whirlwind Ridge.-Quartz monzonite, seemingly identical in appearance and mineralogy with that of Von Frank Mountain, forms the crest and higher parts of the ridge just north of upper Whirlwind Creek. A notable feature of this intrusive mass is the presence, especially on the northwest, of a thick border of porphyry that seems to be of the same composition as the diorite and at places grades into it, though elsewhere the two seem rather sharply defined. The border probably has a maximum thickness of a few hundred feet and represents the quickly chilled outer margin of the intrusive mass. On the west end of the ridge at some places it completely arches over the crystalline monzonite and conceals it. It is likely that on the east the monzonite connects with that of Von Frank Mountain.

The western part of the ridge is only moderately rugged. In many places the porphyry border stands up in sharp peaks on the spurs. To the east the crest of the ridge breaks up into numerous rather sharp conical peaks.

At the two places examined the'monzonite is separated from the limestone to the south by a thin band of slate and sandstone, but at other places it may invade the limestone. The contact seems to be steeply inclined on the south and Illore gently inclined on the north. The surrounding Upper Cretaceous beds seem to be domed irregularly by the intrusive. They are but little affected by metamorphism.

Canyon Creek.—A narrow strip of gtanite extends across Canyon Creek along the contact between the Paleozoic limestone and the Upper Cretaceous slate and sandstone. The granite is well exposed in a bluff on Whirlwind Creek, where there has been Some desultory prospecting. Elsewhere it was found only as float but abundant enough to mark its occurrence fairly welL It seems to cross Whirlwind Creek but was not examined farther in that direction, so that its relation to the quartz monzonite is unknown.

The rock is a pink granite rich in coarse-grained quartz. Pink alkali feldspar is abundant, much of it weathered badly to sericite, carbonate, and kaolin, and altered plagioclase is present. The rock contains green biotite, green. hornblende, and a little tourmaline. The occurrence of the tourmaline is rather unusual. The rock is best classified as a granite.

Careful search at several places failed to reveal the nature of the contact between the granite and the adjacent limestone and shale. The granite probably forms an irregular dikelike mass intruded along the great fault that separates the limestone f.rom the Upper Cretaceous rocks. There is no evidence of. notable metamorphism in the adjacent formations.

The granite has a subdued topographic expression and occupies low cols along the interstream ridges between the rugged limestone mountains on one hand and the broken hills of slate and sandstone on the other.

Boulder Creek and Jones Creek.-South of Nixon Fork, extending from Boulder Creek probably as far as Jones Creek, occurs a mass of porphyry which almost certainly represents the top of a granite mass not yet eroded deeply enough to expose the fully crystalline phase. Good exposures of the porphyry in place are found on the smooth slopes west of Boulder Creek. It is either massive or sheeted by close parallel joints. Weathered fragments are yellow or brown, are very resistant, and yield abundant boulders in the creek bed. The porphyry here is very full of dark inclusions of the Upper Cretaceous shale which it invaded. These inclusions are only slightly indurated.

The porphyry as seen in thin section consists of orthoclase phenocrysts, rounded, resorbed quartz grains, and a matrix of fine feldspar rods and quartz. Farther southwest, along a rounded barren ridge, only float is visible. This float is increasingly crystalline toward the center of the mass, and much of it contains coarse flakes of biotite in addition to large phenocrysts of quartz and feldspar.

The sandstones on the southeast dip 20°-30° SE. Elsewhere the structure was not determined. The porphyry doubtless represents the top of an elongated dome.

Area near lower Cottonwood Creek.-An intrusive rock of intermediate composition, probably related to the quartz monzonite, occurs in a small area about 3 miles northwest of the mouth of Cottonwood Creek. It is known only from specimens collected by Mr. Sargent. This rock is darker than typical monzonite and consists of plagioclase, orthoclase, quartz, and accessories, such as augite, biotite, apatite, and magnetite. It is therefore a granodiorite. Probably it is related to the rock in the small area of extrusive rocks near by.

Nixon Fork mines.-The quartz monzonite area at the Nixon Fork mines is described under the heading "Economic geology" (p. 124) in connection with the ore deposits that are so closely related to it.

Crooked Creek.-The area on Crooked Creek also is treated under the heading "Economic geology" on page 139.

DIKES AND SILLS

Innumerable porphyritic dikes and sills cut the Upper Cretaceous sandstone and slate in the general vicinity of the larger intrusive bodies. None of these dikes and sills are shown on the map (pl. 5), although at many places they form the most conspicuous, if not the most extensive portion of the bedrock. Although many of the large intrusive masses lie close to the limestone and even intrude the limestone at the Nixon Fork mines, similar dikes and sills are almost unknown in the limestone. A few dikes cut the limestone at the Nixon Fork mines, but none whatever were seen elsewhere. This seems to indicate that the limestone was peculiarly resistant to injection, whereas the shale and sandstone were peculiarly susceptible.

Sills appear to be more numerous than dikes. Some of them exceed 100 feet in thickness. The thickest dike observed was about 50 feet thick. The best exposures are found in bluffs along streams, such as Nixon Fork and Whirlwind Creek, but fair exposures can be found on many ridges above timber line.

The sills are notably porphyritic. The usual phenocrysts are feldspar; phenocrysts of biotite and quartz are less common. In thin sections of rock from upper Nixon Fork the feldspar is seen to be plagioclase and the accessories to be hornblende, biotite, and magnetite, with traces usually of quartz. This mineral composition corresponds closely to that of the neighboring quartz monzonite, and the rock probably should be called andesite. The sills south of Sunshine Mountains are much richer in large quartz phenocrysts and also contain orthoclase. They are classified as rhyolite or quartz latite porphyry. In most of the sections examined there is intense alteration in the form of replacement by carbonate minerals and to a less extent by sericite, chlorite, and quartz. Some sections seem to contain nearly 50 per cent of calcium carbonate and would approach limestone in chemical composition.

A platy structure is well developed in most of the sills. The plates average 1 to 2 inches in thickness and seem invariably to be parallel to the walls, thus giving a clue to the structure.

The dike rocks of the upper Nixon Fork differ from the sills only in minor features. Generally they are denser, finer grained, and of darker color and lack the sheeting peculiar to the sills. They include types which should probably be classified as dacite porphyry, vogesite, and quartz latite, but all the sections examined contain large amounts of secondary carbonate minerals with some silica replacing both matrix and phenocrysts and seemingly destroying the original ferromagnesian minerals. Pyrite of later introduction than the original minerals is present in some sections.

Dikes near the Sunshine Mountains are of virtually the same composition as the granite (p. 116) and include rhyolite porphyry and soda rhyolite porphyry.

The intrusion of the dikes and sills as a rule metamorphosed the adjacent sedimentary rocks but little if at all. Near the Sunshine Mountains, however, many of the dikes show narrow borders an inch or so in width of altered green slate, spotted with muscovite, biotite, and chlorite, and impregnated with silica. A large dike on Nixon Fork just below Cottonwood Creek has caused extensive slickensidihg and some graphitization of the intruded shale.

Many of the dikes and sills are conspicuous topographically, as they are resistant and form long asymmetric ridges, sharp conical peaks, and broken cliffed slopes in the shale areaS.

AGE OF ACIDIC INTRUSIVE ROCKS

The bosses, dikes, and sills of acidic intrusive rock cut rocks of Upper Cretaceous and in part perhaps of Eocene age and are believed to be either Eocene or earliest Oligocene. They are undoubtedly closely related to the later extrusive lavas and probably are of nearly contemporaneous formation.

CONTACT BETWEEN PALEOZOIC AND UPPER CRETACEOUS BEDS

The contact between the thick Paleozoic limestolle and the Upper Cretaceous beds south of Nixon Fork is of unusual interest. The fossils indicate that the beds are widely separated in age. Such a break must mean either UIlconformity or faulting. Owing to the heavy cover of residuum and talus the contact was not found definitely exposed,although its zone was examined at numerous places over a distance of more than 20 miles. Several lines of indirect evidence, however, have a bearing on its interpretation.

Topographically the limestone rises abruptly in rugged ranges above a subdued lowland of broken ridges. The contact zone is occupied nearly everywhere by short valleys etched out on the shale at the foot of the limestone, ridges, the main drainage being transverse to the contact. Low cols and saddles mark the spurs along the contact. These features and the character of the fragments of the Upper Cretaceous rocks indicate that in most places the softer and finer-grained beds of the Upper Cretaceouslie nearest the limestone.

Ordinarily, where clastic beds like those of the Upper Cretaceous in this region rest unconformably on other rocks, fragments of the underlying formation are found in them, especially in the basal beds near the contact. Not a single fragment of limestone was found in the Upper Cretaceous beds, however, either in the field or in thin sections. These beds consist mainly of fragments of igneous and metamorphic rocks (p. 107).

If the contact is unconformable the Upper Cretaceous beds should overlie the limestone. Although the relations were not positively determined the evidence points ratherto the opposite conclusion, that the limestone atpresent overlies the Upper Cretaceous beds. Near fossil stations 17, 18, and 19 and also near stations 15 and 16 the massive limestone is arched into broken anticlines, which within a few hundred feet of the contact are overturned and dip 75-80° SE. (See fig. 5.) At most other places the dips are variable but steep in diverse directions. The Upper Cretaceous beds near the contact seem to dip rather uniformly to the southeast, as if passing beneath the limestone. Near the junction of Canyon and Whirlwind Creeks the dips over a large area are 15°-45° SE. Near fossil station 7 and near Boulder Creek the dips are monoclinal to the southeast for long distances near the contact.

The inclosed area of Upper Cretaceous beds near the Nixon Fork mines is especially significant. Here the shale and sandstone form a lowland, cut through on the southwest by the monzonite mass, surrounded on all sides by a rugged rim of limestone. The limestone of this rim seems to dip away from the shale as described on page 126, indicating anticlinal structure. This area of Upper Cretaceous beds might be explained in the following ways:

1. As a graben dropped by a rather complicated oval system of normal faults. Such a fault system would be unusual and the location of a graben on an anticline rather anomalous.

2. As an infolded remnant resting unconformably on the limestone. The deposit must then occupy a basinlike area eroded in the limestone. The absence of fragments of limestone and the presence of igneous and metamorphic material in the Upper Cretaceous beds are scarcely explainable on this hypothesis.

One other line of evidence is suggestive. The Upper Cretaceous beds nearly everywhere north of the limestone area are cut by innumerable intrusive dikes and sills. Not a single dike or sill was observed in the adjacent limestone near the contact. Only at the Nixon Fork mines, where a major monzonite mass itself invades limestone, are a very few dikes present in that formation. If the limestone underlies the Upper Cretaceous beds unconformably and presumably at no great depth, along the contact, then these small intrusive masses must have risen up through it, and their absence in the limestone, where it is exposed, is most remarkable.

All the features of this contact, it is believed, may be satisfactorily explained as a result of thrust faulting. Under this interpretation the limestone has been thrust upward and to the northwest, overriding the Upper Cretaceous beds along a front of at least 30 miles and for a maximum distance of at least 6 or 7 miles. Its position seemingly above the shale is thus readily explained, and so also is the absence of fragments of limestone in the Upper Cretaceous beds. The dip of the Upper Cretaceous beds beneath the limestone is natural, and the dikes and sills may be considered as rising

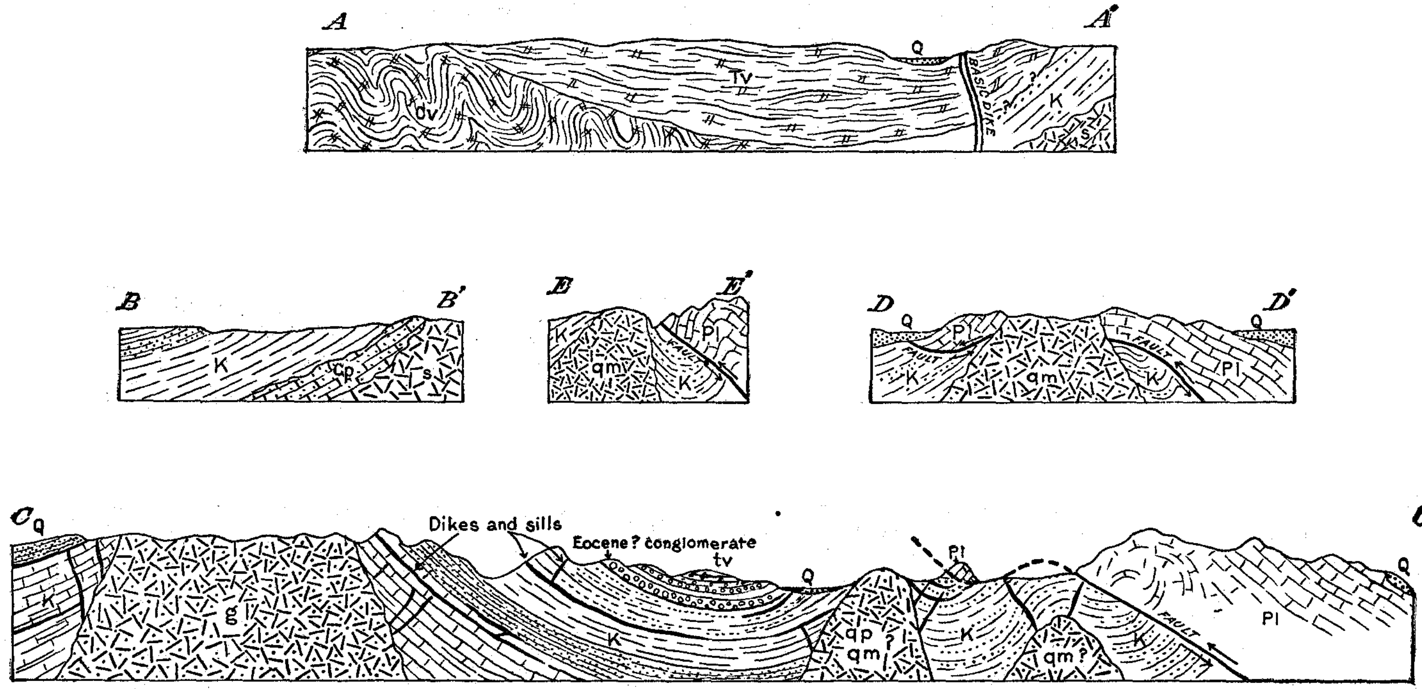


FIGURE 5.—Structure sections in the Nixon Fork country. (See locations on pl. 5.) Q, Quaternary; K, Upper Cretaceous; Cp, Permian; Pl, Paleozoic limestone; qm, quartz monzonite; qp, quartz porphyry; g, granite; s, schist; Ty, Tertiary volcanic rocks; ov, older volcanic rocks

through the yielding thin-bedded shale and as being checked by the massive limestone above. The area of Upper Cretaceous beds at the Nixon Fork mines thus occupies naturally the crest of a breached fold domed by an intrusive mass which penetrated barely through the shale into the overlying limestone. This interpretation is illustrated in Figure 5.

Certain minor features may seem to be not fully in accord with this interpretation. The main contact on the northwest is rather straighter than might be expected of a thrust fault, although at places it is sinuous. Moreover, no outliers of limestone were found to the northwest beyond the border of the main mass. Both these facts may well be explained as a result of later folding, which has caused the thrust plane to dip steeply to the southeast along this front.

One other explanation is possible. The main northwestern contact might be a normal fault and the area of Upper Cretaceous beds at the Nixon Fork mines might be a graben, as previously mentioned (p. 121). On this assumption, however, the shale should dip away from rather than toward the limestone, owing to drag. Also, the occurrence of the intrusive mass of the Nixon Fork mines at the center of a graben would be anomalous.

