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RECONNAISSANCE OF THE GOLD FIELDS OF SOUTHERN ALASKA, WITH SOME NOTES ON GENERAL GEOLOGY

by

GEORGE F. BECKER

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INTRODUCTORY.

Early in 1895 Congress appropriated $5,000 for the investigation of the gold and coal resources of Alaska, to be expended under the direction of the United States Geological Survey. The Director committed the work to my charge. At my desire he requested Mr. William H. Dall to accompany me and make an examination of the coal deposits, with which his former well-known explorations had in large measure familiarized him. Mr. Chester W. Purington also accompanied me as personal assistant.

By the courtesy of the Navy Department, the U. S. ship *Pinta* was placed at our disposal for examinations in the Alexander Archipelago. Thanks to the kindness of Lieut. Commander A. R. Couden, commanding, and his officers, we enjoyed every facility for visiting points accessible by water in southeastern Alaska. All efforts to procure suitable transportation to the westward of Baranof Island failed. We reached St. Paul, Kadiak, by the mail steamer, and there secured a small tugboat of 24 tons, gross, in which, with great discomfort and some risk, a cruise of over 1,300 miles was accomplished. Kadiak was circumnavigated, Chirikof was visited, Cook Inlet, Turnagain Arm, and Kachemak Bay were explored with such thoroughness as time permitted, and landings made at various points on the Alaska Peninsula from Cape Douglas to Unga Island. From Unga to Unalaska the mail steamer was again resorted to. At Dutch Harbor a steamer was chartered for a brief visit to Bogoslof and Grewingk, and the *Bertha*, with a cargo of seal skins, transported us from Dutch Harbor to San Francisco.

Mr. Dall's report on Coal and Lignite of Alaska has already appeared in the Seventeenth Annual Report, Part I. The report on gold, delayed by unforeseen events, is here presented. Besides notes on gold, it has been considered best to include such observations on other matters of geological interest as were made on the trip. Mr. Purington has assisted most efficiently in the elaboration of the material.

GEOGRAPHICAL NOTES.

The well-known gold deposits of Alaska are divisible into two greater groups. Of these one lies upon the Yukon River close to the British frontier and some 300 miles from the coast. The other stretches along the coast from Sumdum Bay westward as far as Unalaska. Gold has also been detected on the Kowak and the Kuskokwim rivers. The examinations recorded in this report were confined to the coastal mines. Pl. I exhibits the general distribution of the deposits, and more detailed maps are given in connection with the detailed descriptions.

The direct distance from Sumdum Bay to Unalaska is some 1,250 statute miles, and the coast line is of course much longer.[1] It is therefore desirable to group the coastal auriferous localities more minutely. The most easterly mines are all either on islands of the Alexander Archipelago or on the adjoining mainland. The largest town of the Territory, Juneau (originally called Harrisburg), is on the mainland. Just opposite the town, on Douglas Island, is the Alaska-Treadwell mine and its extension, the Mexican. On the mainland within a few miles of Juneau are the Silver Bow Basin and the Sheep Creek districts. Sumdum is on the mainland some 55 miles to the southeastward of Juneau; and Seward City, near Berners Bay, is about 50 miles to the northwestward. There are also gold-quartz veins on the northern end of Admiralty Island, 30 miles west of Juneau.

The last district of importance in the Alexander Archipelago is near Sitka, on Baranof Island. Sitka is about 100 miles west of south from Juneau. Another group of deposits lies in the region of the Kenai Peninsula, which forms the southeasterly shore of Cook Inlet. The only deposits actually exploited on the mainland in this region are the stream gravels on Turnagain Arm. At Yakutat Bay there are auriferous beaches, as there are also on Kadiak Island. On this island, too, there is a group of gold-quartz veins, which are being explored and tested.

The Apollo Consolidated mine is on Unga Island, one of the Shumagin group, some 450 miles westward from the Kenai Peninsula. The auriferous area of Unga seems to extend across a narrow strait to Popof Island. Traces of gold are said to have been found on the Alaska Peninsula, and there is certainly a trace of gold on Unalaska, although as yet no valuable deposit has been found there.

The physical conditions of the Alaskan coast can not be said to be unfavorable to mining. In spite of the high latitude, the winter is not severe. The summer is never hot. The precipitation, however,

[1] The coast line of Alaska, including islands, is said to be 26,364 miles, while the Atlantic coast of the United States, including islands, is only 2,043 miles. Eleventh Census, Alaska vol., on authority of Coast Survey.

is great. In the region eastward of the center of Kadiak, timber is extremely abundant, so much so as to make prospecting laborious where it is not fairly impracticable. West of the line indicated there is no timber. The sea, of course, affords ready means of transportation for the entire coast, but navigation is often somewhat perilous.

The meteorological data available, excepting for the port of Sitka, do not accord very well. The averages are probably derived from a number of years too small to eliminate annual variations.

The following little table shows the average temperatures and precipitation, as given to me by the Weather Bureau:

Average temperatures and precipitation in Alaska.

Station.	Mean January temperature.		Mean July temperature.		Annual rainfall.	
	Degrees F.	Number years.	Degrees F.	Number years.	Inches.	Number years.
Juneau	26.9	4	57.8	3	94	3
Sitka	34.2	6	54.4	7	111.7	7
St. Paul, Kadiak	26.6	11	45	9	39.1	6
Unalaska	33.5	5	49.6	4	50.2	5

The observations of Mr. Frederick Sargent at St. Paul, Kadiak, which are recorded in the report of the Eleventh Census, give the following figures:

Mean January temperature for nine years, 31.3° F.; mean July temperature for ten years, 53.4° F.; mean annual rainfall for seven years, 67.1 inches.

The discrepancy between the Weather Bureau figures and those obtained by Mr. Sargent is probably due to the different years included. Mr. Sargent's lowest temperature is − 2° in 1882.

In the Alaska census volume Mr. S. Applegate states the rainfall at Unalaska for the years 1882, 1883, 1884, 1887, and 1888. The average is 118 inches, or considerably more than the Sitka precipitation instead of less than half as much.

The four stations lie at no great distance from the same isotherm, as appears from the data given or from an inspection of Mr. A. Buchan's isothermal chart. Of course the mildness of the winter is due to the effects of the Japan Current.

HISTORICAL NOTES ON ALASKAN GOLD.

If the early Spanish, Russian, and English explorers of the Alaskan coast detected gold in that Territory, they seem to have omitted all mention of the fact, and as such a discovery would have added to the importance of their explorations it may be assumed that they failed to detect the precious metal.[1] In 1849 Mr. A. Erman published in a Russian journal a map of the world, showing the distribution of gold, which fails to indicate any auriferous locality in Alaska.[2] The Russians looked upon their American possessions as a hunting ground for fur, and had committed its charge to the Russian American Trading Company. In 1848, however, the Government commissioned Mr. P. P. Doroshin[3] to explore for mineral resources about Sitka, the island of Kadiak, and the Kenai Peninsula. He discovered the coal of Cook Inlet and detected gold at several points. In 1851 he again visited the country, but on neither occasion did he find any gold-bearing veins or meet with gravels carrying more than a sixth of a pennyweight per ton. He was afterwards bitterly reproached for not having found more gold, but his failure is not a matter for surprise. He obtained no aid from the natives, who, he declares, had no word for gold, and he was not fortunate in the areas selected for examination. The Kaknu River, which empties into Cook Inlet at Fort Kenai,[4] and Yakutat Bay were among Doroshin's localities.

In 1863 there was considerable excitement about the gold washings on the Stikine River (the Cassiar district), which, however, were entirely in British territory. Gold was reported on the Taku River, not far from Juneau, as early as 1867.[5] In 1873 a gold-quartz vein was found on Silver Bay, 10 miles from Sitka.[6] Fruitless prospecting had been done some years earlier in the same region.[7] The placers of Silver Bow Basin were discovered in 1880 and those of Douglas Island in 1881. In working these last a large body of low-grade quartz was laid bare, which was soon acquired by Mr. John Treadwell. The famous Alaska-Treadwell mine is opened on this body of quartz. Sheep Creek came into notice in 1888, and rich ore was discovered in Sumdum Bay in 1889. In this same year only assessment work was being done at Berners Bay.[8]

On Kadiak Island production can hardly be said to have begun at the time of the examination described in this paper, but the late Prof. J. S. Newberry long since reported gold in specimens from Kadiak.[9]

On Turnagain Arm, at the head of Cook Inlet, there are auriferous stream gravels. At Bear Creek active operations were begun in 1894. In August, 1895, further discoveries were made near the head of the arm.

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[1] According to C. P. C. Fleurieu (1797), Juan de Fuca reported gold, silver, and pearls on Puget Sound, but little credit seems to have been given to the statement. Possibly the natives may have had trinkets obtained by barter.

[2] Archiv für wissenschaftliche Kunde in Russland, vol. 7, 1849.

[3] Idem, vol. 25, 1866-67, p. 225. Doroshin published several other papers.

[4] C. Grewingk, Beiträge zur Kentniss der Nordwestliche Küste Amerikas, 1850.

[5] U. S. Coast Survey Rept., 1867, p. 290.

[6] Mr. Henry Boursin, Eleventh Census U. S., Alaska vol., p. 229.

[7] Russian America, House Ex. Doc. 177, Fortieth Congress, second session, 1867, p. 253.

[8] Mr. J. H. Burfeind, Eleventh Census U. S., vol. Mineral Resources, 1892, p. 101.

[9] An unpublished report to the Secretary of the Smithsonian Institution; cited in Coast Pilot of Alaska, 1869, App. 1, by W. H. Dall.

The beach sands at Yakutat Bay, on the west coast of Kadiak, and in other localities contain gold, and small parties of miners sometimes engage in its extraction without any brilliant success. To the west of Kadiak the Apollo Consolidated mine is the only one which has yielded any large quantity of gold. It was opened about the year 1886. Prospecting has been done at Unalaska and to some extent on the Alaska Peninsula with insufficient success.[1]

On the Yukon gold was first discovered by members of the Western Union Telegraph Expedition. The first mention of this gold field is by Mr. F. Whymper, in 1869.[2] It was also referred to by Mr. William H. Dall in 1870.[3] The first mining excitement on the Yukon was in 1886.

STATISTICS OF GOLD PRODUCTION.

The figures for the gold product of Alaska are necessarily mere approximations in most cases, since no efficient means exist for obtaining accurate returns excepting in the case of a few companies. In the following table the product of the Alaska-Treadwell from 1882 to 1889, inclusive, is taken from the report of the company for 1894. After 1890, the published reports show the products for the year ending June 1. The figures for the Apollo Consolidated for 1891 to 1894 are taken from a table kindly communicated to me by the company, and represent the net proceeds or returned value of concentrates and bullion shipped in these years. All the other figures are taken from the reports of the Director of the Mint. The details of production are on the authority of Mr. C. G. Yale. The last column shows the estimates of the Director of the Mint, based only in part on the direct returns of his agents, for the entire territory.

The silver product of Alaska is not included in the table. Prior to 1894 the Director of the Mint did not estimate as much as $11,000 coining value in any year. His estimates for 1894, 1895, and 1896 are, respectively, $28,782, $86,880, and $187,867. The Apollo Consolidated produced $39,620 in silver, coining value, in 1896, mainly from the sulphurets, which contain much galena. The remainder for the same year seems to have come from the mines of the Alexander Archipelago, the estimate being founded on returns from the smelting works of the Pacific Coast.

[1] Mr. Henry Boursin, Eleventh Census U. S., Alaska vol., 1893, p. 236.
[2] Travels in Alaska and on the Yukon, 1869, p. 258.
[3] Alaska and its resources, 1870, p. 477.

Statistics of gold production in Alaska.

[Stated in dollars.]

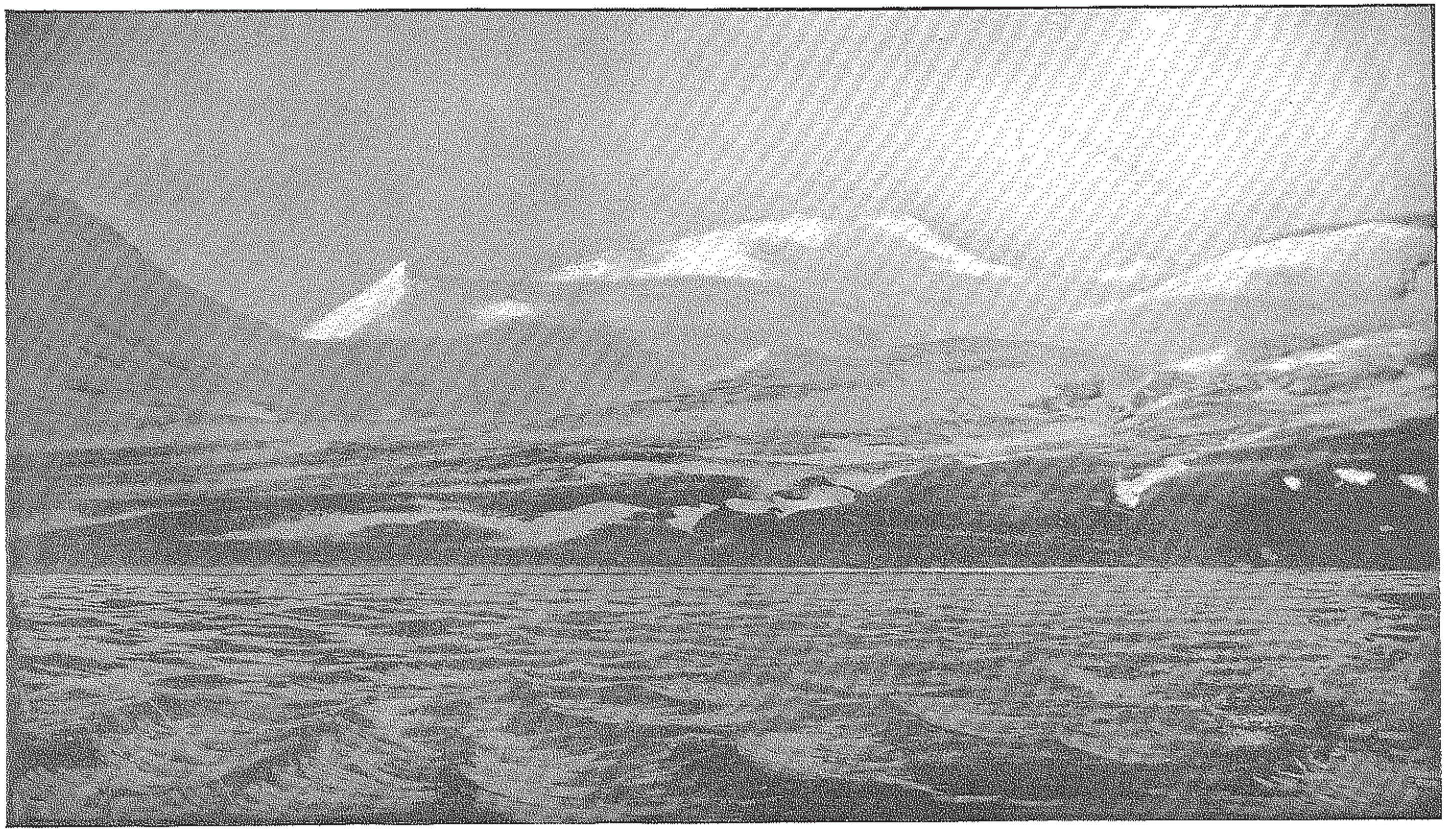
Year.	Alaska-Treadwell mine.	Mexican mine.	Other quartz mines of southeastern Alaska.	Stream placer mines of southeastern Alaska.	Apollo Consolidated mine.	Beach placers.	Cook Inlet placers.	Yukon placers.	All Alaska; estimate of the Director of the Mint.
1880	....	....	....	6,000	....	....	....	....	6,000
1881	....	....	....	13,374	....	....	....	....	13,374
1882		....	....	20,000	....	....	....	....	150,000
1883	10,903	....	2,000	140,000	....	....	....	....	300,000
1884		....	100,000	50,000	....	....	....	....	200,000
1885	242,319	....	....	....	....	....	....	....	300,000
1886	366,180	....	....	....	....	....	....	....	446,000
1887	476,934	....	....	....	....	....	....	....	675,000
1888	429,889	....	....	....	....	....	....	....	850,000
1889	652,491	....	250,000	25,000	....	....	....	....	900,000
1890	613,191	....	68,238	25,000	....	....	....	50,000	762,500
1891	765,673	....	21,843	120,000	780	....	....	100,000	1,020,045
1892	676,226	....	110,820	180,900	30,216	2,500	....	110,000	1,080,446
1893	779,782	....	7,400	....	47,847	6,000	....	200,000	1,000,000
1894	555,307	204,042	19,400	....	35,297	....	....	409,000	1,113,550
1895	818,690	226,258	277,676	2,265	225,395	17,854	50,000	709,000	1,615,300
1896	693,576	245,861	482,382	40,000	400,313	39,000	120,000	800,000	2,055,710

VOLCANIC ACTIVITY AND CHANGES OF LEVEL.

It is very certain that volcanic activity has existed at numerous points along the northwestern coast of America from the Golden Gate northward in comparatively recent times. Less certainty exists in this newly settled region as to historical outbursts. It has been reported on seemingly credible authority that Mount Baker was in eruption in 1843, and the statement has been accepted by Grewingk,[1] Davidson,[2] Whitney,[3] Dana,[4] and Diller.[5] The evidence of a simultaneous outbreak at Mount St. Helens is of the same order of credibility, and it is certain that several of the volcanic cones from Mount Shasta northward still emit small quantities of vapor.

In eastern Alaska, Mount Calder, at the north end of Prince of Wales Island, Mount Edgecumb, close to Sitka, and Mount St. Elias have been reported in action. The only authority for the Calder eruption, supposed to have occurred in 1775, is F. A. Maurelle, and

[1] Verh. Rus. min. Gesell. 1848–49, p. 269.
[2] Russ. Amer., House Ex. Doc. No. 177, Fortieth Congress, second session, 1867, p. 289.
[3] Enc. Brit., 9th ed., vol. 23, 1888, p. 800.
[4] Manual of Geol., 4th ed., 1895, p. 296.
[5] Nat. Geog. Mag., vol. 5, 1893, p. 93.



MAKUSHIN VOLCANO.

Grewingk[1] rejects the report on the ground that if it had been correct it would have been confirmed by other nearly contemporaneous witnesses. The alleged eruption of Mount Edgecumb in 1796 also rests mainly upon the authority of a single witness, E. H. Hoffmann.[2] Sir George Simpson, however, asserts that in 1841–42 there were inhabitants of Sitka who had seen Edgecumb active.[3] On the other hand, had there been an eruption in so conspicuous a position it could hardly have escaped the attention of the Russians.[4] Mount Edgecumb is manifestly a volcanic cone, and smoke from a fire, or even a persistent fog streamer, may have been interpreted by Hoffmann as volcanic smoke.

Mount St. Elias was reported as active in 1839, and again in 1847, and many references to this mountain as a volcano are to be found in literature. Its eruptions were not detected by the sharp and well-trained eyes of the natives,[5] and it is now well known that the mountain is neither a volcano nor even of volcanic origin,[6] a conclusion to which Grewingk came from mere study of the descriptions.

The belt of the present volcanic activity in Alaska begins on the Copper River near Mount Wrangell, and extends along the peninsula of Alaska and the Aleutian Islands to beyond Amchitka Island. Its length is nearly 1,700 miles, which is about the distance from Cape Sable, Florida, to Halifax, Nova Scotia, or from Gibraltar to the Shetland Islands. The ejecta are mainly andesitic. Eruptions have been observed at scores of points, and the intervals are dotted with cones, showing the continuity of the zone of vulcanicity. Mount Wrangell lies at a distance of about 134 miles from the head of Prince William Sound, and, according to Lieut. H. T. Allen,[7] it reaches the great height of 17,500 feet. It was steaming at the date of his visit. It is the loftiest of a group of high mountains, one of which, named Mount Blackburn by Mr. Allen, is only 30 miles from the junction of the Copper River and the Tschichitna, Chechitna, or Chittyna River. I suppose this latter mountain to be that called by earlier writers the Chechitno volcano.

In the following table such records as I have of eruptions on the volcanic belt are arranged according to longitude. The earlier observations were compiled by Grewingk[8] and translated by Mr. William H. Dall, who added data up to 1867. A few more observations, compiled from various sources, are here included, but the list is at best a very partial one. The region is without newspapers, and the seamen or hunters who witness the outbursts are accustomed to the sight.

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1 Verh. Rus. min. Gesell. 1848–49, p. 273.

2 Geog. Beob., gesammelt auf einer Reise um die Welt, 1829; quoted by Grewingk.

3 Journey round the World in 1841–42, vol. 2, 1847, p. 175.

4 Grewingk, op. cit., p. 272.

5 P. P. Doroshin, Erman's Árchiv. für wiss. Kunde in Russland, vol. 7, 1849, p. 230.

6 I. C. Russell, Nat. Geog. Mag., vol. 3, 1891, p. 167.

7 Exped. to Copper River, Rept. Secy. of War, 1887, p. 59.

8 Loc. cit., p. 277. A few of Grewingk's data must have been obtained from the natives, for the Russians do not appear to have sighted the Alaskan coast till 1741.

Volcanic eruptions in Alaska.

Locality.	Approximate longitude.	Year.	Phenomena.
	°		
Calder, Mount	133½	1775	Reported active.
Edgecumb, Mount	135½	1796	Said to smoke.
Chechitno, Mount	144½	1760	Smoked.
		1784	Erupted.
Chugach, Gulf. (Prince William Sound.)	146 to 149	1790	Eruption near.
Wrangell, Mount	145	1819	Emitted fire.
		1884	Eruption.
Redoubt, Mount	152½	1819	Smoked.
Iliamna, Mount	153	1741	Grew quiet.
		1778	Resumed action.
		1779	Active.
		1876	Eruption.
St. Augustin, Mount	153½	1883	Violent eruption.
		1885	Steaming, shore to summit.
		1895	Crater steaming.
Veniaminof, Mount (Black Peak).	159	1830–1840	Smoked.
		1892	Violent ash outbreak.
Pavlof, Mount	162	1762–1786	Active.
		1790	Do.
		1838	Smoked.
		1880	Red glare.
		1892	Smoke.
Medviednikof, Mount	162	1768	Active.
Walrus Peak	163	1768	Do.
Amak Island	163	1700–1710	Do.
		1796	Unquiet.
Termination Alaska Peninsula, 163½°.			
Unimak Island	164	1690	Crater formed on Mount Khaginak.
		1775–1778	One volcano active, (probably Shishaldin).
Shishaldin, Mount	164	1778	Smoked.
		1790–1825	Active.
		1824	Flames.
		1827–1829	Fire.
		1830–1831	Very active.

Volcanic eruptions in Alaska—Continued.

Locality.	Approximate longitude.	Year.	Phenomena.
	°		
Shishaldin, Mount	164	1838	Fire.
		1865	Smoked.
		1871–1874	Steamed.
		1880–1881	Smoked.
		1883	Steam and ashes.
		1895	Steamed.
Isanotski, Mount (a little east of Pogrumnoi).	164½	1795	Exploded.
		1825	New crater, ashes.
		1830	Flames.
Pogrumnoi, Mount	164½	1795	Active.
		1827–1829	Fire.
		1830	Ashes.
Akun Island	165½	1828	Smoked.
Akutan Island *a*	166	1790	Do.
		1828	Do.
		1838	Do.
		1883	Steam and ash.
		1887	Lava eruption.
Makushin, Mount, Unalaska Island.	167	1768	Active.
		1790–1792	Do.
		1802	Vigorous.
		1826–1838	Smoked.
		1844	Do.
		1865	Active.
		1871–1874	Steam.
		1880	Do.
		1883	Ashes.
		1891	Steam.
		1895	Do.
Unalaska Island	167	1768	A second volcano active.
Bogoslof Island	168	1796	Rose.
		1806	Emitted lava.
		1814	Threw out stones.
		1820	Smoked.
Grewingk, or New Bogoslof	168	1883	Rose; ashes and lava; has steamed ever since.

a Mr. Dall regards this volcano as usually active and as emitting more lava than any other in the chain.

Volcanic eruptions in Alaska—Continued.

Locality.	Approximate longitude.	Year.	Phenomena.
	°		
Grewingk, or New Bogoslof	168	1890	Emitted ashes.
Vsevidof, Mount	168½	1784	Smoked.
		1790	Active.
		1817	Great eruption north peak.
		1830	Eruption southwest end.
Tanak-Angunakh Island	170	1774	Active.
		1828	Smoked.
Four Craters Islands	170	1796–1800	Active.
		1838	Smoked.
		1871	Steaming.
		1874	Do.
Yunaska Island	171	1817	Smoked.
		1824	Great eruption.
		1830	Eruption.
		1873	Steamed.
Amukta Island	171	1770	Became quiet.
		1786–1791	Active.
Seguam, Mount	172½	1786–1790	Do.
		1827	Smoked.
		1873	Steamed.
Atka Island	174½	1760	Smoked.
		1828	Do.
		1830	Do.
Kluchefskoi, Atka Island	174	1873	Steamed.
Korovin, Mount, Atka Island	174	1830	Smoked.
		1844	Do.
		1873	Quiet.
Sarychef, Mount, Atka Island.	175	1812	Violent eruption.
Koniuji Island	175	1760	Rose.
		1827	Smoked.
		1828	Do.
Great Sitkin Island	176	1792	Fire.
		1829	Smoked.
Adakh, Mount	177	1760	Active.
Kanaga, Mount	177	1763	Solfataras.
		1786	Flames.
		1790	Active.

Volcanic eruptions in Alaska—Continued.

Locality.	Approximate longitude.	Year.	Phenomena.
	°		
Kanaga, Mount	177	1791	Smoked.
		1827	Do.
Tanaga, Mount	178	1763–1770	Constantly active.
		1791	Smoked.
Gareloi Island	179	1760	Do.
		1792	Emitted lava.
		1828	Smoked.
		1873	Active.
Semisopochnoi Islands	180½	1772	Smoked.
		1790	Do.
		1792	Do.
		1830	Do.
		1873	Active.
Sitignak Island (near west end of Amchitka).	181	1776	Do.
Little Sitkin Island	181½	1828	Smoked.

No active vulcanicity is recorded west of longitude 180½°, but Buldir Island, in 184°, is described by Dr. Dawson[1] as a once symmetrical volcanic cone much eroded by the sea. The Semichi Islands are low and flat. Attu, Bering, and Copper islands are reported to consist largely of pre-Tertiary igneous rocks, but Dr. Dawson reports basalt also on Bering Island. On the mainland of Kamchatka there are, as is well known, many finely developed volcanic cones forming a chain with a northwesterly trend, and several of them have been observed in activity.