The evidence in favor of thrust faulting is strong but not conclusive, and the field should be searched for other facts. If the thrust hypothesis is correct, then the fault is of later age than the Upper Cretaceous beds involved but earlier than the quartz monzonite at the Nixon Fork mines, which cuts through it into the overlying limestone, and also earlier than much of the folding which accompanied the intrusion of the larger igneous masses, approximately in Eocene time. The overthrust would belong therefore to an early stage in those violent dynamic disturbances which took place during or immediately after the Eocene epoch.

ECONOMIC GEOLOGY

MINES NEAR NIXON FORK

The only notable mining operations in the Nixon Fork country have been in a small area bordering the monzonite mass in the southwestern part of the great limestone range south of Nixon Fork. A brief description of this region by Martin[28] was published in 1921. The present description is more complete, although only a few days were available for the examination and several of these were almost continuously rainy. Furthermore, the underground workings had been closed down and were mostly inaccessible, so

[28] Martin, G. C., Gold lodes in the upper Kuskokwim region: U. S. Geol. Survey Bull. 722, pp. 149-161, 1921.

that little could be seen of the actual occurrence of the ore. On the other hand, the people living in the district assisted the Survey party freely in every possible way. The writer is much indebted to all those who were so uniformly courteous and helpful, particularly to Mr. E. M. Whalen, joint owner and operator of the principal developed mine.

INTRUSIVE QUARTZ MONZONITE AND PORPHYRY

The most striking geologic feature of the mining district is a small elongated body of quartz monzonite and associated porphyry, very similar in composition and occurrence to the other larger intrusive masses (pp. 115-118). Its area and relations are shown in Plate 6. It differs from most of the other intrusive masses mainly in that at places it cuts the Ordovician and Silurian limestone as well as the Upper Cretaceous slate and in that the mineralization accompanying the intrusion was more extensive than elsewhere.

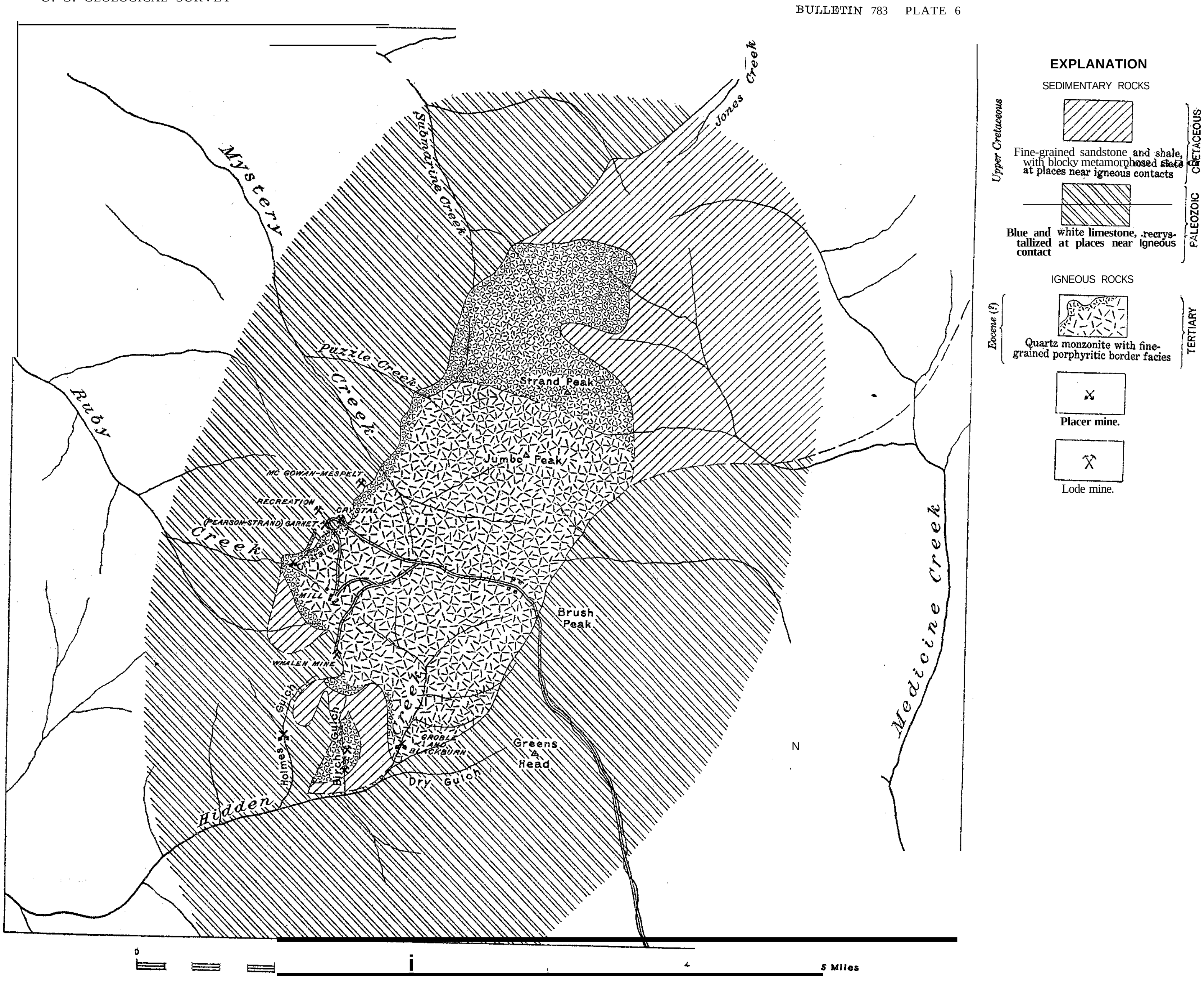
The monzonite is of rather variable appearance. It closely resembles granite, but as a rule it is rather darker than true granite. Thin sections show both orthoclase and plagioclase feldspars, quartz, brown biotite, green hornblende, and minor accessories, such as apatite, iron oxides, and pyroxene. The monzonite is exposed in a few low ridges, as those near the Whalen shaft and west of Brushy Peak, and in numerous road cuts and prospect pits. It also forms two small cliffed masses on Jumbo Peak. Between the Whalen shaft and the Pearson-Strand claims the monzonite contains many dark xenolithic patches, which probably represent incompletely absorbed inclusions of shale.

Porphyry closely related in composition to the quartz monzonite occurs in the area in two ways-as a chilled border phase and as dikes. The porphyry border partly encircles the monzonite, separating it from the intruded rocks. It probably is not more than 100 to 200 feet thick at many places. The outcrop is usually only a few hundred feet in width, but at the northeast it broadens into a wide nose, forming the whole of Strand Peak and completely arching over the monzonite beneath. There the porphyry contains abundant inclusions of the overlying intruded Upper Cretaceous shale.

The porphyry dikes cut both the limestone and slate and probably the monzonite as well, for porphyry float is abundant in road cuts and prospect pits within the monzonite. Pearson and Strand state that they have followed a dike from monzonite into limestone in prospecting.

Martin[24] also describes a basic dike cutting the limestone.

[24] Martin, G. C., op. cit., p. 157.



GEOLOGIC SKETCH MAP OF THE VICINITY OF THE NIXON FORK MINES

In part from geologic maps prepared by Livingston Wernecke of Alaska Treadwell Gold Mining Co.

UPPER CRETACEOUS(?) SLATE AND SHALE

Shaly rocks cover a large area to the northeast of the monzonite and near the intrusive mass have been metamorphosed into small patches of slate. The fossil collections from these rocks are poor, but in conjunction with the lithology they indicate almost unmistakably that the rocks belong to the Upper Cretaceous series as described on pages 107-110. Southwest of the monzonite the slate occurs only as float in the placer mines and ditches. Blocky pieces a foot through are abundant at the Groble & Blackburn placer.

PALEOZOIC LIMESTONE

The limestone surrounding the monzonite and slate belongs to the Paleozoic limestone formation and resembles most closely the thicker-bedded phase described on page 102 The beds in this locality, however, range from 3 to 12 inches in thickness as a rule. On a fresh fracture the rock is gray-blue, and it is commonly called the "blue lime." It is seamed by a great many small veinlets of pure white calcite.

Traces of fossils are found at many places, but good material is generally obtained only in float. Collections Nos. 1 and 3 are the only ones obtained near the mining district. Fossils similar to those in No. 3 can be found sparingly in places on Submarine Creek, and traces of fossils were also seen on Brushy Peak. fossils are reported also from other localities not visited. Collections Nos. 1 and 3 indicate that the rock is of middle Paleozoic age, probably in part Ordovician and in part Silurian.

The thickness of limestone about the borders of the intrusive mass was not determined, but probably it is more than 2,000 feet, although less than the thickness of limestone farther east.

At most points near the intrusive mass the limestone has been mildly metamorphosed. On the southeast border of the monzonite the chief effect is recrystallization, accompanied by a yellow color and some silicification. On the northwest border metamorphism has been more pronounced in certain irregular patches a few hundred feet in length or breadth. These effects are described later in connection with the associated mineralization. Where slate intervenes between the limestone and the monzonite metamorphism is scarcely noticeable in the limestone.

The topography of the limestone is much bolder than that of the shale and monzonite. It forms an imperfect rim of steep or cliffy slopes encircling the lower and more rolling hills of monzonite and shale. This rim, however, is trenched by the gorges of many small outward-flowing streams. The limestone contact, whether with monzonite or shale or porphyry, usually occupies cols on the interstream ridges.

STRUCTURE

The structure of the region was not well worked out, but the sedimentary rocks are believed to form an irregular anticline arched up by the intrusion of the monzonite mass. South of the monzonite mass the asymmetry of ridges strongly suggests dominant southward dips, and definite southward dips were observed on Brushy Peak, although associated with dips in other directions. Along Submarine Creek, north of the intrusive mass, dips of 20°-40° NW. were seen clearly in good exposures for a distance of a mile or more. The structure of the slate and shale could not be made out at any place.

The upper surface of the monzonite and the associated porphyry mass almost certainly was dome shaped, and the borders dip beneath the sedimentary beds at an angle steeper than that of the bedding. The straightness of the contact and the virtual absence of the porphyry border on the south suggest that the dip there is very steep, whereas on the north it is probably much less, the porphyry border being well defined at most places and the contact irregularly sinuous. This relation, however, is probably due in part to faulting. The great extent of shale and porphyry on the northeast compared to that on the southwest also suggests that the anticline plunges much more steeply on the southwest. This interpretation, as stated on page 103, is based on the assumption, not fully proved, that the limestone is overthrust on the shale by faulting, as shown in Plate 6. This assumption is based partly on the fact that the limestone along its contact with the shale stands high above it topographically and appears to dip away from it, and that the monzonite and porphyry, coming from below, appear to have invaded the shale at many places without having encountered the limestone. The shale, moreover, as discussed on pages 107-110, shows none of the features that would be expected on the interpretation that it overlies the limestone.

The structural relations are undoubtedly complicated by normal faulting later than the supposed thrust faulting, the folding, and the intrusion of the monzonite mass. A partial examination of the underground workings at the Whalen shaft showed many small slips and shear zones, and in a prospect pit near by recrystallized limestone is clearly in fault contact with monzonite (p. 129). Normal faulting, however, can not be mainly responsible for the outlines of the intrusive mass, because the contact effects about its border are continuous and the thin border of porphyry is very persistent. Extensive faulting would cause these thin zones to be cut out and would bring the monzonite into contact with unaltered sediments at many places.

Erosion does not seem to have, cut very deeply into the monzonite mass, and it is unlikely that the highest point of the intrusive mass ever stood much more than 1,000 feet above its present surface.

ORE DEPOSITS

HISTORIOAL NOTES

Martin summarizes the history of the discovery and development of this district prior to 1920 as follows:[25]

For several years a few small placer mines have been worked on Ruby and Hidden creeks, which are tributary to Nixon Fork from the south. In the course of this placer mining it was found that the gold became more abundant as it was followed up the creeks, but that above certain points it was no longer found. Shafts sunk into the bedrock at the limits of the placer gold revealed rich gold-bearing lodes lying on or near a monzonite-limestone contact. Further prospecting at this contact revealed the presence of other gold lodes. Shafts weresu;nk early in 1919 on two of the more promising of these lodes, and from one of them several hundred tons of high-grade ore was mined in the winter of 1919-20. This ore was sledded to Kuskokwim River, and in the summer of 1920 it was shipped to the Tacoma smelter. In the meantime prospectors had traced the contact of the monzonite boss near the margin of which the known lodes lie, had staked claims along probably the entire contact, over much, if not all, of the monzonite area, and over part of the surrounding limestone, and had dug many trenches and pits along the contact and at other places, revealing the presence of many ore bodies of different sizes and richness. Many of the more promising claims, includi.ng the one from which ore had been shipped, passed into the control of the Alaska Treadwell Gold Mining Co. and associated interests early in 1920. During the summer of 1920 the Alaska Treadwell Co. was actively engaged in prospecting its holdi,ngs, and prospecting was being continued on a smaller scale on some of the other claims.

The operating company was the Treadwell Yukon Co. (Ltd.), owned and controlled by the Alaska Treadwell Gold Mining Co. and locally called the Treadwell Co. From 1920 until late in 1923 this company actively prospected and developed some of the more promising prol?erties, particularly three groups of claims—those of Whalen & Griffin, Pearson & Strand, and McGowan & Mespelt. The original and principal property was that of Whalen & Griffin. Considerable work was done also on the Pearson-Strand property but little on the third group of claims.

In 1921 a 10-stamp mill was erected, and this mill is stated to have produced $114;024 in gold during four months of operation in 1922.[26] The mill was also operated iJ11923. The total output is reported locally and unofficially as about $235,000. This gold came chiefly from the Whalen mine and some of it from the Pear-

[25] Martin, G. C., Gold lodes in the upper KUSkokwim region: U. S. Geol. Survey Bull. 722, p. 149, 1921.
[26] Weed, W. H., Mines H,andbook, vol. 16, P. 175, 1925.

son-Strand claims. The operations are generally admitted to have been at a loss.

During this time the company maintained a camp of 20 or 30 men and kept the 12 miles of wagon road to Berrys Landing in passable condition.

The best ore in sight at the Whalen mine had by this time been nearly exhausted, and no promising new ore bodies had been located. Accordingly, the company decided to abandon the venture, and the claims reverted to their original owners. The mill still belonged to the Treadwell Yukon Co. (Ltd.). There was still some good ore at the Whalen shaft, much of it broken but not milled, owing to a fire which had destroyed the engine house. The mine and mill were therefore leased to an association of four men, including E. M. Whalen, one of the owners, and these four, assisted by several hired men, milled the remaining ore in 1924. It was generally reported in August that the clean-up for the season would run about $80,000. After this the mine was to be virtually abandoned, although Mr. Whalen expected to do some further prospecting underground.

Pearson & Strand were actively prospecting in 1924, but the McGowan & Mespelt claims were idle.

In addition to the lode claims several small placers had been operated continuously, yielding a few thousand dollars yearly. From 1920 to 1924 the region had been pretty thoroughly prospected both for lodes and for placer gold.

LODES

WHALEN MINE

The Whalen mine is on a low knob at the head of Holmes Gulch, in an altered portion of the Paleozoic limestone or "blue lime." The limestone forms an irregular narrow tongue or possibly even an isolated "island," although the ridge to the west was not examined to determine this relation. The topography suggests that slate may intervene along the saddle between this limestone and the main front farther west.

The altered limestone is less than 200 feet from exposures of fully crystalline quartz monzonite, and it seems likely that the porphyry border usually present around the monzonite has been cut out at the surface by faulting. In a prospect shaft 300 feet about N. 20° E. from the main shaft the contact is very clearly a fault between limestone and monzonite. The fault trends almost toward the shaft. Contrary to expectation monzonite forms the hanging wall, as the fault dips about 80° SE. The drag also suggests that monzonite had dropped against limestone, possibly as the result of some later reversed movement along a previously normal fault by which limestone must have been dropped against monzonite, cutting out the porphyry border.

Mr. Whalen conducted the writer down the shaft to the 100-foot level, where the ice prevented further descent. The shaft is in-cliried about 80°, away from the monzonite contact. Down to the 100-foot level it penetrates altered limestOIie. A drift trending N. 15° E. also penetrates limestone for about 50 feet, where there is a fault contact with much altered porphyry, in which the drift extends 25 feet. This fault trends nearly east, and dips steeply. The opposite drift to the southwest is in limestone for 50 feet, as far as it was accessible. So also is a short crosscut to the south. Jointing, slickensiding, gouge, and brecciation show evidence of movement with intense shearing.

Much of the altered limestone is a white or gray rock, recrystallized but not otherwise greatly modified. Mixed through this rock in irregular streaks or bands are masses of darker rock that is much more severely altered. This darker rock consists of typical contact-metamorphic silicates, such as zoisite, pyroxenes, garnet, and similar minerals, together with a great deal of fine-grained quartz, which replaces the original limestone. These masses in many places are closely associated with irregular knots and blebs of much modified intrusive matter, doubtless originally monzonitic.

The ore occurred in irregular masses and ore shoots not confined to any definite vein or structure. It has been almost wholly oxidized to the bottom of the workings, but enough of primary ore remains to indicate that it consisted mainly of pyritic sulphides, especially pyrite and chalcopyrite, with free gold, the gold being the chief portion of value. The sulphides have altered to limonite, malachite, and black earthy oxides of copper, and the ratio of copper to iron is rather high. The circulating ground water which assisted in this oxidation has modified considerably the original distribution of the copper and carried it into shear zones where no ore was originally present. For this reason the gold does not follow strictly the distribution of the copper minerals, although in general the richest gold-bearing material corresponds to the material that has the higher content of copper. The amount of copper is small, probably not more than 1 or 2 per cent for any considerable tonnage of ore.

The metals were irregularly distributed, but considerable good ore running $70 and more to the ton was extracted. Martin[21] stated that in 1920 a crosscut on the 4O-foot level showed 32 feet of ore, reported to average $68 a ton in gold. The "clean-up" ore being

[27] Martin, G. C., op. cit, p. 160.

milled in 1924 was estimated by the operators to run about $56 a ton.

In addition to gold, the ore carried from 1 to 3 ounces of silver to the ton. The richest ore was restricted definitely to the upper part of the workings, above the 100-foot level, and was mined out above this level until the surface caved into a large "glory hole." One or two pockets or ore, smaller and not so rich, were found between the 100 and 200 foot levels but nothing of great value.

Two main significant facts can be gleaned from the description of this mine. First, the ore forms a fairly typical contact-metamorphic deposit; second, its richness near the surface was almost certainly due in a considerable measure to enrichment. As the other deposits in this district are of much the same character the bearing of these facts on the future possibilities of the mines will be discussed collectively elsewhere (pp. 139-140).

The ore was hauled to the mill, half a mile away, on an easy downhill grade, in wagons. After passing through the stamps it was treated by amalgamation. Tables were used, however, to concentrate the pyritic and cupriferous minerals, which carried most of the gold. It is said that this treatment left $7 to $8 in gold to the ton in the slimes. These slimes at first were ponded, but later for lack of convenient space no effort was made to save them for possible further treatment.

PEARSON-STRAND CLAIMS

The Pearson-Strand claims lie just south of the divide between Ruby and Mystery Creeks, at the head of a small ravine called Crystal Gulch. The limestone here forms an irregular salient, topping the ridge and presumably overlying the sloping surface of the monzonite. The prospects are in more or less altered limestone at and near the contact. The underground workings were not examined, and the structural relations are not clear, but there is no definite evidence of faulting. The porphyry border of the monzonite seems to be present here or near by. The shape of the salient of limestone also suggests that it overlies the monzonite without much disturbance, so that faulting was probably of less consequence than at the Whalen mine.

Four main openings have been used in prospecting these claims. The Keen shaft and Crystal shaft have been abandoned for some years, and the following descriptions by Martin[28] are quoted:

> The Keen shaft is on the wagon road near the head of Crystal Gulch, about 1,000 feet east of the western border of the monzonite. It is said to have revealed a vein 4 feet wide, and material from this vein on the dump shows

[28] Martin, G. C., op. cit., pp. 159-160.

quartz with much yellow stain containing numerous small flakes of a grayish mineral with metallic luster (probably arsenopyrite) and a few small cubes of pyrite.

The Crystal shaft is near the head of Crystal Gulch, a tributary of Ruby Creek. It is in the monzonite not far from the limestone. The shaft was begun in January, 1919, and was sunk in the winter of 1919-20 to a depth of 65 feet. The workings, which were inaccessible at the time of the writer's visit, were made for the purpose of mining whatever ore could then be shipped at a profit. It is said that the ore body thus mined was a lens 10 by 20 by 65 feet in dimensions and that there was "6 feet of sulphides in the bottom of the shaft." The ore is unoxidized and, as shown by specimens on the dump, consists of chalcopyrite, pyrite, and bornite in a gangue of calcite, siderite, and a zeolite, probably scolecite.

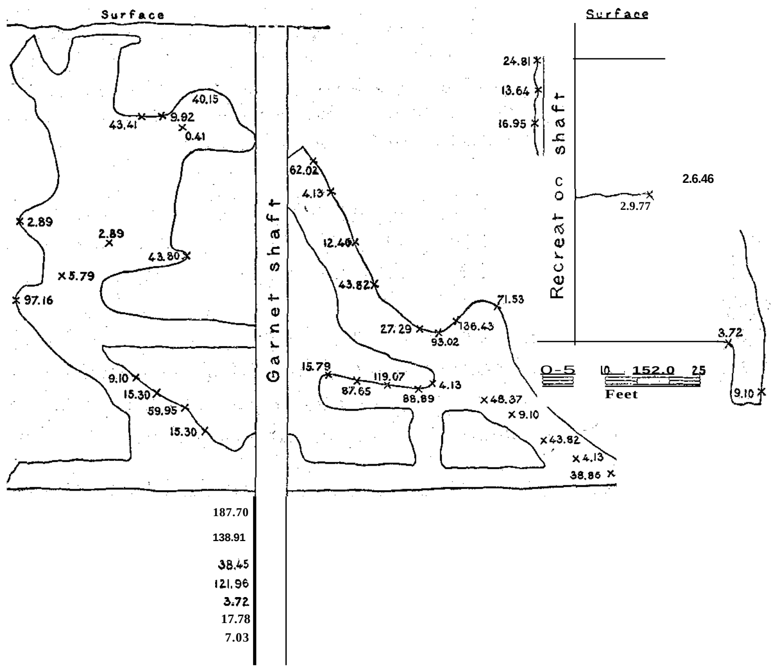


FIGURE 6.—Assay plan of Garnet and Recreation shafts. Figures indicate assay value in dollars to the ton

The Garnet shaft is south of the wagon road near the head of Crystal Gulch. It is in limestone, about 100 feet from the outcrop of the monzonite, but masses of monzonite show in the lower workings. The shaft was 76 feet deep when visited, and there was about 70 feet of drift. At the surface the ore is the full width of the shaft which does not show the walls. At the bottom of the shaft the vein is not more than 4 feet wide. The ore, which is thoroughly oxidized, consists of chloritic material, iron ores, and quartz with many thin films and small masses of malachite and azurite.

The Garnet shaft was the principal scene of the Treadwell Co.'s later explorations on this property. The shaft was sunk to 270 feet, and a winze was driven 40 feet deeper. The lower workings were in monzonite with little or no ore. In the upper part of the workings some very rich ore was found, mixed in spotty fashion with much lean material, as is well illustrated in the assay plan (fig. 6). Some of this ore was hauled to the mill and treated. The ore was at least partly unoxidized, as pyrite and chalcopyrite show in the dump material.

Near the Garnet shaft and the near-by Crystal shaft there is a considerable body of dense red garnet rock, which represents limestone very intensely altered and replaced. Martin[29] described the Recreation shaft as being

in the limestone about 600 feet west of the margin of the monzonite. A shaft 50 feet deep with a drift 35 feet long exposes a vein having a maximum thickness of 6 feet. The vein has been traced by surface cuts for about 200 feet. The ore is thoroughly oxidized and shows in thin section. iron oxides and hydroxides, quartz, chlorite, which is in part. spherulitic, malachite, probably some azurite, and a little apatite. The specimens show much dark-green and some blue stain, probably derived from copper minerals. No sulphides or metallic minerals were seen.

This shaft also was used by the Treadwell Co. and deepened. to about 100 feet. The assay plan (fig. 6) indicates something of the distribution and amount of the valuable metals. A little of this ore also was milled.

The ore on the dump, as stated by Martin, consists mainly of oxides and carbonates of copper but contains also unaltered cores of chalcopyrite and bornite. The associated rock seems to be simply silicified limestone and lacks the contact minerals common at other places.

During 1924 Pearson & Strand sunk three shafts 25 to 40 feet in depth and did some little drifting in ground 150 to 300 feet south of the Recreation shaft. They found a loose capping of decomposed limestone containing very rich ore. Probably about 100 tons of this material was on the dump. It consisted of rich copper carbonate and oxide with some secondary chalcocite and abundant visible tracesof free gold. It is stated that the value of some of this ore will run into hundreds of dollars a ton. As a whole, however, it probably averages between $50 and $100 a ton.

The character of this ore and the assay plans of the Garnet and Recreation shafts show clearly that enrichment has been active here as at the Whalen mine, and the surface ore will doubtless prove to be considerably richer than that below.

The Treadwell officials claimed that this ore responded to treatment much less satisfactorily than that of the 'Whalen mine. Unverified reports say that the recovery was not more than 50 per cent of the value. The greater amount of unaltered sulphides present in the ore doubtless explains its more refractory nature. These sul-

[29] Martin, G. C., op. cit., p. 160.

phides probably remain because there has been less fracturing and crushing since the ore formed, and leaching has been less thorough. Some other treatment than simple amalgamation will probably be required for the recovery of the gold in this ore.

The presence of porphyry dikes cutting the limestone at these prospects should be noted. The porphyry float shows at the surface, and Pearson & Strand state that in prospecting they have traced two dikes, each 30 or 40 feet wide, from the vicinity of the Recreation shaft southward across Crystal Gulch and beyond Ruby Creek. Some of the ore in the limestone may follow in general the location of such dikes.

M'GOWAN-MESPELT CLAIMS

The McGowan-Mespelt property, often called the Southern Cross, lies on the slopes leading to Mystery Creek, several hundred feet from the Pearson-Strand claims and in a similar position along the limestone-monzonite contact. Nothing was being done at these claims in 1924, the owners were absent, and for lack of time the claims were not visited. The following descriptions from Martin[30] apply to this property.

> The Garnet trench is on the contact between the monzonite and limestone, south of Mystery Creek and near the northeast corner of the Southern Cross claim. The ore consists chiefly of garnet containing many thin films and small masses of malachite and azurite. The thin section shows, in addition to garnet, augite, a little sericitized plagioclase, apatite, epidote, and chloritie material.
>
> The Twin shafts are near the center of the Southern Cross claim. They are in an oxidized zone on the contact of a fine-grained porphyry dike intrusive into limestone. The ore was so much decomposed that no microscopic study or determination of the constituent minerals was possible. It is said to carry about $10 worth of gold per ton.

The writer later met Mr. Charles Mespelt, one of the owners, who said that the upper 30 feet of the ore in a 50-foot shaft, sampled and assayed by Mr. Bullard, of the Treadwell Co., averaged $90 to the ton in gold. The material from a 20-foot shaft and 6-foot drift in rotten porphyry along the contact averaged $20 a ton. It is plain that the prospect resembles closely those already described.

GENERAL FEATURES OF THE PRINCIPAL LODES

The ores of the three lode claims above described, which constitute the only notable claims in the district, are of the type commonly called contact or contact-metamorphic deposits, such as are formed typically around the borders of an igneous intrusive mass, especially in limestone wall rock. The ores were deposited from rising

[30] Martin. G. C., Op. cit., pp. 160-161.

solutions given off from the monzonite as it cooled and crystallized. These solutions were fairly hot. They contained gold and copper and carried much silica and other common substances. On reaching the limestone they found a favorable place to deposit their heavy mineral content, and they penetrated along any convenient fractures, bedding planes, or cavities, irregularly replacing the limestone, altering it to quartz and silicates, and depositing copper and gold.

Such ore bodies are usually irregularly distributed more or less along the contact but in places even several hundred feet from it. They occur in localized ore shoots or bunches, and the valuable material is generally spotty. Most of the ore bodies seem to have been rather small, generally less than 100 feet in lateral or vertical extent, and other ore bodies that may be discovered will probably be of similar dimensions.

ENRICHMENT

Enrichment is the process by which the ore near the surface has been modified so that its valuable content runs much higher than that of the material below. It has come about chiefly in three ways. First, the limestone is easily broken down and washed away; the gold, which is heavier, tends to remain behind and become concentrated in the soil and loose rock where the ore body was exposed. Some gold, however, has also been carried down the gulches to form placer deposits. Second, the limestone is much more soluble than the gold, and it has been dissolved, decomposed, and carried away in solution, leaving behind a loose mantle of soil and rock containing most of the original metallic matter. Third, gold and especially copper are themselves somewhat soluble and tend to be dissolved and carried downward by ground water. When they come into contact with unaltered sulphides they are reprecipitated on the sulphides, thus enriching the original deposit. The oxidized nature of the ore bears abundant witness to the effectiveness of these processes of enrichment, especially in the upper 100 feet. It is not likely that unusually rich ore running more than $50 or $100 to the ton will be discovered below this depth. Oxidation has also been effective in freeing the gold from its association with the copper sulphides and rendering it free milling. Ore discovered below 100 or 200 feet in depth will probably be largely unaltered sulphide and not as suitable for amalgamation as that above.

PROSPECTING

Contact-metamorphic ore bodies are not necessarily confined strictly to the contact of the igneous mass. Even the Treadwell Co., in the writer's opinion, stuck rather too closely to the immediate vicinity of the contact in exploring the ore bodies. Surface outcrops show that ore may occur several hundred feet from the monzonite. In the vicinity of known ore bodies, therefore, surface prospecting anywhere in the limestone is justified, and underground it is fully as desirable to drive crosscuts away from the contact as toward it, at least for distances of a few hundred feet. The vicinity of dikes that cut the limestone near the monzonite is probably an especially favorable place for prospecting.

GROSHONG CLAIMS

H. Y. Groshong and a partner own four lode claims lying above two placer claims on Birch Gulch. The lode claims so far have yielded only placer gold, which is fairly coarse and little worn and evidently not far removed from its original source. There seems to be no copper with the gold. Mr. Groshong has spent several years sinking many pits in endeavoring to discover the source of this gold. He believes it to be connected with a porphyry dike that is supposed to cut the slate bedrock in the vicinity. Porphyry boulders are abundant, but whether or not they come from a dike or merely from the chilled border of the monzonite is uncertain. The occurrence of porphyry bedrock in the placer below might suggest that this is the outer shell of the intrusive monzonite. Dikes, however, may occur anywhere.

A tongue or perhaps an isolated mass of limestone projects into the slate here and seems to be faulted against slate or mixed slate and porphyry on the southeast. The rock is blue limestone, much veined by calcite and strongly recrystallized.