Whether there is an immediate and direct connection between the volcanic belt of Alaska and that of Kamchatka is questionable. The distance from Buldir to the Alaskan coast is nearly 600 miles, and between them is a deep submarine channel. Even if the basalt which Dawson noted on Bering Island is a recent rock, a break of over 400 miles spanning the channel remains. On the other hand, the eruptive character of the more ancient rocks on Attu and the Commander islands indicates that vulcanicity once existed in the interval, though now totally extinct. A very handsome diorite is also abundant in Unalaska, and fragments of diorite have been brought up by the eruption of Bogoslof. But ancient eruptives are so widely disseminated that it is not justifiable to associate the earlier and later extrusions without further evidence. That which is available is of a very

[1] Bull. Geol. Soc. America, vol. 5, 1894, pp. 117–146.

general character. The connection between the Alaskan volcanic belt and that of Washington, Oregon, and California, so recently extinct, is also interrupted, and to the southward of this series of volcanoes there is another break before the volcanoes of Mexico and Central America are reached. In short, the shores of the Pacific seem marked at intervals by belts of volcanoes nearly parallel with and at no great distance from the edge of the continental plateau.

The geological structure and the fossil fauna of the Pacific coast manifest a marked tendency to parallelism nearly on the present lines. The Mesozoic upheavals and eruptions were substantially parallel to the present edge of the plateau, and characteristic fossil shells stretch along the coast for great distances. The Pacific coast of the Americas lies along a line of weakness in the earth's lithoid shell, upon which movements seem to recur as often as the tendency to isostasy is brought into action by redistribution of matter on the earth's surface, or by other causes. Such lines of weakness seem to be of great antiquity and, as has been suggested before now, may have been outlined early in the Archean. In accordance with Dana's theory of the permanence of continental areas, the shore line from time to time comes back nearly to the edge of the abysmal submarine plain of the North Pacific, now lying nearly 3 miles below the surface of the ocean.

To me it would appear that there is a close relationship, though no direct continuous connection, between the modern volcanic belts; and that in past geological periods also there have been various stretches of the coast similarly affected by vulcanicity, these sometimes overlapping the present volcanic belts. The Alaskan belt seems to have existed since the late Eocene or early Miocene, and may coincide with still earlier lines of activity.

During the Oligocene (Kenai Group) something like one-half of the Territory of Alaska was submerged.[1] In the late Pliocene a great uplift took place in British Columbia,[2] and about the same time the Mount St. Elias Alps were formed.[3] This uplift probably affected western Alaska, and united the Asian and American continents. A partial subsidence seems to have followed,[2] succeeded by a gradual rise, still in progress, from about longitude 145° W. to Bering Sea. The limits of time just indicated correspond to the period during which it is known from fossil evidence that volcanic activity has been in progress. To me it also seems most natural to conceive of vulcanicity as due to the active progress of upheavals and subsidences, the fusion of the lava being ascribable to the dissipation of the energy of uplift.[4] The immediate disturbance of equilibrium which gives

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[1] W. H. Dall, Bull. U. S. Geol. Survey No. 84, 1892, p. 251.

[2] G. M. Dawson, Trans. Royal Soc. Canada, vol. 7, sec. 4, p. 54.

[3] I. C. Russell, Nat. Geog. Mag., vol. 3, 1891, p. 174.

[4] If the rocks at a certain depth are near the point of fusion, but are solid on account of the pressure to which they are subject, the principal expenditure of heat would be in supplying the "latent heat of fusion."

rise to the recent uplift is perhaps in part due to the erosion of the Yukon and the Kuskowim rivers.

The effects of uplift are manifest all along this part of the southern coast of Alaska, and were familiar to Grewingk, as well as later writers. Raised beaches and almost unscarred baselevels at elevations of 100 feet, more or less, are very abundant. The Tertiary beds are usually raised to a height of some hundreds of feet, while the western end of Kadiak, Chirikof Island, and other localities seem to represent very modern elevations. Grewingk suggests that the peninsula of Alaska may have been a series of islands comparable to the Aleutians, and certainly if the coast were now to sink 200 or 300 feet the peninsula would be resolved into several insular masses.

A portion of the uplift seems to be historical. At a slight earthquake in 1868 the elevation is said to have amounted locally at Unga to over 20 feet; the Isanotski Strait has become impassable; near St. Michael, windrows of rotten driftwood lie far above the reach of storm waves, and barnacle shells are found 15 feet above high-water mark.[1] Dr. Dawson records evidences of recent elevation amounting to from 10 to 30 feet at Unalaska, Attu, Bering Island, St. Paul Island, and St. Matthew Island, while concluding that the Aleutian Islands as a rule have been unsubmerged since the Miocene.

Possibly the recency of the last uplift may explain the treelessness of western Alaska. One of the most striking contrasts which the country affords is that between the exceedingly dense forests of the east and the absolute treelessness of the west. There is no apparent climatic cause for the sudden disappearance of the spruce west of a line passing through Kadiak. The temperature scarcely changes on a course following the coast along this line. The rainfall maintains the same superabundance, the winds are not severe enough to explain treelessness excepting in very exposed places, and the soil of wooded Edgecumbe can not be very different from that of the treeless Alaska Peninsula. On the other hand, salt-water straits with heavy tidal currents might prove very effectual barriers to the advance of the forests. If Bristol Bay was connected with Cook Inlet by the way of Iliamna and Clark lakes in recent times, and if the western portion of Kadiak was then under water it would be quite intelligible that the spruce should not have made its way to the westward of the meridian of Redoubt, or 153°.

Bering Sea is, on the whole, a very shallow one. About one-half of its area is within the 100-fathom contour, but there is a deeper basin to the northward of the western end of the active volcanic belt, which seems to connect by a deep channel with the adjacent floor of the Pacific Ocean. Bering Strait is so extremely shallow that a further rise of the country of less than 200 feet would connect the continents of Asia and America. Were such an uplift to occur the

[1] W. H. Dall, Alaska and its Resources, 1870, p. 465.

land would be continuous from the Cape of Good Hope to the Straits of Magellan, excepting for the Suez Canal, or to the east coast of Labrador and to Cape Finisterre. The continental area would then be unbroken except by man over more than 130° of latitude and 313° of longitude. In the more philosophical sense of the word "continent," in which the shoal-water plateau is recognized as continental, Asia and America are already united, while Newfoundland and Ireland are not insulated. There is no doubt that the two continents were united by dry land, perhaps more than once, during the Tertiary.

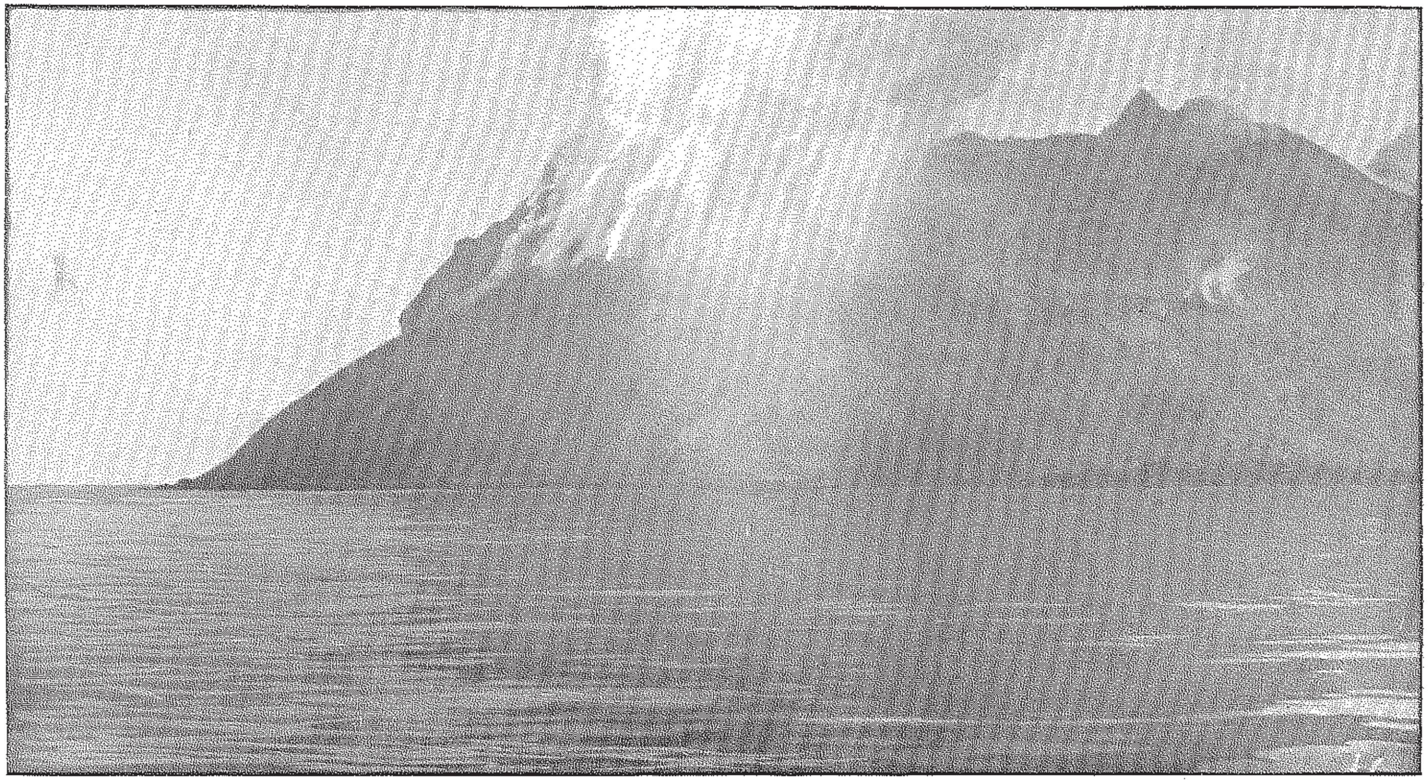
So far as the ocean currents and the climatic features dependent upon them are concerned, the union of Asia and America would make little or no difference. Mr. Dall has shown the commonly received opinion that a branch of the Japan Current flows through Bering Strait to be erroneous. His own observations and a careful discussion of all the known records show that the currents in the strait are chiefly tidal and that they are cool. "The strait is incapable of carrying a current of warm water of sufficient magnitude to have any marked effect on the condition of the Polar basin just north of it."[1] When the land in this region was at a considerably lower level, so that a free and ample communication existed between the Pacific and the Polar basin, more warm water must have reached the Arctic, and the climate of northern Alaska must have been relatively mild, as was long since pointed out.

FORM OF VOLCANIC CONES.

The volcanic belt of Alaska shows many symmetrical cones of the type of Fujisan. There are at least equally numerous cases in which the eruptions have produced masses without marked symmetry. It is quite conceivable that when the volcanic conduit is vertical, its cross section being nearly round and the ejecta mainly ash, the ejecta should be symmetrically disposed about the orifice. When such symmetry of conditions is wanting, it is highly improbable that symmetry of form would result. Hence similar lavas, under circumstances which differ only accidentally, may produce mountains of very regular or of very irregular geometrical character. While the conditions broadly considered or on a large scale may nearly approach symmetry, it is substantially impossible that circumstances should be sensibly uniform when the minuter details are considered. Hence regularity, resulting from general average, can reasonably be looked for in the larger features of a volcanic cone.

When volcanoes are symmetrical—and such volcanoes are extremely numerous—the form is found to correspond, except in scale, to the well-known outline of Fujisan, in Japan. The generating curve is a continuous one, so far as can be judged by inspection. Mount St. Augustine, a view of which is given on Pl. X, is of this type.

[1] Coast and Geodetic Survey Rept. for 1880, App. 16.



GREWINGK, BEARING NW. BY N., IN 1884.

Volcanic cinder cones a few score feet in height are comparable with artificial heaps of loose material sloping at the "angle of rest." The problem might be proposed to find, for a mass of loose, dry material, with a circular horizontal cross-section and an indefinite volume, the loftiest continuous geometrical form consistent with stability. The solution, however, would not answer exactly to a volcanic cone with a very small crater. Even damp ash behaves differently from dry material, the film of water between adjacent grains producing a powerful adhesion through capillary attraction,[1] and there is no doubt that wet volcanic ash hardens, or "sets," to a relatively firm continuous mass. Volcanic cones are also composed in part of lava streams which have solidified from the liquid state. The volcanic cone, therefore, seems to me to be substantially a continuous solid of finite height. In such a mass the pressure per unit area on any horizontal cross-section may be assumed to be uniform over the whole cross-section, while a conical heap of loose material exerts a pressure on the base which is very far from uniform, being greatest at the axis.[2] But while the mountain as a whole is to be regarded as continuous, its external form is determined very largely by the fact that it is built up of layers, each of which consists mostly of ash at the time of precipitation, though it subsequently consolidates to firmer material.

A mountain thus formed must be subject to many vicissitudes, and it is not to be supposed that such a method of genesis can lead to an invariable form. Neither does observation show that volcanoes are all of one shape, as was stated above. Thus Makushin, Pl. II, and Bogoslof, Pl. VII, are irregular masses. On the other hand, there may be a theoretical form to which volcanoes will approach under favorable conditions of symmetry and when the ejecta are mainly ash.

The problem which seems most nearly to correspond to the case of the well-formed volcanic peaks seems to be this: To find the loftiest figure of given volume and continuous curvature which can be built up of successive showers of ash, each ash layer being supposed to become indurated after its deposition. Near the summit the slope will be determined by the angle of rest of the cinder, and the radius of curvature of the generating curve must be infinite at this point. In lofty volcanoes the slope can not be uniform throughout, because the pressure per unit area on a horizontal cross-section of a rigid right cone would be simply proportional to the height of the cone, and the pressure would thus ultimately exceed the resistance. At a great distance from the summit the load per unit area may approach

[1] Everyone is aware that two wet glass plates adhere strongly. The points of contact of moistened sand grains are held together in the same way. Compare. Am. Inst. Min. Eng., 1894, p. 131.

[2] In a right cone of loose material sloping at 45° it is easy to show that the pressure at the center of the base would be proportional to half the height, while the average pressure on the base would be proportional to one-third of the height.

the limit of resistance, and in the loftiest possible volcano of given volume this limit must be approached.

Let the summit be taken as origin, and let the distance from the summit, measured parallel to the axis of the mass, be x. Then y being the radius, y' y'' its differential coefficients with reference to x, and ρ the radius of curvature of the outline, it is well known that

$$\rho = \frac{(1+y'^2)^{3/2}}{y''}.$$

At the summit ρ is to be infinite, while y' for $y=0$ is the cotangent of the angle of rest and is finite. Hence y'' must be zero, when $y=0$ and $x=0$. Now, assuming the curve to be continuous, it must also be possible to express y'' in terms of y, or, by Maclaurin's theorem,

$$y'' = f(y) = ay + by^2 + cy^3 + \ . \ . \ . \qquad (1)$$

a, b, and c being constants of the form $d^n f(0) / \, n! \, dy^n$.

When x is great, the load on a horizontal section is to approach the limit of resistance, so that if σ is the specific gravity of the material and $\varkappa$ the resistance per unit area at the elastic limit

$$\sigma \int y^2 dx = \varkappa y^2.$$

The corresponding value of y'' is, by simple differentiation,

$$y'' = \frac{\sigma^2}{4\varkappa^2} y, \qquad (2)$$

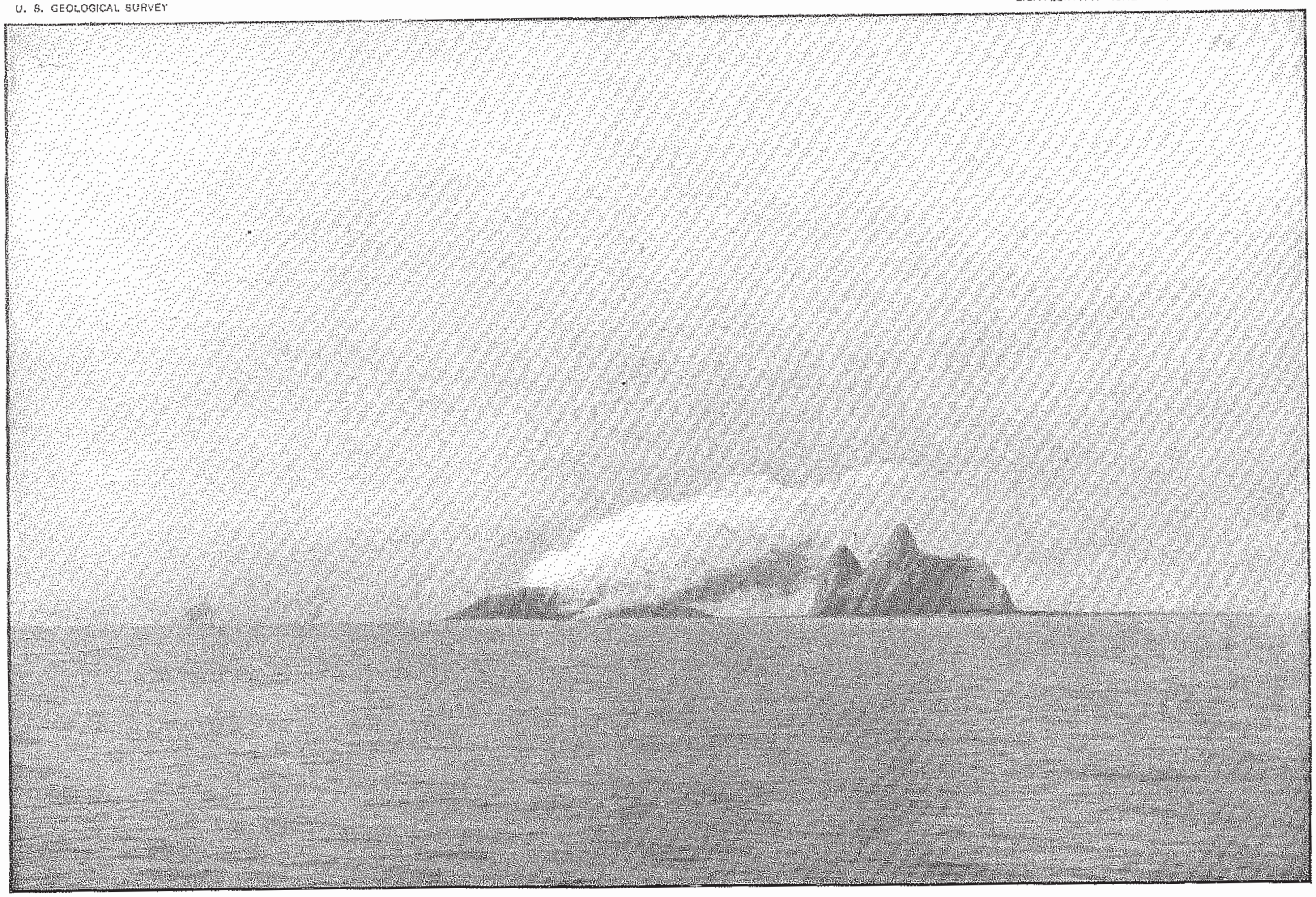
and this is the form which (1) must assume when x and y are sufficiently large. But (1) can not possibly assume this form for large values of y unless b, c, etc., are all zero. Hence, if there is any continuous curve which will express the conditions postulated, its differential equation is of the form (2).[1]

A first integration of (2) gives

$$y'^2 = \frac{\sigma^2 y^2}{4\varkappa^2} + \frac{1}{a^2}$$

where a is the tangent of the angle of rest. Now, this tangent is by definition the ratio of the frictional resistance of a surface to the normal pressure of a body resting upon it. This resistance can not exceed the pressure which excites it, and the ratio can not exceed

[1] It is not worth while to regard σ as variable; for, excepting near the summit of a volcano, the cubical compression will be nearly uniform and for such material as rock the variation of density is extremely small within the elastic limit.



BOGOSLOF AND GREWINGK, BEARING N. $\frac{1}{4}$ E., IN 1891.

unity. Hence the maximum possible value of the tangent of the angle of rest is unity,[1] or, for the present case, $a=1$. This gives

$$\frac{y}{c}=\frac{\varepsilon^{x/c}-\varepsilon^{-x/c}}{2}=\sinh\frac{x}{c}, \tag{3}$$

where for brevity c is written for $2\varkappa/\sigma$.

It is easy to see that this curve answers the conditions postulated. The ratio of pressure to resistance for (3) may be written

$$\frac{\sigma\int_0^x y^2\,dx}{\varkappa y^2}=\frac{2\varkappa}{\sigma}\,\frac{yy'-x}{y^2}=\frac{\sinh\frac{2x}{c}-\frac{2x}{c}}{\cosh\frac{2x}{c}-1} \tag{4}$$

which continually approaches unity for increasing values of x. At the summit y and y'' vanish, so that the radius of curvature at that point is infinite. Both conditions therefore are fulfilled.[2]

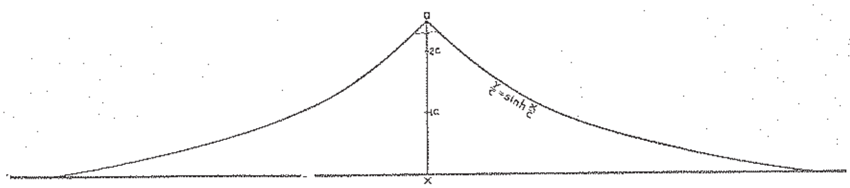


FIG. 1.—Form of volcanic cones.

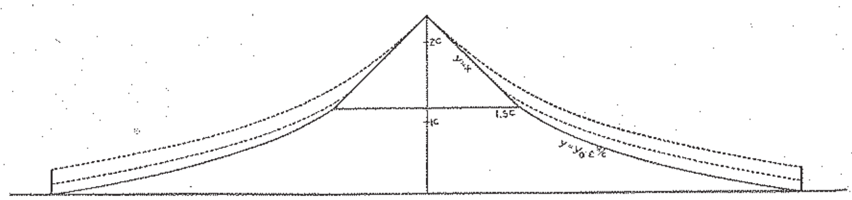


FIG. 2.—Form of volcanic cones.

The curve $\sinh\frac{x}{c}=y$, shown in fig. 1, agrees remarkably well with the form of volcanic mountains as displayed in photographs, and the

[1] According to Weissbach, the maximum angle of rest for sawdust is 44°.

[2] The expression for the volume in (4) is found without labor, as follows: To each member of the first integral of (2), viz, $y^2/c^2=y'^2-1$, add $y^2/c^2=y\,y''$, which is merely equation (2) multiplied by y. Then

$$\frac{2y^2}{c^2}=y\,y''+y'^2-1=\frac{d}{dx}(y\,y'-x).$$

This is one integral of a differential equation of the second order which includes (2), but is more general. It is of the form,

$$y''=\frac{y}{c^2}+\frac{b}{y^3}.$$

If $x=2.5\,c$, the case illustrated in fig. 1, the load on the base is about 19/20 of the resistance.

values of $\varkappa$, deduced from cases where the scale is known, are reasonable,[1] being comparable with those of brickwork and rubble masonry.

It may reasonably be asked why a volcanic cone might not be composed of two distinct portions: first, a right cone near the summit, of such dimensions as to exert upon its base a pressure per unit area equal to the resistance of the material; and, second, a pedestal of logarithmic form and such dimensions that the pressure per unit area at any level is the maximum which the material will bear.[2]

The elements of such a figure are easily computed. Suppose a logarithmic column generated by the revolution of

$$y = y_0 \varepsilon^{x/c}$$

truncated in such a manner that the tapering portion cut off will be of volume just sufficient to form a right cone of base πy_0^2 having a slope of 45°. Then the volume of the cone must be $\pi y_0^2\, c/2$, and if h is the height of the cone, $\frac{h}{3}\,\pi y_0^2 = \pi y_0^2 \frac{c}{2}$ or $h = 3c/2$. The height and radius in a cone sloping at 45° are the same, so that $h = y_0 = 3\, c/2$. The cotangent of the angle at which the logarithmic column slopes at the base of the cone is

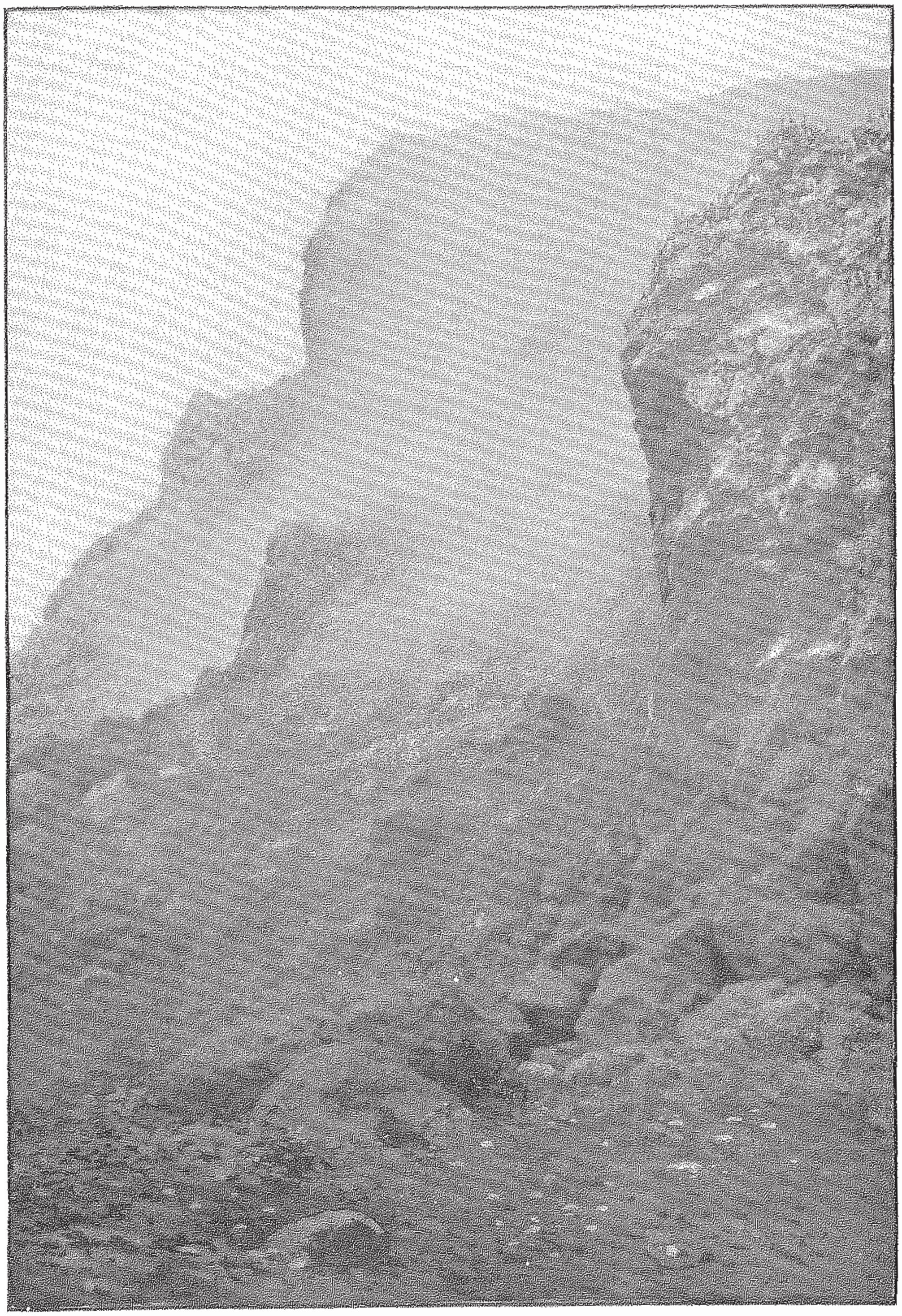
$$y' = \frac{3}{2} = \cot 33^\circ\, 40'.$$

Thus this figure would show an abrupt change of slope at the base of the cone, the angle suddenly diminishing from 45° to 33° 40′. The outline of this mass is shown by the full line in fig. 2 (p. 23).