OTHER LODE PROSPECTS

Martin[31] describes the Matthews & Blackburn prospect, "in the valley of Hidden Creek near the south end of the area of monzonite. Only a shallow excavation had been made * * * and no well-defined ore body exposed. The prospect is situated on the outcrop of a basic dike intrusive into limestone, near the margin of the main mass of monzonite." The dike is the one mentioned on page 161. The writer did not visit this prospect, which never amounted to anything. Only stains of copper and a little gold were found, it is said, all the gold within the monzonite.

The margin of the intrusive mass and much of its surface as well have been pretty thoroughly and rather intelligently prospected by shallow pits and trenches in search of outcrops of mineralized rock. The porphyry knob at Strand Peak in particular is covered by pits, trenches, shallow shafts, and tunnels. The porphyry contains abun-

[31] Martin, G. C., op. cit., p. 161.

dant streaks and masses of shale and rusty iron stains suggesting mineralization, but it is said that scarcely a trace of gold was found.

Even in the limestone away from the contact with the monzonite and in the shale area to the northeast many pits have been dug, but none of them ever yielded anything encouraging.

PLACERS

GENERAL FEATURES

Placers were discovered before the lodes, and prospecting for placer gold has gone on almost continuously. Only four workable deposits, all of small size and low grade, have been found. All are unfavorably situated for obtaining water. No streams of any consequence flow through the area, and the placers are mainly near the heads of small creeks that are dry except for brief periods early in spring and after the heavy summer rains. These conditions make operations difficult in ground which, under more favorable conditions, would have yielded profits for a short time.

HIDDEN CREEK

F. E. Matthews, of Berrys Landing, owns the largest placer in the district. This property was operated in 1924 by Charles Groble and Lewis Blackburn. Martin[32] in 1920 reported that "the pay gravel is said to be 75 to 125 feet wide, and it has been shoveled in to a depth of about 4 feet." Operations since then have been extensive, and a large area of ground has been worked out.

The covering over bedrock is 10 or 12 feet deep. The upper 3 or 4 feet consists of muck, which is removed by ground-sluicing. The lower part is composed of coarse gravel, boulders, and sand with little silt. A drag-line scraper is used to remove the boulders, which range from 1 to 3 feet in diameter. They consist chiefly of three kinds of material-blocks of dense slate with rectangular sides, rough blocks of yellow porphyry, and rounded boulders of monzonite. The bedrock is rotten monzonite, although slate tops the ridge to the northwest and limestone lies near by on the southeast. The stream appears to have trenched down into the intrusive rock beneath the overlying sediments. The monzonite makes an excellent floor, easily worked and cleaned.

All the gold occurs near bedrock and is said to run about 50 cents to the square foot. About $14,000 is said to have been cleaned up in 1923, and rather less was expected in 1924.

Native bismuth is rather abundant in the black sand recovered with gold at this placer and occurs also in the other placers of the

[32] Martin, G. C., op. cit., p. 161.

district. The writer saw one nugget of bismuth an inch in diameter. The source of this material is unknown, and little if any search has been made for it.

BIRCH GULCH

Mr. Groshong, whose lode claims are described on page 135, has two placer claims lower down on the same gulch, which he had leased in 1924 to two men, who had just completed a ditch more than a mile long and expected to take out a little gold late in the season. The porphyry bedrock is said to lie about 24 feet below the surface. Very large boulders occur in the poorly sorted overburden. The pay probably is narrow and patchy, for the gulch is a very irregular steep channel, usually dry. The placer gold found just above on the lode claims is coarse and little worn.

HOLMES GULCH

A placer property on Holmes Gulch, owned by E. M. Whalen, the owner of the Whalen mine, has produced gold for several years and was being worked by Jensen & Matson in 1924. In tracing gold up this gulch the lodes at the Whalen mine were discovered.

The stream channel from the Whalen mine down to the placer, a distance of about three-quarters of a mile, seems to be mainly or wholly in limestone, although the float on the slopes just to the southeast is composed of slate and porphyry. The placer bedrock is limestone, partly blue and cavernous and partly what the operators call a "yellow sandy lime." This yellow rock may be a slightly altered and recrystallized phase of the blue limestone, and suggests that the monzonite is near the surface. The surface of the blue limestone is very rough and hard to clean; the yellow rock is much easier cleaned.

The gravel is 9 or 10 feet in depth and contains but little muck. It is very coarse and hard to handle. The coarsest boulders are porphyry. Fine-grained boulders of monzonite are present, and limestone boulders are abundant. Some of these boulders bear copper stains, indicating that they probably come from the lodes near the Whalen mine. Some of the gold itself contains fragments of silicified limestone stained with copper. Some of the coarse gold bears square and rectangular impressions, evidently those of pyrite crystals among which it was deposited. It seems fairly certain that the Whalen lodes have furnished most if not all of this placer gold.

The black sand recovered with the gold consists chiefly of magnetite but contains traces of bismuth.

The pay gravel is said to be poor and spotty, and the operators stated that they were not making expenses.

CRYSTAL GULCH

At the lower end of Crystal Gulch and on Ruby Creek just below it small placers have been worked for several years. Pearson & Strand were doing a little mining in 1924 on Crystal Gulch. The ground was reported to be very poor, running only 15 to 25 cents to the square foot. All the better ground has been worked out.

The gold in these placers doubtless is derived mainly from the Pearson-Strand lode claims at the head of Crystal Gulch. Here, as at the other placers, a trace of bisrnuth is reported. These placers have also yielded a considerable amount of coarse lump magnetite, such as is common in many contact-metamorphic deposits in limestone in other regions, though it has not been noted in any of the developed workings here. This fact suggests that possibly some other ore body not yet discovered may have contributed to this placer gold. The source of this material might be worth investigation.

OTHER PLACER PROSPECTS

On almost every creek and gulch within this district more or less prospecting for placer gold has been done without any encouraging results, except at the four localities described.

RECOMMENDATIONS FOR PLACER PROSPECTING

A few generalizations regarding placer prospecting seem safe. First, all streams and gulches that drain nothing but areas of unaltered limestone ("blue lime") are not worth prospecting. Such streams, for instance, are those draining southeastward from Greens Head and Brushy Peak.

Second, a stream or gulch draining the monzonite area or some portion of its contact is suitable prospecting territory within and near the monzonite but for not more than a mile away from the monzonite. The gold does not occur in great quantity originally and becomes scattered quickly.

Third, gulches heading in or near known lode deposits are the most favorable areas for prospecting. It would seem, therefore, that the best remaining area is Mystery Creek and gulches draining into it, from the Southern Cross or McGowan-Mespelt claims. So far no pay ground has been discovered below these prospects. Possibly, however, none exists.

In view of the amount of prospecting already done and the nature of the developed placers, it appears unlikely that any placer ground of large area or great richness remains undiscovered. Small amounts of pay dirt may yet be found, however. There is little or no hope that large areas of low-grade ground suitable for dredging exist.

Wherever placer gold is discovered it should stimulate search for lode deposits. The character of the rocks and minerals associated with the gold should be studied and their source sought in deposits of similar kind upstream. The source of the gold on Hidden Creek, the most productive placer stream in the district, has never been found. The valley of this creek is much larger than any of the others and drains a large area of monzonite as well as smaller areas of slate and limestone. This gold may perhaps have come from a large number of small and insignificant veins in the monzonite and porphyry. On the other hand, it may have come from contact deposits similar to those already discovered but now almost or entirely eroded away. It hardly comes from any known contact deposit. The association of gold with bismuth may assist in locating the source, and bismuth itself in any notable quantity would be worth discovering.

DEPOSITS ON CROOKED CREEK

West by southwest from the Nixon Fork mines an isolated mountain ridge rises from the connected flats of the Kuskokwim and Nixon Fork. This range is reliably reported to be composed mainly of blue limestone similar to that at the Nixon Fork mines, with a small area of monzonite in the heart of the range. Whether or not slate occurs in the range is not known.

A stream called Crooked Creek heads in the monzonite area and drains southward to the Kuskokwim. On this stream, it is reported, Dave Clow and John Strand have found placer gravel running 38 cents to the square foot on two claims. They were expected to take out a little gold in 1924.

Lode deposits are not known to occur in this area. One report stated that a deposit of asbestos had been located.

The principles that have been brought out in describing the deposits at the Nixon Fork mines probably apply to this area also.

POSSIBILITIES FOR DISCOVERY OF OTHER LODE DEPOSITS

PALEOZOIC LIMESTONE

Whether or not other contact deposits occur in the limestone ranges north and east of the Nixon Fork mines is not positively known. Their presence depends mainly on whether or not other bodies of granite or monzonite intrude the limestone in that region. The writer explored the north slope of these ranges from the Nixon Fork mines to the head of Whirlwind Creek pretty thoroughly by actual observation and by studying the gravel in the beds of each stream crossed, and feels reasonably sure that no intrusive masses save possibly small dikes occur on that slope, except near Whirlwind Creek, as described on page 115. Prospectors might do well to make a similar examination of the slopes draining to the Kuskokwim, if that has not already been done. If pebbles and boulders of granite or monzonite are found in stream beds it should be easy to trace them to their source, and the margins of the intrusive masses should then be explored for lodes and the streams prospected for placer gold.

On the north slope of the limestone ranges, extending southward across Canyon Creek, pink granite is apparently in contact on one side with limestone (p. 117). The contact was studied from Canyon Creek southwestward to the end of the granite and shows no signs of mineralization, but between Canyon Creek and Whirlwind Creek it was not examined. It might be worth while to go over the ground carefully here and look for possible signs of mineralization. There has been so much prospecting for placer gold on Whirlwind and Canyon creeks in this region, however, without yielding anything promising, that it is not likely that valuable lode deposits occur along this contact.

UPPER CRETACEOUS SHALE AND SANDSTONE

No promising signs of mineralization have yet been found on the borders of the masses of monzonite and granite that cut the Upper Cretaceous shale and sandstone, and rocks of this kind are not generally as favorable as limestone for the occurrence of contact and replacement ore bodies. Careful examination of many contacts, both of the larger intrusive bodies and of the dikes and sills, failed to reveal any notable traces of mineralization, though pyrite has been introduced in scattered crystals at many places. Panning here and there in the streams yielded no unusual minerals, and the large amount of prospecting already done by experienced miners without success indicates that rich mineral deposits can not be common in this region.

Unverified reports state that silver-bearing veins have been found in the Sunshine Mountains. The contact of granite with slate in these mountains is very clearly exposed and was studied carefully about the head of Clearwater Creek without finding any evident signs of valuable minerals. A vein of pyrite several feet long and about 6 inches in maximum thickness was found in the slate at one place, and a sample was taken for assay. Along with this material a sample from a rusty quartz vein 4 or 5 miles northeast of this locality, in the slate, was also assayed. The results are given in the table below.

Assays of mineral samples from Sunshine Mountains [a]

	Silver ounces per ton)	Gold ounces per ton)
Pyrite vein near granite contact, Clearwater Creek	2.59	0.01
Rusty quartz vein northeast of Sunshine Mountains	Trace.	Trace.

[a] Analyses by E. T. Erickson, of the U. S. Geological Survey.

PLACER GOLD IN THE NIXON FORK COUNTRY AS A WHOLE

pREVIOUS PROSPECTING

Signs of the prospector can be found on almost all the larger streams of the region, and probably there is not an area of 5 miles square, outside the broad flats, where some prospecting has not been done. Nevertheless this region is one of the parts of Alaska little frequented by prospectors. Aside from the area near Nixon Fork containing the mines described above attention seems to have been directed mainly to three localities-the upper Nixon Fork basin, the Sunshine Mountains, and the area of schist and metamorphic rocks about the head of Our Creek.

From 1910 to 1915 reported strikes on the head of Nixon Fork near Von Frank Mountain and on lower Whirlwind Creek caused two or three small local stampedes, from which nothing ever developed. Nutnerous pits, ditches, dams, and cabins remain in these localities as evidence of the transient occupation. It is said that colors were found in many places on Whirlwind and Canyon Creeks. The area of porphyry near Boulder and Jones Creeks (p.118) has also attracted attention, and the streams are said to yield colors of fine flake gold.

B. J. Bower, Jack Nixon, and others have prospected in the Sunshine Mountains and state that colors have been found at many places. Even the present gravel bars on Clearwater Creek are said to yield colors occasionally. Farther south, between Hosmer and Cottonwood Creeks, there has also been prospecting, and colors have been found which were supposed to come from the coarse conglomerate beds there, though this mayor not be their true source. The writer suspects that they are more probably comiected with the intrusive monzonite (p. 118) in the region.

Herman Hillman and Joe Saint Jemay have lately spent three or four years in the Our Creek region somewhere near the head of Bridge Creek. They are known to have found prospects at several places but apparently nothing that would pay to mine.

POSSIBILITIES OF GOLD IN THE DIFFERENT ROCK FORMATIONS

LIMITS OF PREDICTION

No geologic examination, however thorough, can take the place of actual prospecting in determining certainly whether or not a region contains valuable mineral deposits, especially placer gold. Neyertheless the geologist may indicate with fair accuracy the general nature of occurrences and the relative chances in different areas. These areas as a rule, correspond with the areas of the different rocks and will be discussed in that way.

EXTRUSIVE IGNEOUS ROOKS

The extrusive igneous rocks include both the older and younger lavas described on pages 111-114. They lie mainly north of Agate Fork. The miner can recognize these rocks usually by their fine-grained texture, with scattered coarse crystals here and there, by, their brown, reddish, or purple colors, and by their occurrence generally as loose-jointed pieces.

Volcanic rocks of this kind do not as a rule furnish favorable places for gold or other minerals unless later mineralizing solutions have formed veins in them. No evidence of such mineralization was noted, and no reports of placer gold in these areas were received. These rocks do not form promising territory for prospecting and probably are as unfavorable as any others in the region.

SHALE, SLATE, AND SANDSTONE

Shale, slate, and sandstone are the forms in which the Upper Cretaceous rocks described on pages 107-110 occur in this area. They cover a large area, as shown on Plate 5. The shale and slate are readily recognized by their fine grain and black color and the slaty fragment.s. The sandstone is also easily recognized. With these rocks should be included the coarse conglomerate beds south of the Sunshine Mountains (p. 107).

These rocks are cut by quartz veins at many places, especially near the intrusive igneous rocks, and by calcite veins at a few places. No veins containing valuable minerals were noted. The most favorable localities for prospecting are areas near the intrusive masses of quartz monzonite and granite which cut these'rocks. The prospects'reported from these rocks are usually poor, however, yielding only colors of placer gold. On the whole these rocks in the Nixon Fork country seem to be rather poor ground for prospecting, although possibly they may contain workable placer gold atlocalities not yet discovered. It is' worth remembering that these are the same rocks in which the rich camps at Iditarod, Candle Creek, and Innoko are located.

LIMESTONE

Mineral deposits in the limestone have been rather fully covered in describing the deposits at the Nixon Fork mines and other possible contact deposits (pp. 123-138). Unless igneous rocks can be found cutting the limestone it is useless to prospect these areas for placer gold.

SCHIST AND METAMORPHIC ROCKS

The metamorphic rocks in the vicinity of Our Creek and westward to Nowitna River consist mainly of schist but include also slate, quartzite, crystalline limestone, and greenstone. As a rule experienced prospectors recognize these rocks readily. The schists and slaty rocks have a cleavage that causes them to break readily into thin, platy fragments, many of which glisten with mica and other crystals. On the whole, the places where these rocks occur are believed to be the most favorable in the area for prospecting. Placer gold in several camps near this area, as at Ruby, Long, and Poorman, has come from rocks of this class, and similar rocks in other parts of Alaska are a common source of gold. Moreover, the most reliable reports obtainable indicate that, except for the district of the Nixon Fork mines, these rocks have yielded better showings of gold than any others in the area.