If one now supposes a fresh shower of ashes to fall on such a mountain, none of the new material can lodge upon the 45° slope, which offers no adequate frictional resistance. On the other hand, fresh ash will lodge upon the shoulder and gradually back up onto the higher slope. Thus the shoulder would be built out into a sensibly continuous curve. But the additional load, if confined to the neighborhood of the shoulder, would overweight the lower portion of the pedestal, which would then yield and broaden. The mass as a whole would not necessarily yield if the fresh ash were distributed over the whole surface below the shoulder. Now, such a layer would evidently build up the mountain to a form closely resembling the dotted lines in fig. 2, which are in fact drawn from the equation $\frac{y}{c} = \sinh \frac{x}{c}$, the locus of which is shown in fig. 1. Thus the discontinuous hypothesis of the volcanic cone leads to results ultimately indistinguishable from the continuous hypothesis, but it serves to throw light on the

[1] A graphic comparison of the continuous curve with the outlines of Fujisan and several other volcanoes will be found in the Am. Jour Sci., vol. 30, 1885, p. 289. Prof. John Milne has also made such comparisons, Trans. Seism. Soc. Japan, vol. 9, part 2, 1886, p. 179.

[2] In the logarithmic column the pressure per unit area at any level is constant, or, in other words, the area of the cross-section is proportional to the volume of the overlying mass.



GREWINGK, WEST SIDE, IN 1891.

process of evolution of the mountains. It appears that if a peak like Fujisan were carved by erosion or other means into any form not inconsistent with stability, fresh eruptions of ash would tend to restore its present symmetry.

In discussing the form of the volcanic cone I have assumed the angle of rest as the maximum possible, i. e., 45°. This angle can never be quite reached, and, as a matter of fact, the steepest talus slopes dip at about 40°. This is of little consequence so far as the theory of a continuous cone is concerned, because on the hypothesis of continuity the maximum angle would then be found only at the sharp apex of the mountain, while real volcanoes have craters of finite size at their summits. In the discontinuous hypothesis there is a long straight slope, and this would necessarily fall as low as 40° if the material were loose. The right cone would then intersect the logarithmic pedestal at a point where its radius is $1.79c$ and where the dip of the surface is 29° 10′. The average energy potentialized in the continuous mountain for $x=2.5c$, the case shown in fig. 1, would be about nine-tenths of that potentialized in the mountain composed of cone and pedestal, the volume being the same in each.

BOGOSLOF AND GREWINGK.

The island of Bogoslof appeared above the sea in 1796, and a neighboring island, sometimes called New Bogoslof, but for which Mr. Dall has proposed the name Grewingk, rose in 1883. Each island has undergone changes, and the more recent one has been photographed at various intervals. The history of these islands is a very interesting subject, but the data are by no means precise. Estimates of the height of an island made from the deck of a vessel are very untrustworthy, and the fact that successive observers give different altitudes is not valid evidence that a change in elevation has intervened. Even the photographs are unsatisfactory, since the precise position of the camera is generally unknown and the different photographs are not immediately comparable. Mr. Dall[1] has condensed the description of the birth of the earlier island as follows:

On the first of May [1796], according to Baranoff, a storm arose near Umnak, and continued for several days. It was very dark all this time, and low noises resembling thunder were continually heard. On the third day the sky became clear very early, and a flame was seen arising from the sea between Unalaska and Umnak. North of the latter smoke was observed for ten days. At the end of this time, from Unalaska a round white mass was seen rising out of the sea. During the night fire arose in the same locality, so that objects 10 miles off were distinctly visible. An earthquake shook Unalaska, and was accompanied by fearful noises. Rocks were thrown from the new volcano as far as Umnak. With sunrise the noises ceased, the fire diminished, and the new island was seen in the form of a black cone. It was named after St. John the Theologian (Joanna Bogoslova). A month later it was considerably higher, and emitted flames constantly. It con-

[1] Alaska and its Resources, 1870, p. 467.

tinued to rise, but steam and smoke took the place of fire. Four years after no smoke was seen, and in 1804 the island was visited by hunters. They found the sea warm around it, and the soil in many places too hot to walk on. It was said to be $2\frac{1}{2}$ miles around and 350 feet high. The soil emitted an odor of bitumen. It is 45 versts, or nearly 34 miles, due west from the north point of Unalaska. In 1806 lava flowed from the summit into the sea on the north side. Fissures appeared, lined with crystals of sulphur. Veniaminoff says that it ceased to enlarge in 1823, when it was of a pyramidal form and about 1,500 feet high. There are many strong currents about it, and a reef extends from a rock west of it to Umnak.

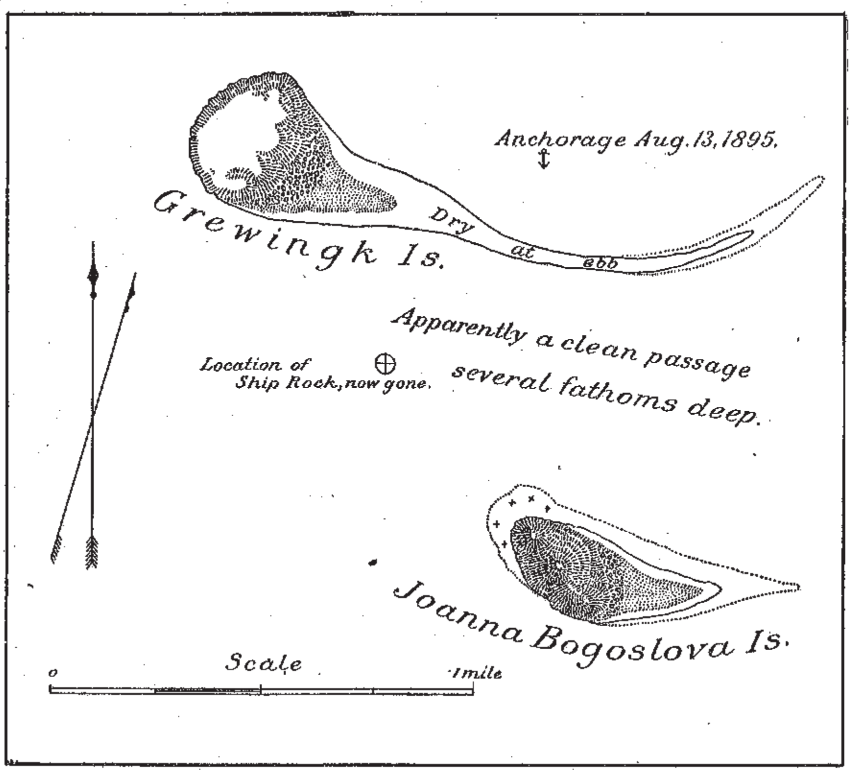
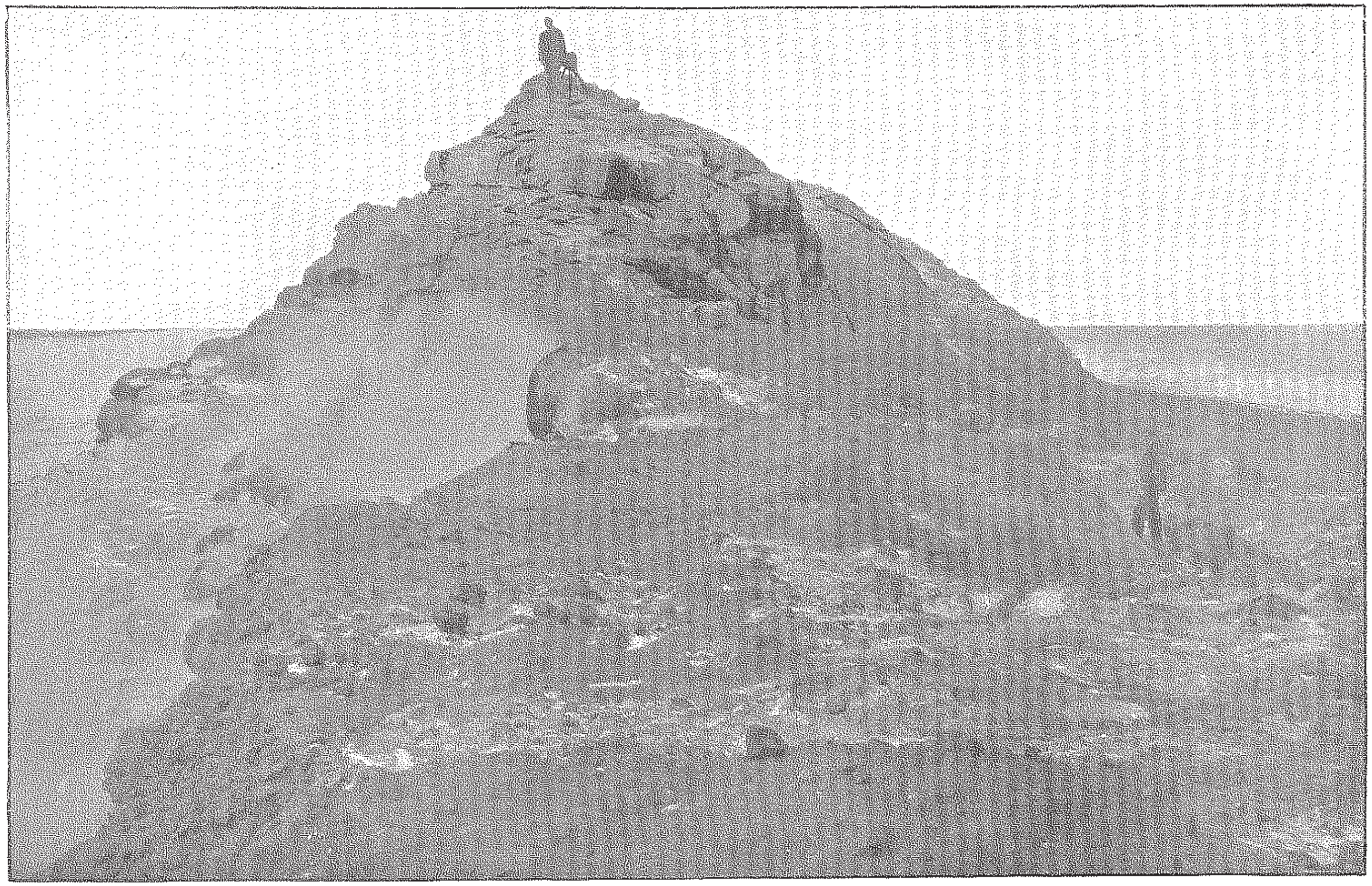


FIG. 3.—Sketch map of Bogoslof and Grewingk.

About half a mile north and west from the island was a perpendicular square-topped pillar, called on modern charts "Ship Rock," possibly, but not certainly, identical with that so named by Cook.

Mr. Dall gathered such information as was available concerning the new island in 1884.[1] Captain Hague, of the *Dora*, observed eruptive action in the locality in the summer of 1883, but the maximum activity occurred in October of that year. Soon after Captain Hague reported the island as three-quarters of a mile in diameter and from

[1] Science, Jan. 25, 1884. Prof. Geo. Davidson also described it in the same journal, March 7, 1884.



GREWINGK, WEST SPUR, FROM ABOVE, IN 1891.

500 to 800 feet in height. Since that time it has undergone various changes.

The island was visited by the U. S. revenue cutter *Corwin*, Capt. M. A. Healy commanding, in 1884, and in the report of that cruise six photographs are published. Comparing these views with those taken in 1891 and 1895, it appears that Bogoslof, the old island, has since undergone no visible change in outline or in apparent elevation since the appearance of the new island, but it seemed to Mr. Dall less lofty than in 1880.

In 1884, however, Grewingk was considerably higher than it now is or than Bogoslof. It was rough and pinnacled and from one point of view dome-shaped. In 1891 it had assumed the flat-topped form, which it still preserved in 1895. In 1884, as shown by the *Corwin* photographs and as mentioned by Mr. Dall, Ship Rock had not disappeared, and a sand spit enveloping Ship Rock extended between the two peaks. This beach was reported continuous in ordinary weather, though showing evidence of submergence in storms. In 1887 the conditions seem to have been unchanged, as is shown by a rough sketch

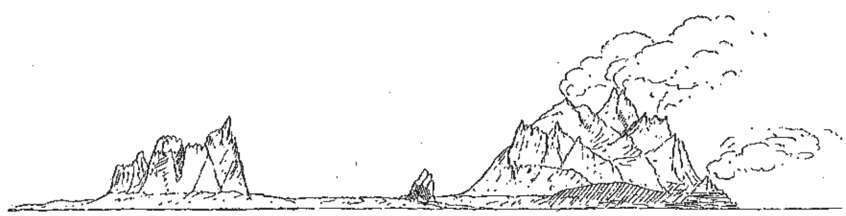


FIG. 4.—Sketch of Bogoslof and Grewingk in 1887, by Mr. William C. Greenfield.

by Mr. William C. Greenfield, kindly given me by him and reproduced in fig. 4. In 1891 Ship Rock had disappeared, and the photographs do not seem to indicate continuous beach between the peaks. In 1895 an apparently clean passage nearly three-quarters of a mile in width separated the two islands. The new island then appeared to be not more than some 300 feet in height. It still steamed vigorously, though not violently, and was colonized to some extent by solan geese. Solfataric decomposition was progressing, with some deposition of sulphur. There was no trace of present or recent volcanic activity on the old island, on which every available nesting place was occupied.

The sketch map of the islands as they existed in 1895 was prepared by Mr. Dall from inspection and some logging, but without survey. Pl. III is from a photograph by Chief Engineer A. L. Broadbent, of the *Corwin*. It is believed to have been taken either in 1884 or in 1885, probably the former, and represents the southerly side of Grewingk. Pls. IV, V, and VI are from photographs taken by Messrs. N. B. Miller and C. H. Townsend, of the United States Fish Commission steamer *Albatross*, in 1891. Pls. VII, VIII, and IX are from photographs by Mr. Purington in 1895.

The islands seem to be composed entirely of hornblende-andesite, with some included fragments of diorite. Nothing sedimentary was detected. The igneous material is ash, agglomerate, and tuff, no solid flows being anywhere observed. The rocks will be described in detail in another portion of this report.

ST. AUGUSTINE VOLCANO.

Mount St. Augustine is a volcanic mountain forming an island in Cook Inlet. It is charted as lying in latitude 59° 23′ and longitude 153° 31′ W. It was discovered and named by Captain Cook, who describes it as of conical figure and of very considerable height. In May, 1794, Vancouver[1] wrote:

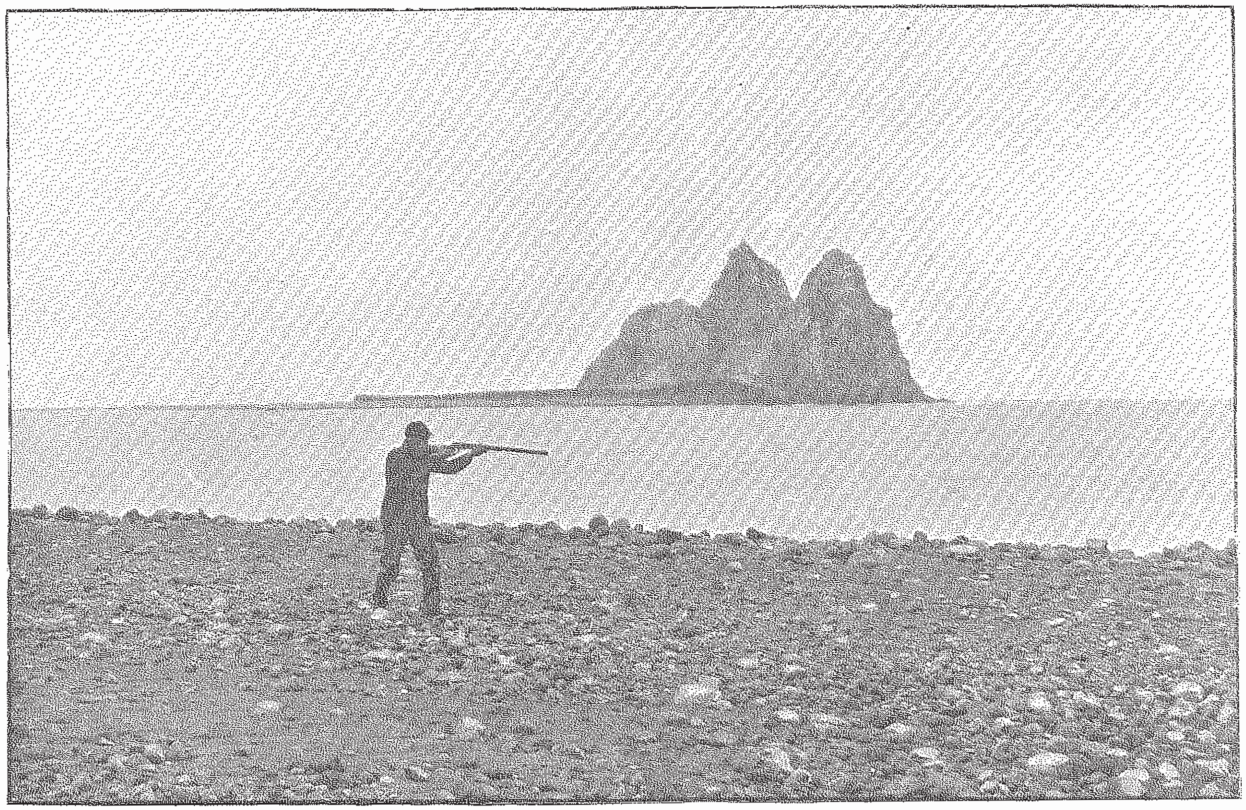
> This island is stated by Mr. Puget to be about 9 leagues in circuit; toward the sea side it is very low, from whence it rises, though regular, with a rather steep ascent, and forms a lofty, uniform, conical mountain, presenting nearly the same appearance from every point of view, and clothed down to the water's edge with snow and ice, through which neither tree nor shrub were seen to protrude.

In 1880, according to Mr. Dall, St. Augustine measured 3,800 feet in height by angles from different stations. The peak was not sharp. It is possible that the height was increased at the last eruption, but the rounding of the summit mentioned by Mr. Dall probably refers to the appearance from the south.[2]

The only historical eruption of St. Augustine occurred in the autumn of 1883, being contemporaneous with the rise of Grewingk or New Bogoslof from Bering Sea. On the morning of October 6, the atmosphere being very clear, the people at Port Graham heard a loud report and saw dense volumes of "smoke" issue from the top of St. Augustine. A column of steam is also said to have arisen from the sea near the island, and the water was so agitated as to make landing or embarkation there impossible. Twenty-five minutes after the explosion a great earthquake wave, 25 or 30 feet high, came in upon Port Graham, and it was followed by others. The fall of ash at this point, 60 miles from the volcano, amounted to 4 or 5 inches. A new island, 1½ miles long and 75 feet high, rose between St. Augustine and the mainland, and a little harbor on the west side of the island was filled up. It was reported immediately after the eruption that the mountain had been split from base to summit in an east-west direction. This last statement is certainly an exaggeration. Mr. Ivan Petroff made drawings of the mountain from three sides eight months after the eruption. They represent it substantially as it existed in 1895, and show that only a shoulder of the mountain had been blown

[1] A Voyage of Discovery to the North Pacific Ocean, book 5, chapter 5.

[2] Science, vol. 3, 1884, February 25.



BOGOSLOF, FROM THE NORTHWEST, IN 1895.

out, exposing a secondary cone within the remaining portion of the outer crater rim.[1] The view given on Pl. X partially shows this break and gives a good general idea of the form of the mountain.

In 1895 the mountain was still emitting steam in varying quantities. The variation could be observed in watching particular vents, but doubtless the apparent quantity was affected by the relative humidity of the atmosphere. At a distance of a few miles the steam was sometimes scarcely visible, while at one time it ascended to fully twice the height of the mountain above the summit. On ascending to the edge of the crater it was found that steam escaped from countless crevices, most of them on the inner cone. This was blanched and reddened by solfataric action, and masses were from time to time detached, rolling down to the bottom of the deep moat which separates the outer crater wall from the inner cone. So continuous was this disintegration as to excite wonder that any moat remained. During the two hours which I spent in watching on the outer edge of the crater, it was estimated that not more than thirty consecutive seconds elapsed during which masses of rock were not clattering down that portion of the inner cone which was in sight from my station. Though relatively small, these pieces of rock were often many tons in weight. The inner cone being nearly as high as the outer rim, not more than a third of its surface was visible.

The outer crater rim was estimated at about 1,200 feet in diameter, but was perhaps wider than this. The inner wall of the outer rim was nearly vertical, and showed well-developed columnar structure. The moat was 600 or 800 feet deep. The northwestern side of the outer crater was broken through, and a solidified lava stream extended from it nearly to the water's edge. Evidently the ash must greatly have exceeded the liquid ejecta in quantity at the eruption of 1883.[2] The new island has entirely disappeared. It may have been a mass of floating or lightly grounded pumice.

The mountain is very largely composed of ash, but solid lava is by no means lacking. The prevalent type is apparently an asperite, or andesite of trachytic texture, and clearly in the main a pyroxenic rock. Portions of the rock are black and glassy, and on many masses shrinkage cracks are very apparent.

The form of the mountain, as seen from the south at a distance of a few miles, is very symmetrical, and corresponds closely to the locus assigned to such mountains in another part of this report. From this point of view the actual summit appears rounded, a fact due to an accidental irregularity in the lip of the outer crater wall. When

[1] Prof. George Davidson collected the accounts of this eruption (Science, vol. 3, February 15, 1884). He also showed me Petroff's drawings.

[2] It is possible that Mr. Purington and I were the first human beings to ascend this peak. The natives avoid such places with superstitious dread, and fur hunters are generally too busy. I could not learn that the ascent had ever been made. It had once been attempted without success.

ascending the mountain the local topography is found to be very irregular, and it strikes the climber with astonishment that the distant view can bring general order out of such chaotic details. When seen at a distance from other points of view, St. Augustine is less regular. There is a bit of a shoulder on the southern side, and the broken crater mars the symmetry from the north, but from all points the tendency toward a symmetrical form is apparent.

PLAGIOCLASE DETERMINATIONS.

In examining the rocks described in this report pains was taken to determine the species of the lime-soda feldspars by modern methods. The difference of refraction between a mineral and the balsam or between two minerals in contact, according to the method of Prof. F. Becke, is often useful, and Prof. J. E. Wolff was good enough to determine for me the index of refraction (1.5393) of the Canada balsam used in the final mounting of the slides of this Survey. Much more useful still is the method which Prof. A. Michel-Lévy has developed in two memoirs which should be in the hands of all petrographers.[1] It was intended also that the Fédoroff table should be used in connection with the examinations, but unforseen delays in procuring this bit of apparatus prevented its application on an extended scale. The method of Professor Michel-Lévy does not necessitate the use of the Fédoroff table, at least in rocks which show an abundance of well-developed feldspars.

In such rocks it is usually sufficient to deal with the feldspars, which are cut nearly perpendicular to the brachypinacoid (010) or g^1 or $\infty P \breve{\infty}$. When a crystal is cut in this zone, of course the albite twin lamellæ extinguish at equal angles on opposite sides of the cross-hair of the microscope. When a crystal is twinned both according to the albite law and the Carlsbad law, this fact can be detected by placing the trace of the twinning plane at an angle of 45° to the principal sections of the nicols. The associated albite twins are then equally illuminated and cease to be apparent. On the other hand, the Carlsbad twins are not then equally illuminated, so that a crystal twinned according to both laws seems to resolve itself into a mere Carlsbad twin. The Carlsbad junction commonly shows signs of interpenetration, and is broken or irregular, while the albite junctions are straight. Supposing such a section in the zone under discussion, one has in general two sets of albite lamellæ, each extinguishing at an equal angle to the cross-hairs, but each pair at a different angle; and furthermore, the orientations of the two pairs of albite lamellæ bear a definite relation to each other, because the difference of orientation is due to Carlsbad twinning. If angles in the zone are counted from the front edge of the prism, and if one pair of albite lamellæ is cut by a plane making an angle φ with the front edge, then the other pair of

[1] Étude sur la détermination des feldspaths, 1894. Same, second fascicle, 1896.

GREWINGK, FROM THE SOUTHEAST, IN 1895.

lamellæ is cut at an angle of $180°-\varphi$ to the same edge. Professor Michel-Lévy's beautiful stereographic projections (first fascicle) show how the extinctions in such cases will arrange themselves. He has also plotted the extinctions for this particular zone, and shows that when a compound albite-Carlsbad twin is cut in this zone it can in almost all cases at once be referred to its proper species and its proper orientation.

By some mischance errors have crept into this diagram of the extinctions of the feldspars in the zone of symmetry, and I have taken the liberty of replotting it on Pl. XI (p. 36) from the stereographic projections. I have also added plots of the extinctions at 10° from the zone of symmetry in either direction. In a thin section of a rock the chances are infinitely against any feldspar being cut with mathematical precision in the zone of symmetry. Hence the question at once arises how the extinctions will vary in case the plane of symmetry is slightly inclined. These supplementary diagrams give this information at a glance and assure the observer whether or no the variation of the orientation from the position of exact symmetry precludes precise determination.

In a very great number of cases feldspars exhibit traces of zonal structure due to gradual variation in the composition of the successively deposited layers of the crystal. Professor Michel-Lévy has shown in his second fascicle that if one regards the several plagioclases as mere mixtures of albite and anorthite, instead of as independent species, the position of equal zonal illumination is absolutely characteristic of the orientation of a feldspar in the zone of symmetry. There is only one angle in each quadrant at which equal zonal illumination occurs. This method can be used, for example, in determining when a crystal is cut so nearly perpendicular to the prismatic axis that the extinction of Carlsbad lamellæ should be taken upon opposite sides of the cross-hair. In that case the angle of equal zonal illumination can not exceed 11°. The angle of equal illumination as a rule is less sharply determinable than, for example, that of equal illumination of albite lamellæ.