The creeks of this area pass within rather short distances from their short, steep upper courses onto rather broad, flat courses with a deep filling of muck and gravel. Prospect pits must therefore be rather deep, except very near the heads of streams, where concentration of the placer gold probably is not so great as farther down. If workable gold occurs at all on a stream, however, it should be found within reach of prospect pits at some places. Although a little prospecting has been done in this area without much success, the writer believes there is hope of finding pay gravel here.

EFFECT OF GLACIATION ON PLACER PROSPECTS

Prospectors should appreciate the fact that some ground in the Nixon Fork country which might otherwise be favorable for prospecting has been glaciated, as described on page 111. This process destroys in a great measure the chances of finding placer gold, because the glaciers gouge up, tear away, and scatter the loose gravel in which the gold has been concentrated. Here and there the prospector may dig through the coarse glacial gravel and find a small pocket of gravel that was not disturbed and may possibly contain gold, but this is a rare occurrence.

The glaciers occupied nearly all the granite area in the Sunshine Mountains and spread out to the north and east, so that it is not likely that placer gold in paying quantity will be found there, even if it ever existed. This same situation is believed to have existed north of Von Frank Mountain, although this region was not examined at close range.

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COAL IN THE NIXON FORK COUNTRY

Coal very likely occurs at some places in the Nixon Fork country in the shale and sandstone of the Upper Cretaceous and Eocene(?) rocks (pp. 107–110). These same rocks contain a number of thin coal seams in regions not far away. Mertie and Harrington[33] make the following statements about coal in near-by areas:

> Coal-bearing rocks of Cretaceous age occur at numerous places in the lower Yukon basin, and some small seams have been opened in them, but the demand for coal has been slight, and consequently development has not been intensive. * * *
>
> Coal has been found in a prospect hole sunk to a depth of 50 feet on Lower Poorman Creek. * * * Only a small quantity of the coal has been mined-at most a few tons. It is subbituminous, igniting with difficulty but burning readily after ignition.
>
> Maddren obtained information in 1910 from a prospector to tlie effect that coal had been found on Homestake Creek, in the Nowitna basin, at a depth of 46 feet, and that it also oC,curred at the head of the Nowitna.

A reliable person at the Nixon Fork mines made the following statement:

> There is a great deal of conglomerate on lower Hosmer Creek. It makes' a big hogback near the Nixon Fork. Behind this, up Hosmer Creek, is black shale, and at one place there is 6 inches of coal in the shale.

This is the only definite information regarding coal in the Nixon Fork country. Any coal that might be found would probably be inferior in quality to the good bituminous coals in the United States and not of more than local value.

POSSIBLE OCCURRENCE OF PETROLEUM

For the sake of the completeness of this report a few words on the possible occurrence of petroleum in the area may be appropriate. No oil seepages are known or reported in this area, and the geologic features indicate that oil is not likely to be found. The only rocks that might possibly contain oil are the sandstone and shale of Upper Cretaceous and Eocene(?) age (pp. 107-110). These rocks seem to have been deposited partly in shallow sea water, but chiefly in deltas and flood plains on the land near the sea. The beds change in thickness and lithology within short distances. Moreover, they have been much'folded and probably also faulted, and along the divide between Nowitna River and Nixon Fork they are cut by many masses of intrusive igneous rocks. These features are in general unfavorable to the accumulation of petroleum.

[33] Mertle, J. B., and Harringtoo, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 119–120, 1924.

SILVER-LEAD PROSPECTS NEAR RUBY

By JOHN S. BROWN

INTRODUCTION

When the writer was on the way to the Nixon Fork country in 1924 his attention was directed to some silver-lead lodes that were reported to be promising. A brief examination of the property was made in July. At the time of this visit no one else was there, and the principal workings were not accessible, but later one of the partners interested in the prospects, Mr. Harry Boland, supplemented the writer's observations with valuable data. Later in the season the writer was able to stop again at these prospects and make some further examination.

The prospects are on the slopes north of Beaver Creek, about 14 miles nearly due south of Ruby and about 2 miles east of the present "Fourteenmile" roadhouse. They were indicated on the geologic map in the report by Mertie and Harrington,[1] but that report contains no further information about them.

GEOLOGIC FEATURES

The prospects consist of lenticular veins of silver-bearing galena, partly altered to cerusite, accompanied by a large amount of iron, which has been found only as limonitic masses. The veins attain a maximum thickness of a few feet and lie parallel to the cleavage of the inclosing wall rock, which is chiefly a micaceous quartz schist, in some places black and slightly carbonaceous and in many places considerably veined by small quartz lenses and stringers. Associated with the schist are minor quantities of slaty and cherty rocks. The cleavage, as indicated by exposures about a quarter of a mile west of the prospects and in a tunnel at one of the prospects and by the strike of the ore leads, has a regional trend of about N. 25°-30° E. and a dip of 60°-80° SE. The walls of the tunnel show considerable jointing and probably slight faulting in a nearly horizontal direction. These rocks belong to the metamorphic series described by Mertie and Harrington.[2]

[1] Mertie, J. B., jr., and Harrington, G. L., The Rnby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pl. 3, 1924.

[2] Idem, pp. 14-17.

DEVELOPMENT WORK AND RESULTS

The plan of existing development work is shown in Figure 7. The first prospect. was found on the nose of a hill between a small ravine and the edge of the narrow flats of Beaver Creek. A slight escarpment, fairly steep and from 25 to 100 feet high, borders the flats and turns back up the west bank of the ravine. Along this escarpment float from the underlying schist bedrock is common, and

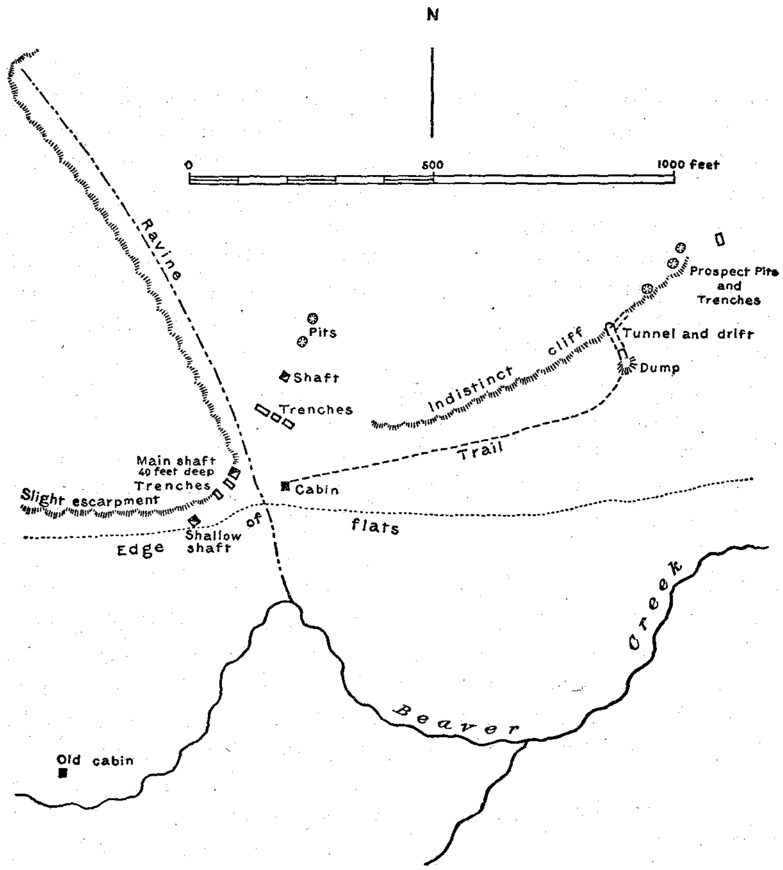


FIGURE 7.-Sketch map of silver-lead prospects near Ruby

exposures are found in places a few hundred feet to the west. Masses of limonitic cap rock carrying some galena were found on the surface and led to prospecting. A shaft 40 feet deep was sunk on the nose of the hill. This shaft is now nearly full of water. According to Mr. Boland the surface showing of mixed iron rock and galena was 15 feet wide, and at the bottom of the shaft the vein was 8 feet wide, with schist walls. The iron was completely oxidized and the lead partly so. The dump contains a few tons of are, more or less separated from the waste. It consists of lumps of limonite, the largest a foot or more in diameter, carrying irregular masses and stringers of galena and a small amount of scattered cerusite crystals. Black stains and powder, apparently oxides of manganese, are fairly common. Much of the material is porous and cavernous. Inclusions of irregular size, shape, and distribution of the schist wall rocks are common.

The best assay obtained from this material is said to have been 32 ounces of silver to the ton and a trace of gold. This and the other assays quoted are said to represent reasonably careful sampling of the entire vein and not merely picked or grab samples. Sampleso£ considerable size were cut and quartered and assayed by the Alaska station of the United States Bureau of Mines at Fairbanks.

Southwest of the shaft at intervalso£ about 30 feet are two hill-side trenches, several feet deep at the upper end. The trench nearest the shaft shows a ton or two of ore which is said to have assayed 26 ounces silver to the ton and is similar to that at the shart. The next trench showed no ore. A shallow shaft at the edgeo! the flat also showed no ore. This shaft contained much of a peculiar sandy slate, seamed by thin bands of limonitic matter along joints.

The bed Mthe ravine north of the shaft is filled deeply with muck and alluvium, but 150 feet away on a bearing of N. 25°-30° E. a shallow trench cut the continuation of the lead, which is said to have been thereabout 3 feet wide. The dump shows only a little mineralized material, which assayed 8 ounces of silver to the ton. Other diggings to the northeast, on the supposed line of strike, failed to find any trace of the lead. The hillside, however, is deeply covered by residuum, and bedrock is reached with difficulty.

This first lead was abandoned, and search was made for further outcrops. A single small piece of iron rock carrying some galena was found 800 or 900 feet northeast of the first outcrop at the foot of a faint cliff, much less distinct than the first escarpment but otherwise resembling it. A shallow excavation is said to have revealed three small seams of vein matter, only one of which carried any galena. These seams united at a depth of 8 or 9 feet to form a vein 4 feet wide. Down the hillside about 100 feet from this pit a tunnel was driven to crosscut the vein at a depth of about 40 feet. The lead was found, but only at the northeast side of the tunnel, and seemed not to extend to the southwest at that depth. A drift was driven to the northeast for 20 feet along the strike of the lead, which showed a thickness of 7 to 8 feet of vein matter, only a foot or two of which contained galena.

The dumps from the tunnel and from the open pit above both contain a few tons of ore, very similar at each place and not particularly different from that at the first shaft, except perhaps that the material contains less galena and proportionately more cerusite, much of it in long crystals. A trace of ruby silver was noted in one piece, separate from the galena. Copper stains are said to have been found, but the writer failed to recognize them in the material on the dumps.

The ore, especially that containing the most lead carbonate, is said to have been the richest encountered, one assay showing 82 ounces of silver to the ton for a width between 1 and 2 feet.

About 75 feet northeast of the surface opening a pit showed a mere trace of vein matter. A single small lump bearing galena was found on the dump. Other pits and trenches to the northeast failed to disclose any indication of ore. These prospect pits were all located on a bearing of N. 45°_60° E. from the first surface opening, and the writer questions whether they were well placed. Observations in the outer 50 feet of the tunnel, the remainder not being accessible, indicated that the strike of the schist and presumably of the vein was about N. 30° E., the same as that of the first vein and corresponding also to the regional strike of the schist as exposed farther west in the slopes north of Beaver Creek. As a drift was driven along the vein at the end of the tunnel, however, the strike of the lead should have been determined. Possibly the prospect pits should have been located somewhat farther northwest. The trace of ore in the first pit may represent not the main lead but another lead on an offshoot.

PROSPECTING

Prospecting in this region is difficult because of the thick overburden above bedrock and the lack of even float exposures. The writer searched the surrounding hill slopes to and beyond the next ridge to the northeast, from half a mileto a mile away, and found scarcely a piece of float rock. The slopes are covered mainly by a dense growth of tall redtop grass, which has occupied a considerable area of burnt birch and spruce forest. Fallen trees add to the mantle of vegetation, and the residual soil and muck beneath is at least several feet deep, except along the slight escarpment and the bench, indicated on the sketch, both of which have been searched carefully for signs of mineral. The operators propose constructing a ditch and sluicing off the overburden to expose the bedrock along a small stream nearly a mile to the northeast. Whether this would be worth while is questionable. No water is available in the vicinity of the prospects. The writer suggests that perhaps charges of dynamite placed at intervals several feet apart and as deep as necessary along a line cutting across the probable extension of a lead might be used to advantage in uncovering float material that would indicate the location of the ore body.

South of the prospects lie the flats of Beaver Creek, which are less than a quarter of a mile wide at most places. These flats are undoubtedly underlain by 25 to 100 feet of muck and alluvium. The country beyond for a mile or more is low and covered by moss and residuum, so that it would be difficult to trace the leads in that direction.

TRANSPORTATION AND SUPPLIES

The prospects are only slightly more than a mile at the nearest point from the Government road between Ruby and Long. A hill-side road on a reasonable grade could be constructed to them without unusual difficulty, although all road building in this region is expensive. Winter transportation is used mainly at present. Powder is said to have cost 50 cents a pound for the work already done, and other supplies are costly, though not unreasonably so for this region.

Wood for fuel and mine timbers is available in sufficient quantity at no great distance on the adjacent hillsides. Water under gravity head could hardly be obtained, but an adequate supply for all purposes could be pumped from Beaver Creek.

CONCLUSIONS

It seems that the veins constitute. small lenticular masses intercalated in the schist. From the nature of the oxidized ore it is probable that the unoxidized material consists of mixed carbonates and sulphides, probably galena and siderite, with some rhodochrosite (manganese carbonate), calcite, a trace of quartz, and possibly some pyrite. The upper, oxidized part has probably been somewhat enriched in silver both by the removal of other matter from the vein and by the carrying down of silver as erosion proceeded; Therefore, if the veins were followed down in depth they would probably contain less silver than at the surface, though possibly some spots might be richer than any surface ore yet discovered.

Most of the veins found are probably small and lenticular, pinching out within a short distance both laterally and vertically. New lenses of ore are often found,however, by following the line of probable continuation of such a lead, and larger ones may exist here and there.

Ore bodies of this nature.must be very rich in precious metals to repay the cost of prospecting and extracting. The quantity of galena is too small to be of any great consideration.' It is not impossible that an ore body large enough and rich enough to repay working would be discovered by further prospecting of the surface or by sinking to greater depth, but the chances are rather remote and hardly worth the risk by anyone who can not afford to lose if necessary considerable money. Nevertheless, it should be emphasized that most of the prospecting already done was justified by the surface showings, even though the results have been disappointing. Any similar outcrops of lead ore in the locality should be prospected sufficiently to determine their size and richness.

SUMMARY OF RECENT SURVEYS IN NORTHERN ALASKA

By PHILIP S. SMITH, J. B. MERTIE, Jr., and W. T. FORAN

INTRODUCTION

Early in 1923, shortly after President Harding ordered a tract of more than 35,000 square miles in northern Alaska set aside as a naval petroleum reserve, the United States Geological Survey, at the invitation and at the expense of the Bureau of Engineering, Department of the Navy, undertook surveys to map the reserve and to determine the geologic facts necessary for guiding the Navy Department in the proper administration of this Government property. Preliminary plans and estimates of time and cost for such surveys prepared by the Geological Survey called for five years' field work and an expenditure of approximately $500,000. A little more than two years has been devoted to this work, and the expenditures to the end of the fiscal year 1925 were about $140,000.