In his second fascicle Michel-Lévy regards all the plagioclases as mere mixtures of albite and anorthite, and defines the special occurrences in percentages. There is, of course, a very great amount of evidence for this position, and, so far as the needs of the working lithologist are concerned, it is probably without sensible error. At the same time it may be remarked that were there no dissipation of energy accompanying the union of the albite and anorthite they would not tend to unite. The liberation of energy corresponding to their actual tendency to union must, one would think, be accompanied by some modification in physical qualities; but this change, so far as known, is negligibly small.

Michel-Lévy's new attitude toward the feldspars involves some slight changes in the diagrams. He has given a new diagram for the extinctions in the zone of symmetry, showing the zero angle for the same orientation in all varieties. He does not give a new set of stereographic projections for the several species, and the means are therefore not at hand for plotting the extinctions at 10° from the zone of symmetry. For this reason I have not redrawn the diagram given above of the extinctions. The changes which would be involved appear inconsiderable, and I have found the diagrams for what may be called latitude ±10° too useful to be willing to abandon them. It should be noted that Michel-Lévy's new fascicle gives stereographic diagrams for microcline.[1]

While the zone of symmetry is the most useful one, and is usually sufficient where material is abundant, cases also arise in which other parts of the stereographic projections are indispensable. When needful, a skillful use of the stereographic projections will suffice to determine almost any doubly twinned phenocrysts, however cut, and sometimes mere albite twins. With the aid of the Fédoroff or Klein stages any phenocrystic albite twin can be determined, but the use of such a table involves the application of low powers only.

While Michel-Lévy's method of Carlsbad twins, referred to above, is usually sufficient to determine the species of the feldspars of primary generation in porphyritic rocks, it is not easily applicable to the microlitic feldspars of secondary consolidation. Such microlites are twinned, according to both the albite and Carlsbad laws, less frequently than are the phenocrysts; they are also often entirely embedded in groundmass which obscures the extinctions, and relatively high powers must be employed in examining them. Nevertheless, with patience and good eyesight, determinations can often be made. Such determinations have been used as a check upon another method which presents no difficulties, and which will now be described.

In studying the groundmass of lavas from Alaska and California, I have observed many minute, nearly square, sections of plagioclase microlites.[2] These sometimes show albite twinning parallel to one pair of sides, while in more numerous cases no twinning is visible.

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[1] Taking albite as $NaAlSi_3O_8$, molecular weight 263.36, and anorthite as $CaAl_2Si_2O_8$, molecular weight 279.09, I find the following percentages of anorthite in the several feldspars. Michel-Lévy gives somewhat different values in his second fascicle, page 107.

Feldspar.	Symbol.	Percentage of anorthite.
Albite	Ab	0
Sodic oligoclase	Ab_4An_1	20.95
Calcareous oligoclase	Ab_3An_1	26.11
Andesine	Ab_5An_3	38.88
Sodic labradorite	Ab_1An_1	51.45
Calcareous labradorite	Ab_3An_4	58.55
Anorthite	$Ab_{11}An_{200}$	95.06

[2] The length of a side is usually less than two one-hundredths of a millimeter. Sometimes there are two generations of microlites.

GREWINGK, WEST SIDE, IN 1895.

They also in some cases exhibit a truncated corner. It appears probable that these microlites are elongated in the direction of the edge between the base and the brachypinacoid, and that they are cut nearly at right angles to this edge, being occasionally truncated by a hemi-domal face. This suspicion is confirmed by comparison between the extinctions of such square sections and those of microlites in the same slides which show both albite and Carlsbad twinnings. An elongation in the direction of this edge is also to be expected from Bravais's theory of crystallization; the two faces, base and brachypinacoid, being those of perfect cleavage. Where such microlites present themselves it is easy to see whether they are cut perpendicularly to their axes by following the microlite through the slide; for if the little prism is inclined, the image in focus will shift laterally as the objective moves.

Now it happens that prisms bounded by these faces, and in a vertical position, are very favorably situated for discrimination. This will appear by examining Michel-Lévy's stereographic projections of the various feldspars at 90° to the pole *p*. In this neighborhood there is a saddle in the extinction surfaces of the feldspars (the central point of the saddle answering to Michel-Lévy's "most frequent extinction"), and the consequence is that an inclination of even 10° affects the extinction of a square microlite section very little. Furthermore, the difference between the behavior of different feldspars is great, so that a confusion between the different species is almost impossible, as may be seen from the little table below.[1]

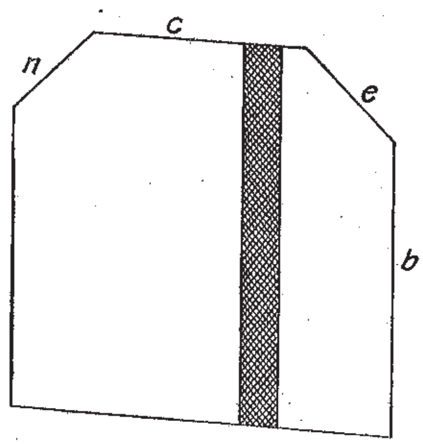


FIG. 5.—Cross-section of bacillar feldspar microlite.

In favorable cases the sign of the extinction can be made useful in the determination of these microlites, which are not really square. In albite the faces *c* (001) and *b* (010) make an angle of 86° 24′, while in anorthite this angle becomes 85° 50′. The divergence from rectangularity is thus sensible, and the proper position of the crystal is then with an acute angle in the upper left-hand quadrant (fig. 5). When the hemi-domal faces appear, *n* (021) truncates the acute angle, making sensibly equal angles of between 46° and 47° with the adjoining faces. The other corresponding hemidome, *e* (021), truncates the

[1] In this table the percentages of anorthite are given as they appear in Michel-Lévy's work. As is mentioned above, these do not answer precisely to the molecular formulas, but whether the formulas or the percentages need correction I am not certain.

obtuse angle and makes angles of from 42° to 43° with the adjoining faces. Andesine and albite can thus be discriminated when orientation is practicable. This discrimination can be confirmed by testing the index of refraction. Andesine has about the same index of refraction as quartz, and a higher index than balsam, while albite has a lower index than either.

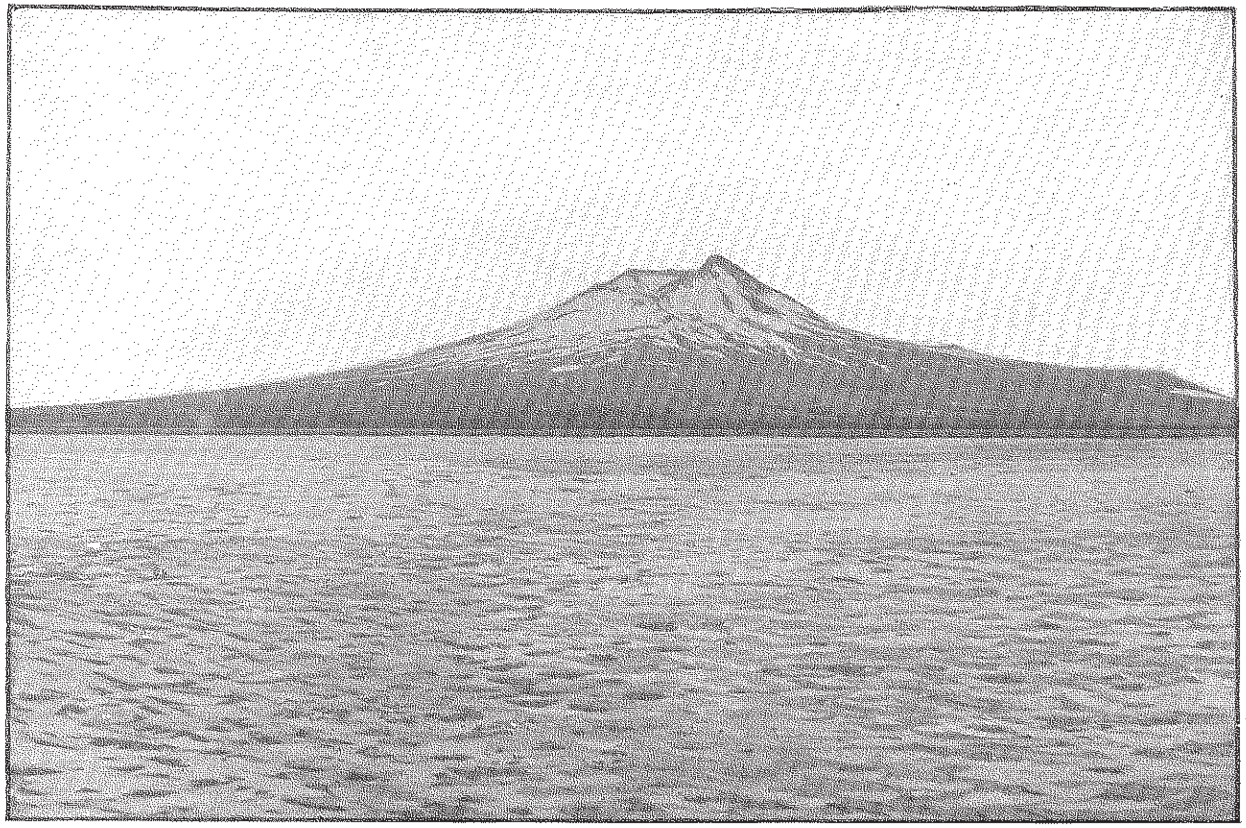
Orthoclase microlites would be exactly square; they would not show polysynthetic twinning, and the index of refraction is much lower than that of oligoclase, which, like orthoclase, extinguishes at 0°.

Extinction of nearly square sections of feldspar microlites cut within 10° of the perpendicular to the edge (001) (010).

Feldspar.	Composition.	Extinction.
		° °
Anorthite	$Ab_{11}\ An_{200}$=96 % An	+42½±3½
Calcareous labradorite	$Ab_3\ An_4$ =60 % An	+38 ±3
Sodic labradorite	$Ab_1\ An_1$ =47 % An	+26½±2½
Andesine	$Ab_5\ An_3$ =34 % An	+16 ±2
Calcareous oligoclase	$Ab_3\ An_1$ =28 % An	+ 4 ±1½
Sodic oligoclase	$Ab_4\ An_1$ =18 % An	+ 0 ±1½
Albite	Ab = 0 % An	−13 ±2½

It need not be said that in many rocks the determination of the microlites is quite as important as that of the phenocrysts, their united volume often equaling or exceeding that of the larger crystals. It is also extremely interesting to compare the character of the two generations. It is usually stated or assumed that the microlites are all of one species. The examination of the square sections, of which a dozen or two are often visible in a single slide, leads me to a different conclusion. As a rule the majority do belong to a single species, but it is seldom that two or three out of ten do not belong to a different species; in short, the microlites in the slides I have examined show an irregularity of species of the same order as, and often greater than, that of the phenocrysts. The square sections often show zonal structure, and nearly always the exterior portion is more alkaline than the inner portion; but in a couple of cases this order was found to be reversed. Occasional reversals of this sort are to be found among phenocrysts also. These facts clearly show that even the residual mother liquor of a consolidating lava is far from homogeneous, even over the area of a square centimeter, and therefore, also, that diffusion in such a liquid must be extremely slow, since diffusion would bring about homogeneity.

The existence of rod-shaped microlites, in connection with the fact that some of them show Carlsbad twinning, throws some light on the



MOUNT ST. AUGUSTINE, FROM THE SOUTHWEST, IN 1895.

origin of twinning. If Carlsbad lamellæ of bacillar shape developed in contiguity but independently, they would form X-shaped crystals. These are said to occur, but are not common in my experience.[1] In the bacillar microlites under discussion one lamella has controlled the development of the rod, and the other lamella has accommodated itself. It is difficult to see how this could happen in mere crystallization, for why should one part resign its tendency to elongation in the direction of the cleavage edge? On the other hand, it is well known, from the investigations of Messrs. Max Baur, O. Mugge, L. van Werweke, J. W. Judd, and others, that there is much reason to ascribe polysynthetic structure largely to stresses called in play by the cooling process. This theory would fully explain the bacillar microlites as well as some beautiful cases of bent phenocrysts where twinning by various laws stands in manifest relation to flexure. It would also afford an explanation of the fact, of which comparison has convinced me, that twinning is less frequent in the microlites than in the phenocrysts, for the smaller the crystal the less is the chance that external stresses upon it would reach the intensity needful to produce mechanical twinning.

In the same connection it may be noted that stresses such as would lead to the mechanical twinning of plagioclases would also set up a mechanical æolotropy in glass. As a matter of experience, I have found it extremely difficult to detect any absolutely isotropic base in some lavas which I had reason to believe contained a small amount of glass. The faint variation of tints observed with the gypsum plate between crossed nicols in such cases may, perhaps, have been due to strain and not to crystalline symmetry of structure.

LITHOLOGICAL NOTES.

GRANITE.

True granite is widely distributed in southern Alaska, but so far as the observations recorded in this report go this rock is of small relative importance. The rocks which in the field might be taken for granite are more often diorities. Dr. George M. Dawson reports that the hornblende-granites of the coast ranges extend in two, and perhaps in three, parallel ranges, with intervals, as far northward as Fortymile Creek. Some of these granites have been described petrographically by Dr. F. D. Adams.[2] Dr. Dall mentions granite as occurring on the Yukon River at the mouth of the Tanana, and Lieut. H. T. Allen vaguely mentions granite on the Tanana River.[3] Mr. C. W. Hayes[4] also refers to rocks regarded in the field as granite, at

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[1] That phenocrysts often take the form of fully developed Carlsbad twins is well known.
[2] Geol. Nat. Hist. Survey, Canada, Ann. Rept., vol. 3, part 1, 1887, p. 31 B.
[3] Reconn. Tanana, Copper, and Koyukuk, 1887.
[4] Nat. Geog. Mag., vol. 4, 1892, p. 139.

different points on the Taku River and along his path to the Copper River, including the region northeast of Mount St. Elias range.