A combined geologic and topographic party which was sent into the field in 1925 continued surveys as late as possible and returned to Washington to work up the field notes and records during the winter. Because of the work which is still in progress and because a report of the work accomplished in 1923 has already been published, it is felt unnecessary to prepare an elaborate separate report of the results of the investigations carried on during the field season of 1924. However, so much interest has been shown in this little-known region that the following summary has been prepared, showing the present state of information (July, 1925) and presenting opinions regarding the possibility of finding oil in the region. Doubtless some of the suggestions will require modification when the results of the explorations made in 1925 are available, but even after the completion of these surveys parts of the reserve still require further examination before all the pertinent and available data are obtained.

GENERAL FEATURES

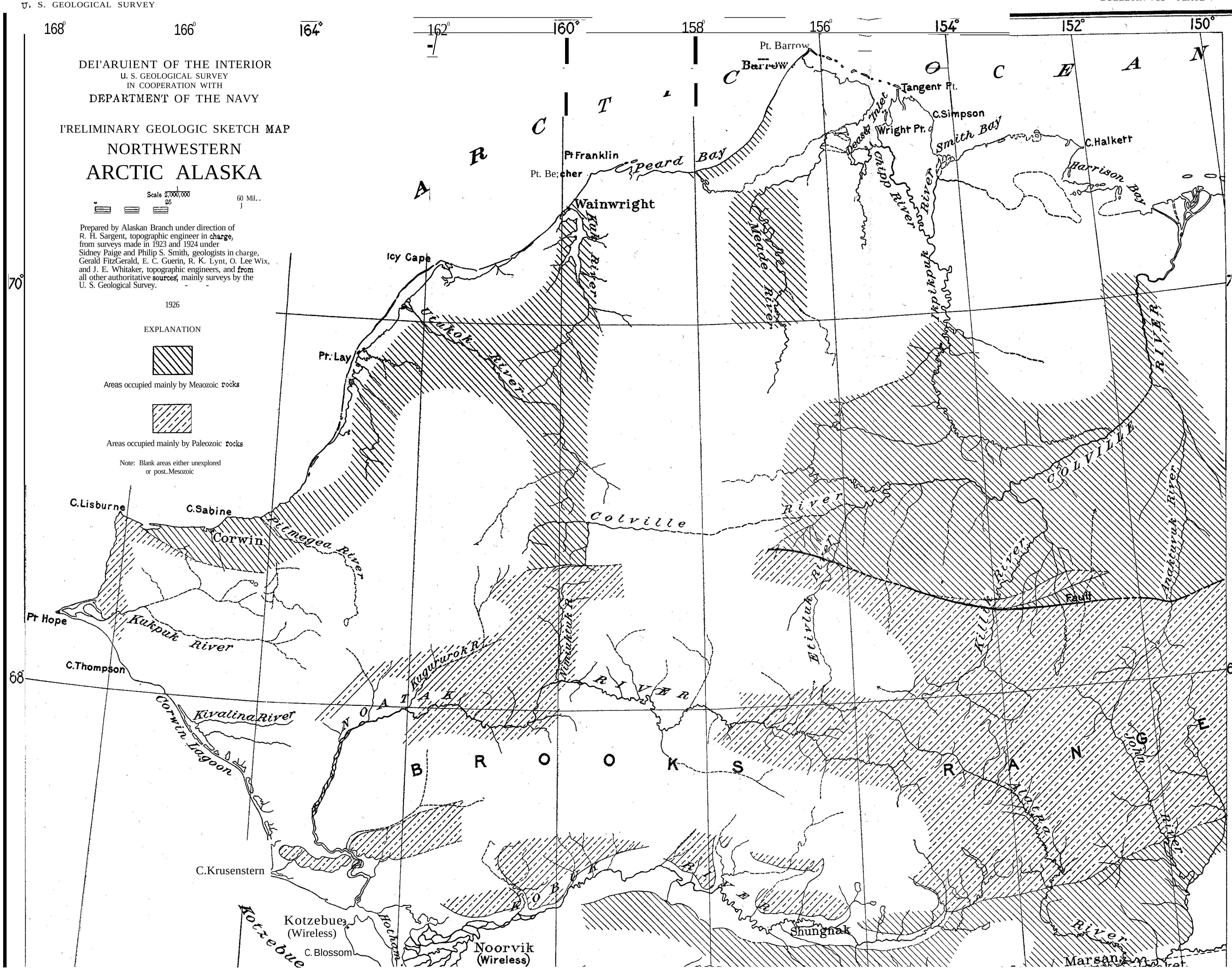
The general location of the reserve, which occupies a large tract in the extreme northern part of Alaska, and the contiguous country are shown on the accompanying sketch map (pl. 7). Topographically the area shown on the map is characterized by a mountainous belt 100 to 200 miles wide that extends in a general east-west direction and forms the western part of the Brooks Range, which crosses northern Alaska, eastward to the international boundary. These mountains are formed mainly of Paleozoic rocks that range from schist and metamorphic limestone to sandstone and slate. Both north and south of the Brooks Range are plateaus developed on later Mesozoic sedimentary rocks that stand 3,000 feet or less above the sea. North of the plateau region is a coastal plain, which is in places 50 to 75 miles wide but gradually tapers toward the west and ends near Cape Beaufort. The mountains closely correspond to the area indicated on the map as formed dominantly of the Paleozoic rocks; the plateaus are indicated by the areas occupied by the later Mesozoic rocks; and the coastal plain is indicated by part of the blank areas near the Arctic coast.

The region as a whole has very little precipitation; the average is less than 6 inches a year at Barrow and less than 13 inches at Allakaket. It has a long, cold winter and a short, warm summer. The mean annual temperature at Barrow is about 10° F. and at Allakaket about 18°. Owing to the low temperature the streams are usually frozen from the middle or later part of September until the later part of May. The ocean is blocked by ice for nearly ten months; in 1924 the first boat reached Barrow in August and the last boat that got out safely left, early in September. No regular lines of ocean transportation run to the region, and the vessels that go there belong either to the Coast Guard or to the Bureau of Education, or are owned or under charter by trading companies. Whaling vessels formerly visited these waters regularly, but now only a few come at infrequent intervals. No spruce or other large trees grow north of latitude 68°, and for a hundred miles south of that latitude trees are not plentiful, so that throughout most of the area the only bushes or shrubs are willows, the largest of them less than 15 feet high, and most of them ranging from shrubs 4 or 5 feet high to prostrate forms that rise only a few inches above the ground.

The entire region is uninhabited except for a narrow fringe near the coast and here and there along the larger rivers, where a few small trading posts have been established that are the homes of perhaps a score or two of whites and a thousand natives. Game is fairly abundant in the back country, where it has not been hunted in recent years by the natives or whites.

KNOWN OCCURRENCE OF PETROLEUM

That petroleum occurs in the reserve has been definitely proved. Under what conditions it originated or how much of it there is has not been determined. Many of the problems that must be solved


DEI'ARUIENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY
IN COOPERATION WITH
DEPARTMENT OF THE NAVY
I'RELIMINARY GEOLOGIC SKETCH MAP
NORTHWESTERN
ARCTIC ALASKA
Scale 2,000,000
60 Mil.
Prepared by Alaskan Branch under direction of R. H. Sargent, topographic engineer in charge, from surveys made in 1923 and 1924 under Sidney Paige and Philip S. Smith, geologists in charge, Gerald FitzGerald, E. C. Guerin, R. K. Lynt, O. Lee Wix, and J. E. Whitaker, topographic engineers, and from all other authoritative sources, mainly surveys by the U. S. Geological Survey.
1926
EXPLANATION
Areas occupied mainly by Meaozoic rocks
Areas occupied mainly by Paleozoic rocks
Note: Blank areas either unexplored or post.Mesozoic
168° 166° 164° 162° 160° 158° 156° 154° 152° 150°
70° 68°
ARCTIC OCEAN
Pt. Barrow
Barrow
Tangent Pt.
C.Simpson
Dease Inlet
Wright Pt.
Smith Bay
C.Halkett
Harrison Bay
Pt Franklin
Peard Bay
Pt. Be;cher
Wainwright
Kuk River
Meade River
Chipp River
Ikpikpuk River
Icy Cape
Utukok River
Pt. Lay
Colville
River
COLVILLE RIVER
Anaktuvuk River
Killik River
Etivluk River
Fault
C.Lisburne
C.Sabine
Corwin
Pitmegea River
Pt Hope
Kukpuk River
C.Thompson
Kivalina River
Corwin Lagoon
Kugururok R.
Nimiuktuk R.
NOATAK RIVER
BROOKS RANGE
John River
Alatna
C.Krusenstern
Kotzebue (Wireless)
Kotzebue
C.Blossom
Hotham
Noorvik (Wireless)
KOBUK RIVER
Shungnak
River
Margan

before commercial development can be undertaken on a sound basis of fact must therefore await the collection of more complete data.

The only direct evidence of the occurrence of petroleum in the reserve is found in the vicinity of Cape Simpson, where two distinct seepages of petroleum occur. These seepages were first reported in publications of the United States Geological Survey by Brooks,[1] who in 1908 noted them on the authority of Leffingwell. Leffingwell[2] apparently did not visit the seepages either at that time or later but based his statements on information given to him by natives and later by Stefansson. He did, however, obtain a sample of the residue collected for C. D. Brower by natives, and this material was analyzed by David T. Day.

In 1921 this region was visited during the open season by geologists and others in the employ of an oil company, and numerous claims were staked.

In 1923 a Geological Survey party visited this region, and the following statements appear in the published report of that expedition:[3]

> A low moss-covered ridge of irregular shape stretches for 2 miles along the Arctic Ocean, its southeast terminal about a mile northwest of Cape Simpson. Its highest point is about 50 feet above the sea. Seepage No. 1 occurs near the inland base of this ridge, a third of a mile from the ocean and 20 feet above tidewater, from which it is visible. Here in an irregular area several hundred feet in diameter the moss is soaked with petroleum, which also slowly seeps from the gentle slope.
>
> Seepage No. 2 is on the southern top, 40 feet high, of a small double knob 3 miles almost due south of seepage No. 1 and 1¼ miles west of Smith Bay. Here the residue from the seepage covers several acres.
>
> The main petroleum flow moves southward down the slope for 600 or 700 feet to a lake. This active channel is 6 to 10 feet wide, though the area covered by residue is several hundred square feet and indicates that a considerable flow is coming from this seepage. The ridge at these two seepages is covered with moss and muck, and there are no surface indications that it is made up of hard rock. In surface form the ridges are not different from others elsewhere that appear to consist of Pleistocene alluvium, but shallow excavations at these localities reveal an aggregate of angular shale débris and clearly prove that hard rock is near the surface and that the ridges are the result of the erosion of bedrock and not of alluvium.

Seepages have also been reported and claims staked by representatives of oil companies in 1921 on Meade River as far south as that stream was surveyed by the Geological Survey in 1923 and possibly even a few miles farther. Although copies of the maps made by the representatives of the oil company, showing these

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[1] Brooks, A. H., The mining industry in 1908: U. S. Geol. Survey Bull. 379, pp. 61–62, 1909.

[2] Leffingwell, E. de K., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, pp. 178–179, 1919.

[3] Paige, Sidney, Foran, W. T., and Gilluly, James, A reconnaissance of the Point Barrow region, Alaska: U. S. Geol. Survey Bull. 772, p. 23, 1925.

reported seepages, were in the possession of the Survey geologists and the places where the seepages were indicated were examined with special care, none of these places proved to contain real seepages or showed any definite indications of petroleum. The signs that apparently have been interpreted as indicating seepages proved in all places, when examined critically, to be films of iron oxide on stagnant pools which, when stirred, broke up into irregular patches that did not readily unite again like oil. These films were seen on a number of pools in the basins not only of Meade River but also of the Colville and the Ikpikpuk and unless carefully examined might prove misleading.

Claims have also been staked on reported oil seepages midway between Barrow and the head of Peard Bay. The coastal part of this area was examined by Paige in 1923, but here again the only signs which might be mistaken for indications of the presence of petroleum were films of iron oxide. The rather high ground in this region suggested the possibility of a structural fold there which might be favorable for the accumulation of petroleum, and the Survey geologists report that the beds apparently do form a low flexure. In spite of the apparently favorable structure, however, no indications of petroleum were seen, and the natives, who traverse much of that part of the region in caring for their herds of reindeer and who are especially observant of most natural phenomena, do not know of any seepages or other indications of petroleum in that whole region.

Petroleum seepages about midway along the southern shore of Teshekpuk Lake, have also been reported, but these were not visited by any of the Survey geologists and nothing definite was learned about them. Seepages in the area east of the Colville have also been reported, but secrecy as to their location has been maintained by those who reported them, and most of the rumors appear to have been circulated by other than those who are supposed to have actually seen the occurrences.

CHARACTER OF THE OIL

The only samples of oil from the naval reserve that have been tested by the Government were collected at the seepages near Cape Simpson. These samples were taken from the surface, where the oil had become weathered and many of the lighter, more volatile parts had probably escaped, so that the true character of the fresh oil is not known. Apparently the oil has a naphthalene base and is rather low in sulphur. According to Paige, it appears to be comparable with the oil obtained in the Blue Ridge field of Texas. The following results were obtained from tests made by the Bureau of Mines on the samples collected by Paige in 1923:

Results of tests of oil sample No. 28510, from Naval Petroleum Reserve No. 4, Alaska

[Seepage at surface collected by United States Geological Survey August, 1923; analyzed by United States Bureau of Mines]

Specific gravity, 0.943; A. P. I. gravity, 18.6°.

Sulphur, 0.36 per cent; water, 7.5 per cent.

Saybolt Universal viscosity at 70° F., 5,160 seconds; at 100° F., 1,370 seconds. Pour point, below 5° F.

Distillation. Bureau of Mines, Hempel method

[Vacuum distillation at 40 millimeters]

Temperature (° C.)	Per cent cut	Sum (per cent)	Gravity		Viscosity at 100° F.	Cloud test (° F.)	Temperature (° F.)
			Specific	A. P. I. (°)			
Up to 200	13.6	13.6	0.894	26.8	34	Below 5	Up to 392.
200-225	10.2	23.8	.920	22.3	68	do	392-437.
225-250	9.0	32.8	.923	21.8	116	do	437-482.
250-275	10.5	43.3	.931	20.5	240	do	482-527.
275-300	10.7	54.0	.936	19.7	Over 400	do	527-572.

Carbon residue of residuum, 4.9 per cent.

Approximate summary

	Per cent	Gravity		Viscosity
		Specific	A. P. I. (°)	
Gasoline and naphtha				
Kerosene distillate				
Gas oil	12.5	0.892	27.1	
Nonviscous lubricating distillate	12.7	.906-.922	24.7-22.0	50-100.
Medium lubricating distillate	9.7	.922-.928	22.0-21.0	100-200.
Viscous lubricating distillate	19.1	.928-.939	21.0-19.2	Above 200.

Results of test of petroleum residue from Alaska, sample No. 23508

[Extraction with benzene]

	Oil (per cent)	Sulphur (per cent)	Specific gravity
Sample marked "dried"	44.5	0.55	1.014
Sample marked "undried"	62.0	.47	.971

As a qualitative test by the Holde-Mueller method[4] showed that only a comparatively small part of the oil was precipitated as asphalt with excess of petroleum ether, it would appear that the unusually high viscosity of the sample is not due to an appreciable extent to the presence of asphalt. Although no chemical study of the oil has been made, it seems probable that the high viscosity may be due to the presence of a large proportion of naphthalene hydrocarbons, a view supported by the general appearance of the sample, its low sulphur content, and the small percentage of carbon residue of the residuum.

[4] Holde, D., Hydrocarbon oils and saponifiable fats and waxes, 2d ed., transl. by Edward Mueller, p. 105, 1922.

The tests indicate lubricant values in the weathered oil, which in fact appears comparable in Baumé gravity, sulphur content, viscosity, and distillation tests to the oil obtained from shallow wells in the Pliocene rocks of the Blue Ridge field, in Texas.[5]

Beyond doubt light hydrocarbons have escaped from the surface seepage, though evaporation in the Arctic climate may not have been so rapid and may not have taken place at so high a temperature as in the better-known regions in lower latitudes. It is to be remembered, however, that the climate of this region is dry. On the whole, therefore, while it is difficult on the basis of the above tests to predict the composition of the unweathered oil, it is practically certain that the oil contains some of the lighter hydrocarbons. It will be seen that 13.6 per cent of the sample was distilled off under 200° C. at a pressure of 40 millimeters.

The expectation that the oil from wells at depth will be of value for its lighter hydrocarbons, as well as for use as lubricants and fuel, is likely to be fully confirmed. At Blue Ridge, Tex., already mentioned, lighter oils are found in the same field at greater depths.

SUGGESTIONS REGARDING PROBABLE SOURCE OF THE OIL

From the foregoing statements it is evident that there is very little specific information on which to base broad generalizations regarding the possibility of obtaining much oil in the region. The only definite facts are those that relate to the seepages at Cape Simpson. Even there, however, observations are not in entire accord, for Paige states that "the material exposed in shallow beds is sandy and calcareous shale whose structure can not be definitely determined, but it appears to be practically horizontal." H. A. Campbell, a geologist of an oil company, who also notes that the lack of sufficient rock exposures makes it practically impossible to determine the structure, states that the dip of the only beds that may be in place was 80° SE.-that is, nearly vertical. Philip S. Smith reported that he saw no indisputable indications of rock in place, although he spent very little time in the vicinity of Cape Simpson and therefore felt that he was not warranted from direct observation in making even a surmise as to the probable structure and specific character of the underlying hard rocks.

In spite of the absence of indisputable evidence, the following inferences regarding the occurrence of oil near Cape Simpson may be made with considerable probability of correctness. One of the most significant conclusions is that the oil does not originate in the mantle of unconsolidated deposits that forms the surface covering of the coastal plain. Among the reasons for this belief is the fact that this mantle is apparently rather thin, and nowhere in any of the exposures of this formation that have been examined are there any con-

[5] Smith, N. A. C., Banes, A. D., and LeJenne, N. F., Properties of typical crude oils from the producing fields of southern Louisiana and southern Texas; Bur. Mines Repts. Inv. 2416, p. 39, November, 1922.

siderable accumulations of organic m9terial which might have been capable of furnishing an appreciable amount of petroleum. All the geologists who have worked in this region believe that the source of the oil is to be sought in the underlying bedrock. Whether or not the bedrock is exposed near the seepages at Cape Simpson is relativelyimmaterial, for. all the geologists who have seen the region agree that the bedrock is probably the same as that which is exposed at many places along Meade River, as shown by the explorations conducted by the Paige expedition in 1923, or that which is exposed along Ikpikpuk and Colville rivers, according to the observations made by the parties of the Smith expedition in 1924.

The formation on Meade River, according. to the paleontologic information now available, is referred to the Jurassic, whereas the beds exposed in the Colville and Ikpikpuk are Upper Cretaceous. The geologists, however, have not been able to diffentiate these formations in the field, so that the distinction has been made solely on paleontologic grounds. Lithologically they appear to be identical, and their mode of formation and subsequent history appear to have been the same. Whether these beds really represent two distinct formations is of considerable economic significance, however, and further work should be done to establish the facts.

The present inability to differentiate the two formations by other than paleontologic criteria has necessitated the description of their general characteristics together. These rocks throughout the greater part of the region consist of sandstone and shale that were deposited in relatively shallow water. Over a large area, however, these rocks have been laid down apparently in swamps and in shallow seas in relatively quiet water. Large accumulations of vegetable matter, now represented by coal beds, were formed contemporaneously with the sand and shale. In the lower and higher members of the later Mesozoic rocks less deposition took place upon and near the land and more in shallow marine waters, as is shown by the marine shells that have been discovered in these beds at many places. On the whole,. the conditions that prevailed while the coal-bearing .portions of the formations were being deposited do not seem to have been favorable for the production of extensive deposits of oil. The accumulation of the organic remains of animals in the higher and lower sandstones might be regarded as favorable material for the origin of petroleum, but nowhere was evidence found of any considerable mass of this organic material.

However, on Etivluk River, a tributary of the Colville, fragments of true oil shale were found, but as these fragments were. not in place, the stratigraphie position of this shale is not accurately known. Furthermore, the structure of the general region where the oil-shale float was found is complex and. is subject to various interpretations.

This shale is exceptionally rich, and specimens of it have been critically studied by David White, the foremost authority on microscopic examination of oil shales. He says regarding the specimen of float submitted:

Examination of thin sections of this specimen under the microscope shows that the rock is made up very largely of the flattened exines of a single type of large megaspore. These exines appear as collapsed or entirely flattened thick golden-yellow bands. The specimen in its fossil constitution is so remarkably similar to tasmanite that no violence would be done in calling it by that name, although the megaspores may have been produced by a different plant and the chemical composition may differ somewhat from that of the material from Tasmania described under the above name. Rough test-tube tests of the material, which is readily combustible, indicate rather copious condensation of hydrocarbon gases in the form of viscous distillate.

Typical tasmanites have yielded on distillation tests an average of as much as 70 gallons of oil to the ton of rock.

The material described above may be the same as that noted by Ensign (now Rear Admiral retired) Howard in his remarkable exploratory trip through part of the region in 1886. He described a material found on the Etivluk as "a substance called wood by the natives. It was hard, brittle, light brown in color, very light in weight, and burned readily, giving out quantities of gas. This material was scattered about in all shapes and sizes and quantities." Later this material was considered by Martin[6] to be probably a petroleum residue. The party of 1924 probably did not visit the exact locality noted by Howard in 1886, but in view of the similarity in physical character between Howard's material and that obtained in 1924 and in view of the optical determination by David White the interpretation that this material is a rich oil shale and not a petroleum residue seems to be warranted.

If an oil shale similar to the specimen collected occurs in the later Mesozoic strata it could furnish an adequate source for a considerable volume of oil. A flat-lying bed 1 foot thick contains about 1,000,000 tons of rock to each square mile, and the equivalent amount of oil it would contain may be computed by multiplying this tonnage by the oil content of a ton of oil shale. In view of the extremely doubtful quality of many of the factors of the problem when applied to the specific field here considered, it does not seem advisable to carry out the foregoing arithmetical process to a conclusion, for such a result would appear to have a definiteness far more specific than the facts on which it is based would warrant. The foregoing analysis is given only to show that apparently an adequate source of a considerable volume of oil is suggested by the field observations.

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[6] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 69-70, 1921.

Some further conclusions may be drawn from acceptance of the assumption that this oil-shale float is really part of the stratigraphie 'sequence and belongs in that sequence rather near the place where theftoat was found. From these assumptions and from theobservations regarding the general structure and stratigraphy of the region it follows that the oil shale must lie fairly well down in the later Mesozoic succession and that consequently it might underlie a considerable part of the reserve north of the latitude of the place where the float was found on the Etivluk. If this conclusion is correct it implies that north of this line, where physical conditions are favorable, there is a reasonable source from which oil may be derived. True, this source maybe too deeply buried to produce deposits of oil within reach of the drill, and the bed may not have been subjected to those earth processes whereby oil was expressed from ,the shale. Furthermore, nothing is yet known that indicates that this oil shale is not a distinctly local deposit, without widespread distribution, either laterally along the strike or along the dip. In spite of these uncertainties, however, it is believed that the original conclusion holds true, for, although interrupted and in places even reversed; the general dip of the b,eds of the region as a whole to the north of this latitude seems to be northward, so that oil or any other liquid would tend to migrate in that direction.

Another conclusion that may be drawn from the assumptions already made regarding the fragments of oil shale is that any oil that might be derived from it will practically be limited to the later Mesozoic sediments lying north of the mountain mass. Certainly the oil shale that has been found is younger than any of the Paleoz.oic or Upper Triassic rocks that have been s'een in the mountain area. Therefore,even if theftoat has moved some distance from its parent ledge, it must almost certainly have come from the area north of the east-west line (see pI. 7) that marks the southern boundary of the later Mesozoic rocks. This statement does not deny the possibility that there maybe infolded orinfaulted patches of later Mesozoic rocks within the area that is reported to be dominantly Paleozoic. In fact, the authors.strongly suspect that there are such areas. It does, however, imply that any such areas are relatively small, are more or lessisolated,andhave a synclinal rather than an anticlinal structure.For all these reasons, therefore,·these areas probably do 'not have much significance with respect to the occurrence of oil. Furthermore,later Mesozoic beds lying within the Paleozoic-Upper Triassic area are in all probability' duplicated to the north of the boundary between the later Mesozoic and older beds, where the folding, faulting, and deformation which the region has undergone first bring in the more continuous sequence of later Mesozoic rocks.

This conclusion is worthy of being carefully tested, for if correct it indicates that prospecting for oil within the Paleozoic area is unwarranted, and furthermore that if test drilling is done in the Mesozoic area to the north of this boundary it should be discontinued when the rocks older than the later Mesozoic are encountered.

In the foregoing paragraphs the assumption is made that the source of the oil is in the later Mesozoic beds in a rock similar to the oil-shale float found on the Etivluk. Before accepting the conclusion based on this assumption as ruling out of consideration search for oil in any of the areas occupied by the Paleozoic and Upper Triassic rocks, it is necessary to consider the possibility that such rocks might in themselves have been a source for oil. So far as is shown by the evidence that has been obtained from any part of Alaska, none of the Paleozoic rocks anywhere in the Territory have shown indications that they have been the source of petroleum. Careful examination of the exposures of Devonian and Carboniferous shales and sandstones and the Upper Triassic chert, wherever seen within the reserve, disclosed nothing even suggestive of the presence of petroleum. The Lisburne limestone, of Mississippian age, which is exposed north of the Brooks Range, from Schrader's section on the Anaktuvuk[7] westward to the area studied by Smith and Mertie and still farther west to the tract traversed by Foran, has in places a petroliferous odor that justifies inquiry as to whether the limestone may not be a source of oil.

The direct answer to this inquiry is that, to the best of the writers' judgment, this limestone is not the source of the oil. The correctness of this belief can not be demonstrated, for it is based solely on negative evidence and as such may be overthrown by the discovery of positive evidence. The composition of the limestone is such that it undoubtedly was at one time rich in organic matter, which might have yielded petroleum. That this organic matter did not yield petroleum, however, is strongly indicated by the fact that nowhere are any oil seepages found near the limestone, though it has been examined at many places along the hundreds of miles of its extent through Alaska. Practically every limestone that has not been intensely metamorphosed or recrystallized has a petroliferous odor on freshly fractured surfaces, so that this feature of the Lisburne limestone in this region is not unique. However, even if the Lisburne limestone is the source of the oil, its texture is such that it does not form a good rock to store much oil, so that any oil emanating from it would be likely to migrate into the overlying, more porous rocks for storage.

In the region traversed by the parties of the expedition of 1924 no rocks were recognized that were laid down in the interval between

[7] Schrader, F. C., A reconnaissance in northern Alaska in 1901: U. S. Geol. Survey Prof. Paper 20, 1904.

the deposition of the Lisburne limestone and the overlying Upper Triassic chert' and that of the Jurassic or Cretaceous beds. Whether no rocks were laid down north of the Brooks Range during this interval-that is, whether the region was then a land surface-or whether rocks were laid down during this period and subsequently removed by erosion can only be conjectured and in a measure is, immaterial for the purpose of the present analysis. Only oil that was expressed from the lower rocks after they were covered by the later Mesozoic rocks which now remain would be preserved. Therefore, for all practical purposes, the distribution of such oil would be nearly the same as that already outlined for oil derived from the assumed source in the oil shale-namely, in the area north of the boundary between the Paleozoic-Upper Triassic sequence and the later Mesozoic beds. True, if the oil were derived from the Lisburne limestone it might be found at somewhat greater depths than if it were derived from a shale member in the later Mesozoic beds, but as no specific position has been assigned to this shale member, this difference in depth is practically negligible in the present discussion. This consideration leads to a repetition of ,the statement made earlier in this report that search for oil south of the Tocks older than the later Mesozoic or drilling below the contact of the later Mesozoic and the older beds north of the Brooks Range is not warranted by the evidence in hand.

OCCURRENCE OF STRUCTURE FAVORABLE FOR THE ACCUMVLATION OF OIL

In addition to the necessity of finding a probable source for the oil, it is essential in attempting to determine the probability of the existence of commercial deposits that there should be suitable structural features and that the rocks should have texture competent to induce the accumulation of oil and should be capable of retaining the oil thus trapped. So far as is shown by the studies which have been made, the later Mesozoic rocks of the region are folded into a number of anticlines or domes, which are features everywhere regarded as favorable for causing the accumulation of oiL The pressure that has produced these features resulted in relatively close folding in the area near the mountains, and this area is succeeded northward by one in which the folding is more open, and this in turn is succeeded nearer the Arctic coast by an area in which the beds are still more gently arched.

Close to the south margin of the later Mesozoic area there isevidence that some of the beds have been overturned, and in the section made by the central party of the expedition of 1924 on the Etivluk the dips of the lowest later Mesozoic rocks' are almost verticaL Under these conditions the structure is not favorable for the accumu-

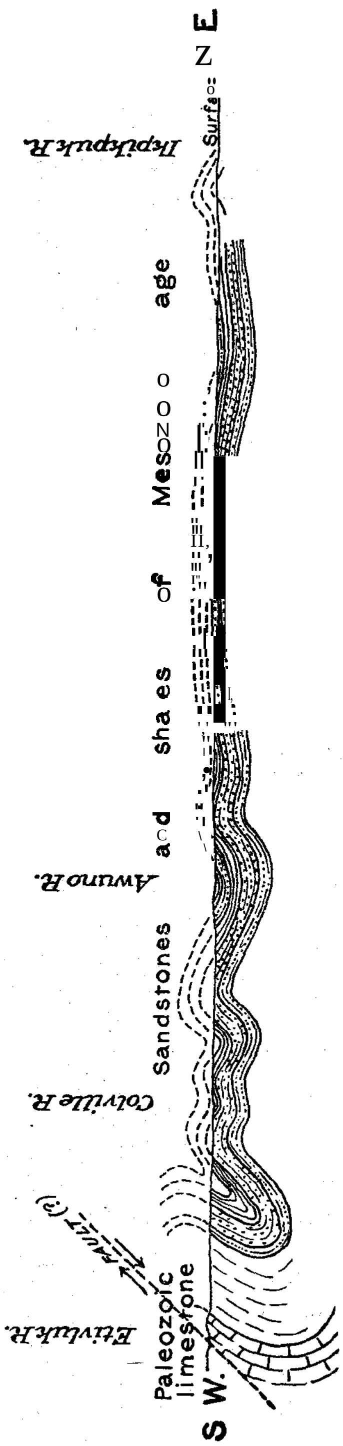

FIGURE 8.—Generalized cross section of northern Alaska from Etivluk River to Ikpikpuk River

lation of oil, but elsewhere, at many places to the north, folding of the rocks seems to be favorable. The general favorable character of the folding does not at all imply that favorable structure is everywhere present. As is well known, in a region of folded rocks folds that are convex upward (anticlines) are separated from one another by folds that bend in the opposite direction (synclines) or by unfolded rocks, and it is on the flanks of the anticlines that valuable oil pools are most likely to be found. A generalized structure section (fig. 8) from the area near the central part of the Etivluk to the most northern exposures on the Ikpikpuk shows the larger structural features observed in the area studied and confirms the statement already made that favorable structures have been noted in widely separated parts of the reserve.

It is perhaps pertinent to suggest that the folding which has been observed may have had an important effect in expressing oil from any oil-shale involved. The folding and deformation of a great series of beds, such as the later Mesozoic in this region, inevitably produced considerable heat or pressure, which are the means employed in the commercial extraction of oil from oil shale in the laboratory or in a manufacturing plant. Where the pressure or heat was intense, the oil may have been driven far from its original source before it reached rocks which were cool enough or which afforded sufficient relief of pressure for it to condense, but in regions where the pressure was less or the temperature was lower it may not have escaped far from its original source. It is therefore in the moderately folded rocks in this area that the best accumulations of oil are to be expected.

The porosity of the later Mesozoic rocks is on the whole favorable for the retention of oil that may have originated in or near them. As already pointed out these rocks are dominantly sandstone and shale. The sandstones have fairly open texture and considerable pore spaces. They are interbedded with shales that could seal in any gas or oil that might be present and prevent the rapid vertical escape of these substances. Therefore, although the sandstones allow the lateral migration of liquids in response to hydrostatic or other pressure incident to the folded structure of the rocks as a whole, the escape of these valuable liquids to the surface is impeded or reduced to a minimum by the intercalated nearly impervious shales.

NEED FOR FURTHER INVESTIGATIONS

In endeavoring to present a fairly consecutive and definite statement of the beliefs now held regarding the possibility of the presence of petroleum in the reserve, the writers have possibly minimized the importance of things not now known and perhaps have seemed to place undue emphasis on some of the observed facts. The foregoing pages, however, should not mislead anyone into too ready acceptance of the tentative conclusions suggested. In fact, the writers feel that the suggestions above presented are really challenges to accumulate more facts and to scrutinize these new facts as well as the old observations most critically. There still remain large areas that have not been visited at all, and there is no assurance that even in the regions that have been reconnoitered all the significant facts have been observed. The first thing to be done, therefore, in continuance of the studies already made, is to explore the country still more thoroughly and collect all the additional data that are available.

This need has been met in part by a survey that was carried on in 1925 by Gerald FitzGerald, topographer, and Walter R. Smith, geologist. As a result of this work most of the now unsurveyed areas in the western part of the reserve and adjacent territory should be mapped topographically and geologically.

There still remains the need of traverses in the coastal-plain region between the Ikpikpuk and Colville, including especially the country adjacent to Teshekpuk Lake and some of the country adjacent to Meade River that was not covered by the explorations of the FitzGerald party of 1925. The writers, however, do not feel very optimistic that such traverses will yield many significant geologic data relating to the probable occurrence of oil, because much of the region is doubtless covered with unconsolidated deposits of late geologic age, which effectually mask the underlying bedrock. Observations of structure will therefore probably be few and far between and not adequate to serve as a basis for a reliable interpretation of the structure of the region. For this reason the writers believe that the next step in determining the possibility that the reserve may contain extensive deposits of oil should be to drill test holes at selected localities. Such test holes need not be very deep and could probably be made with a light drill rig that could be moved around the country rather easily, especially while snow and ice are on the ground.

Apparently the place that should be tested first by drilling is in the vicinity of the oil seepages at Cape Simpson. This place is especially suitable, for it is accessible from the sea and is the place where petroleum is actually known to occur. It is, of course, entirely probable that the petroleum at the seepages has migrated some distance from its original source, but by keeping a careful log of the drilling many significant facts would be learned that would direct further drilling and exploration. A competent geologist should keep in close touch with the drilling so that a complete record of the rocks penetrated, based on samples taken carefully and at short intervals, can be made. After a detailed and comprehensive section is constructed from the drill records, further traverse of the region would undoubtedly yield more practical results than if it were made in advance of such drilling. At that time probably not only scouting through certain of the areas suggested above but also through others that might be indicated by these records would be desirable. For instance, further search for the horizon of the oil shale on the Etivluk should be made, and when this horizon is found it should be traced throughout its extent.

SPECIAL PROBLEMS OF DEVELOPMENT

Although a discussion of some of the broader economic principles regarding the actual development of oil fields does not fall within the main province of the geologist and it may seem premature to discuss the development of a field not yet proved, it does seem desirable to summarize some of the features of Naval Petroleum Reserve No. 4 which make the problem of developing oil in this region unique and which therefore might be overlooked by a mining engineer or promoter, who necessarily approaches the problem first in his office, remote from the field and with only the experience gained in more accessible oil regions.

Many of the unusual conditions have been touched upon in the early pages of this report dealing especially with the general features of the region. Attention was there briefly called to the accessibility, climate, timber, and other features, which take on added significance when considered in their relation to the economic problem of developing a productive oil field in the region. Take, for instance, the matter of accessibility. It has been shown that vessels can not reach Barrow until after the first of August and should be out of that region early in September and that even during this short period they run the hazard of being caught in the ice and lost. Furthermore, there are no harbors for ocean-going vessels for several hundred miles. Vessels must lie in the open roadsteads and can not approach close to the shore, and their cargoes can be taken off or discharged only by lighters or by special arrangements which can be easily removed so as not to be destroyed by ice. Under these conditions it seems extremely unlikely that any considerable quantity of petroleum can be moved by vessels. This conclusion has added weight when the problem is viewed in relation to national defense, for it seems essential that to be effective in time of war the supply of oil must be quickly available at all times and not subject to seasonal obstructions.

Apparently, therefore, a pipe line or railroad would be required to move any material tonnage of oil. A pipe line from the reserve to an ice-free harbor would probably have to be 1,000 miles long. Through half of this distance even trails, on which all supplies and materials would have to be hauled, are lacking, and for a third of the distance there is not even timber enough to build shelters for the workmen. Then, again, the extreme cold will give rise to many new problems in the transportation of oil that will require thorough technical analysis before plans can be prepared for a suitable pipe line with its required heating and pumping stations.

The extension of a railroad through this region would encounter some of the same difficulties as those attendant on the construction of a pipe line and would also face others inherent only to railroads. The writers can not give any close estimate as to the cost of building a railroad into the reserve. Statements of the cost of the construction of the Alaska Railroad are of course available and may serve as a guide for conjecturing the cost of an additional 500 to 600 miles of railroad to reach the reserve.

One other aspect of the problem of development and also one on which geologists can not venture an expert opinion is the adequate safeguarding of the oil in transit if it is to be used for national defense. It is apparent that if this region is developed as a source of oil for the Government adequate protection will necessarily have to be provided, not only for the ocean terminal and for the producing field but also for the long stretch of unsettled country between, through which the oil will have to be transported by pipe line or railroad. This will be a difficult as well as an expensive task, and therefore the cost must be considered as one more proper charge against the prospective operation of an oil field in this region.

The difficulties set forth above have not been enumerated with the idea of deterring development of oil in this region but rather to indicate the magnitude of the oil fields that must be found if these large items of equipment and development are to be amortized by the production of oil. In this region a field capable of yielding a few million barrels of oil may, for all practical purposes, be regarded as of no present importance. The stakes are therefore high, and the risks are grave and the expenses enormous. As a matter of public policy, if this field is not developed by the Government itself, it seems little short of criminal to impose on private enterprises that may attempt development laws and restrictions that are entirely appropriate for oil fields in Oklahoma or California. In order that the uncertainties, the risks, and the costs in the two regions should be at all comparable it is probably no exaggeration to say that the prize played for in northern Alaska should be at least 10 times that required under the same conditions in the States. In fact, it would probably be sound public policy, before granting prospecting permits or leases for oil on the unappropriated public lands in northern Alaska, to require an acceptable showing of adequate financial backing and of sound methods of marketing the product. The region is most assuredly not one where anybody can get rich quick in oil without enormous expenditures of capital for development, and no one should risk funds whose loss will seriously embarrass him, because development of oil in this region is distinctly a wildcat undertaking of the most speculative character, and at the same time the development can be successful only if undertaken on a large scale.

INDEX

SELECTED LIST OF SURVEY PUBLICATIONS, ON ALASKA

[Arranged geographically. A complete list can be had on application]

All these publications can be obtained or consulted in the following ways:

1. A certain number of copies are delivered to the llirector of the Survey, from whom they can be obtained for a limited period free of charge (except certain maps) on application.

2. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at the price indicated. No copies' are available of those marked with an asterisk (*) ; they may be consulted at many public libraries.

3. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they call be consulted by those interested.

The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order for maps amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

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*The geography and geology of Alaska, a summary of'existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U.Goode. Professional Paper 45, 1906, 327 pp.

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The mining industry in 1905, by A. H. Brooks. In Bulletin 284, 1906, pp. 4-9. 25 cents.

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The mining industry in 1907, by A., H. Brooks. In Bulletin 345, 1908, pp. 30–53. 45, cents.

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The future gold-placer mining in Alaska, by A. H. Brooks. In Bulletin 622, 1915, pp. 69-79. 30 cents.
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Tertiary flora of Alaska, by Arthur Hollick.

Igneous geology of Alaska, by J. B. Mertie; jr.

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Map of Alaska (A) ; scale, 1: 5,000,000; 1920, by A. H. Brooks and R. H. Sargent. 10 cents retail or 6 cents wholesale.

*Map of Alaska (B); scale, 1: 1,500,000; 1915, by A. H. Brooks ami R. H. Sargent.

Map of Alaska (C) ; scale, 1: 12,000,000; 1916. 1 cent retail or five for 3 cents .holesale.

Map of Alaska showing distribution of mineral deposits; scale, 1: 5,000,000; by A. H. Brooks. 20 cents retail or 12 cents Wholesale. New editions included in Bulletins 642 (35 cents), 662 (75 cents), and 714-A (25 cents).

Index map of Alaska, including list of publications; scale, 1: 5,000,000; by A. H. Brooks. Free on application.

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Map of Alaska (E) ; scale, 1: 2,500,000; 1923, by A. H. Brooks and R. H. Sargent. 25 cents retail or 15 cents wholesale.

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*Tin deposits of the Ruby district, by Theodore Chapin. In Bulletin 692, 1919, p.337.

*The gold and platinum placers of the Tolstoi district, by G. L. Harrington. In Bulletin.692, 1919, pp. 338-351.

*Placer mining in the Tolovana district, by R. M. Overbeck. In Bulletin 712, 1919, pp. 177-184.

*Mineral resources of the Goodnews Bay region, by G. L. Harrington. In Bulletin 714, 1921, pp. 207-228.

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The Ruby-Kuskokwim region, by J. B. Mertie, jr., andG. L. Harrington. Bulletin 754, 1924, 129 pp. 50 cents.

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The Nixon Fork country; Silver-lead prospects near Ruby; papers by J. S. Brown. In Bulletin 783, 1926, pp. 97-150. Free on application.

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Geology of Fairbanks and Rampart quadrangles,by J. B. Mertie, jr.

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Circle quadrangle (No. 641); scale, 1: 250,000; by T. G. Gerdine, D. O. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also in Bulletin 538, 20 cents.

Fairbanks quadrangle (No. 642) ; scale, 1: 250,000; by T. G. Gerdine, D. C. Witherspoon, R. B. Oliver, and J. W. Bagley. 50 cents retail or 30 cents wholesale. Also in Bulletin 337, 25 cents, and Bulletin 525, 55 cents.

Fortymile quadrangle (No. 640) ; scale, 1: 250,000 ; by E. C. Barnard. 10 cents retail or () cents Wholesale. Also in Bulletin 375, 30 cents.

Rampart quadrangle (No. (43) ; scale, 1: 250,000; by D. C. Witherspoon and R. B. Oliver. 20 cents retail or 12 cents whOlesale. Also in Bulletin 337, 25 cents, and part in Bulletin 535, 20 cents.

Fairbanks special (No. 642A) ; scale, 1:62,500; by T. G. Gerdine and R. H. Sargent. 20 cents retail or 12 cents wholesale. Also in Bulletin 525, 55 cents.

Bonnifield region; scale, 1: 250,000; by J. W. Bagley, D. C. Witherspoon, and C. E. Giffin. In Bulletin 501, 20 cents. Not issued separately.

Iditarod-Ruby region; scale, 1: 250,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578, 35 cents. Not issued separately.

Middle Kuskokwim and lower Yukon region; scale, 1: 500,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578, 35 cents. Not issued separately.

Chisana-White River region; scale, 1: 250,000; by C. E. Giffin and D. C. Witherspoon. In Bulletin 630, 20 cents. Not issued separately.

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Cosna-Nowitna region; scale, 1: 250,000; by H. M. Eakin, C. E. Giffin, and R. B. Oliver. In Bulletin 667, 25 cents. Not issued separately.

Lake Clark-central Kuskokwim region; scale, 1: 250,000; by R. H. Sargent, D. C. Witherspoon, and C. E. Giffin. In Bulletin 655, 30 cents. Not issued separately.

Anvik-Andreafski region; scale, 1: 250,000; by R. H. Sargent. In Bulletin 683, 30 cents. Not issued separately.

Marshall district; scale, 1 : 125,000; by R. H. Sargent. In Bulletin 683, 30 cents. Not issued separately.

Upper Tanana Valley region; scale, 1: 125,000; by D. C. Witherspoon and J. W. Bagley (preliminary edition). Free on application.

Lower Kuskokwim region; scale, 1: 500,000; by A. G. Maddren and R. H. Sargent (preliminary edition). Free on application.

Ruby district; scale, 1: 250,000; by C. E. Giffin and R. H. Sargent (preliminary edition). Free on application. Also in Bulletin 754. 50 cents.

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The Fairhaven gold placers of Seward Peninsula, Alaska, by F. H. Moffit. Bulletin 247, 1905, 85 pp. 40 cents.

Gold mining on Seward Peninsula, by F. H. Moffit. In Bulletin 284, 1906, pp. 132-141. 25 cents.

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Seward Peninsula, northeastern portion, reconnaissance map (No. 55); scale, 1 : 250,000; by D. C. Witherspoon and C. E. Hill. 50 cents retail or 30 cents wholesale. Also in Bulletin 247, 40 cents.

Seward Peninsula, northwestern portion, reconnaissance map (No. 57); scale, 1 : 250,000; by T. G. Gerdine and D. C. Witherspoon. 50 cents retail or 30 cents wholesale. Also in Bulletin 328, 70 cents.

Seward Peninsula, southern portion, reconnaissance map (No. 56); scale, 1 : 250,000; by E. C. Barnard, T. G. Gerdine, and others. 50 cents retail or 30 cents wholesale. Also in Bulletin 328, 70 cents.

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Nome quadrangle (No. 646B); scale, 1: 62,500; by T. G. Gerdine, R. B. Oliver, and W. R. Bill. 10 cents retail or 6 cents wholesale. Also in Bulletin 533, 60 cents.

Casadepaga quadrangle (No. 646C); scale, 1: 62,500; by T. G. Gerdine, W. B. Corse, and B. A. Yoder. 10 cents retail or 6 cents wholesale. Also in Bulletin 433, 40 cents.

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Koyukuk River to mouth of Colville River, including John River; scale, 1: 1,250,000; by W. J. Peters. In Professional Paper 20, 40 cents. Not issued separately.

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Martin Point to Thetis Island; scale, 1 : 125,000; by E. de K. Leffingwell. In Professional Paper 109, 75 cents. Not issued separately.

Northwestern part of Naval Petroleum Reserve No.4, Alaska; scale, 1: 500,000; by E. C. Guerin, Gerald FitzGerald, and J. E. Whitaker (preliminary edition). Free on application. Surveyed for Department of the Navy.

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