In the examinations made for this report, granite was found at Juneau Island, which lies near the Alaska-Treadwell mine, at Funters Bay on Admiralty Island, and at Hot Springs, Baranof Island. A rock collected at the Bald Eagle mine, Sumdum Harbor, is probably a granite, but it is too much decomposed for satisfactory determination. The southern end of the ridge running along the westerly coast of Kadiak Island is called Saddleback, and is granitic, and bowlders found on this coast seem to indicate that there is an area of the rock of considerable size. Finally, on Nagai Island in the Shumagin group granite occurs, as appears from specimens in the National Museum collected by Mr. Dall.

The granite from Juneau Island is a coarse rock of originally normal composition, though now considerably decomposed. It has much original quartz, accompanied by orthoclase, albite, and muscovite, both primary and secondary. The original ferromagnesian silicates have disappeared, but secondary epidote in remarkably large crystals and secondary muscovite are abundant. In a granite from Wrangell Island Dr. Adams found epidote, which he thinks an original constituent. The granite from Funters Bay is somewhat gneissoid and contains much rutile. It is a muscovite-orthoclase rock. At the hot springs on Baranof Island the mass of the granite is normal and contains orthoclase and albite with biotite, but there are also dark streaks in the rock ("schlieren") which contain much andesine-feldspar. A pebble or bowlder from the west shore of Kadiak is a normal muscovite-granite containing a certain amount of a feldspar showing well-developed albite and pericline twinning, but not presenting exactly the appearance of microcline. When examined on a Klein table it appears to have an extinction curve not identical with that of microcline, but nearly parallel to it, giving extinctions of 4° or 5° less than microcline should. Such a depression would be caused by the partial replacement of potash by soda, and the mineral is probably one of the so-called anorthoclases. The other granites mentioned above seem to call for no remark.

DIORITES AND SODIUM-SYENITES.

It was formerly the habit to divide feldspathic rocks into two great groups—the orthoclase rocks and the plagioclase rocks.[1] The prevailing custom is now to draw the line of division between the alkali-feldspar rocks and the soda-lime-feldspar rocks. The classification of rocks at the present day is a very arbitrary matter, and it will perhaps always remain so, yet there are cases in which of two possible

[1] See for example U. S. Geol. Expl. Fortieth Par., vol. 6, 1876, by Prof. F. Zirkel, who, on the subject of definitions, is an excellent authority.

groupings one has advantages over the other. The union of the sodium and potassium feldspars preserves a chemical type, since both of them are polysilicates, although one member of the group crystallizes in a different system from the others. The fundamental idea of this grouping seems to be that sodium and potassium are so closely allied hat they should not be divided, yet it is well known that they do not form parallel series of compounds, sodium salts being more closely isomorphous with those of lithium and silver than with the other alkalies, K, Cs, Rb, Am.[1]

But even the chemical type is not preserved in both rock divisions by this classification. Schuster defined albite as ranging from $Ab_5 An_1$ to $Ab_2 An_1$. If the feldspar of a diorite is $Ab_5 An_1$, then 82½ per cent of this feldspar is sodium-aluminium polysilicate. Now, ordinarily, majorities rule in lithology; and if alkalis are to be pitted against calcium, it would seem more rational to draw the line of demarcation at $(Ab, Or)_1 An_1$. Such a distinction has been proposed between andesites and basalts, and in my opinion it would be more expedient in the case of granites or syenites and diorite than that at present received.

On the other hand, the calcium-sodium-feldspars form a continuous series, the most important in the whole field of petrography. This group of minerals forms an entity, if there is such a thing in mineralogy, and naturally this entity embraces both extremes, both of the two components which in mixture form the series. Is it rational to make a single group of all of this series excepting one of the extremes, and to class this indispensable component in a distinct group? To do so is to ignore the serial character of the feldspars, and that without any compensating theoretical or practical advantage. It appears to me also less consistent with the occurrence of rocks than a division into a potassium-feldspar group and a sodium-calcium-feldspar group. Normal diorites with a large predominance of the albite molecule are common, and there seems to be a complete gradation to a substantially pure albitic rock. Normal granites are characteristically orthoclastic or microclinic; granites with feldspars which may be written $Ab_3 Or_1$, $Ab_4 Or_1$, $Ab_5 Or_1$ are not common. The "sodium-granites" and "sodium-syenites," furthermore, appear to occur rather as dikes, and in regions where diorite dikes are abundant, than like granite, in vast massifs; and there are other indications which point in the same direction. This aspect of the matter, however, would require monographic treatment.

While, then, in compliance with prevailing custom, I shall use the term sodium-syenite in this paper, I do so with reluctancé, and believe that sodium-diorite or albite-diorite would be a more suitable term.

[1] Among other instances in the mineral kingdom, consider leucite and jadeite. The empirical formula is the same, excepting that one is a sodium compound and the other is a potassium compound, but there the likeness ends.

TREADWELL SODIUM-SYENITE.

From an economic point of view the syenite of the Treadwell-Alaska mine is the most important in the Territory, for it is in this rock that the greater part of the famous gold deposit occurs. The mass is fissured or reticulated; the fragments are surrounded by ore, and are impregnated with it, as will be more fully set forth in describing the mine. Most of the rock is greatly decomposed, as may be inferred from its relation to the ore, and it is not an easy matter to ascertain its original character.[1] Much pains was taken to collect the best material available for examination. In an unaltered state this granular rock consisted mainly of albite. A considerable amount of oligoclase was intergrown with the albite, and more basic plagioclases existed in very subordinate quantities. The ferromagnesian silicates have disappeared from most of the specimens, and it is impossible to say in what proportion the various minerals of this group were originally present, but the indications are that augite predominated over hornblende, with some local exceptions. Biotite was also an original constituent. As accessory constituents, the rock contains apatite, zircon, and (in association with biotite) rutile.

The freshest specimen of the rock obtained is a fragment included in gabbro (specimen 90). It contains more quartz than most of the rock, and the albitic feldspars are often broken into fragments, as if the specimen represented a pyroclastic facies of the syenite.

Quartz is not abundant in the slides, and in almost all cases in which this mineral is determinable by the help of Becke's method it appears to be secondary. There is a considerable amount of unstriated feldspar, all of a smaller refractive index than Canada balsam. This feldspar, however, does not present the typical appearance of orthoclase under the microscope, and chemical tests appear to preclude its determination as orthoclase. The following is a complete analysis, by Dr. W. F. Hillebrand, of specimen 95, which is one of the freshest in the collection. The analysis, when reduced to molecular terms, shows that the feldspar should be almost pure albite.

[1] This rock was described by Prof. F. D. Adams from a few small specimens as granite. The scantiness of the material and its decomposed character no doubt account for this reference. Am. Geologist, August, 1889.

Analysis of Alaska-Treadwell syenite, No. 95.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	63.01
TiO_2	.13
Al_2O_3	18.48
Fe_2O_3	.06
FeO	.32
MnO	.06
CaO	2.66
SrO	trace
BaO	.02
MgO	.06
K_2O	.39
Na_2O	10.01
H_2O, below 110° C	.05
H_2O, above 110° C	.27
P_2O_5	.06
FeS_2	2.10
CO_2	2.01
Total	99.69

There is thus twenty-five times as much soda as potash in the rock, and even if the whole amount of potash were present as pure orthoclase the quantity of this mineral would be trifling. On the other hand, most albite contains as much potash as this analysis shows. The analysis also indicates that there is a deficiency rather than an excess of silica, so that the effect of the partial decomposition of the feldspar has been to remove silica. Another specimen (76) shows feldspars similar to those of the rock analyzed. A test was made on the thin section with hydrofluosilicic acid, the result of which was to show abundant soda but no sensible amount of potash. Tests by the same chemical method were made also on doubtful feldspars in other slides of this rock, and specific gravity determinations of the mineral were resorted to in still other cases. All gave accordant results.

The decomposition which this diorite has undergone is manifold. The large amount of calcite present can hardly have been derived from the decomposition of the plagioclases, for the anorthite molecule plays a very subordinate part in the composition of the rock. On the other hand, in the reticule of stringers intersecting the rock quartz vastly predominates, though not to the total exclusion of calcite. Hence, just as in the Ophir district, studied by Mr. Lindgren, it seems that calcite in solution has probably permeated the rock, leaving the silica mainly in the fissures.[1]

Pyrite is abundant in the rock as a secondary mineral, and is often intimately associated with the calcite. This pyrite might have entered the rock as a solution of iron sulphide; or it may be that it is the result of the action of a solution of sulphydric acid on the ferrous-rock components. I incline to believe that the pyrite is mainly due to the latter process, for reasons which will be stated in discussing the ore. That epidote and chlorite should be found in the decomposed rock is almost a matter of course. Zoisite also occurs in some slides as a decomposition product. A green mica is found in some of the slides in such intimate association with the calcite and pyrite as to leave no doubt as to its secondary character.

Mr. Turner informs me of an occurrence in California which deserves to be noted in comparison with that of the Treadwell. It is a sodium-syenite dike to the eastward of Moccasin Creek, Tuolumne County, which is mineralized to a considerable extent, portions of it containing low-grade gold ore.

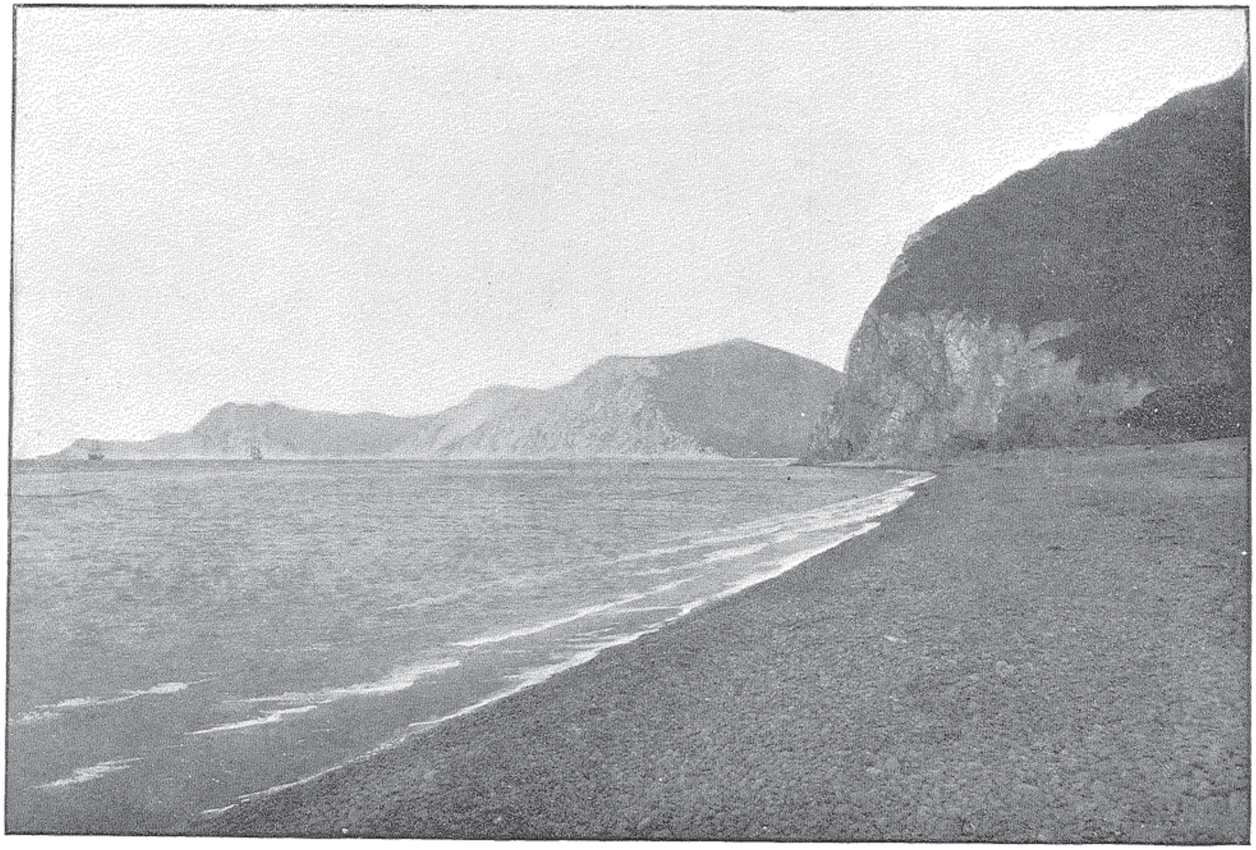
OTHER OCCURRENCES.

Besides the Treadwell rock the only albitic syenite met with occurs as a dike in the granite near Hot Springs, on Baranof Island. This dike presents a somewhat peculiar appearance under the microscope, the feldspar being very imperfectly striated and being mingled with the hornblende in ragged shreds and patches rather than in defined crystals. The hornblende is present in greenish-brown needles, many of them being skeleton crystals, and usually possessing sharp outlines, indicative of early crystallization. The only other original constituent appears to be iron ore, mostly octahedral in form, but seemingly accompanied by a certain amount of leucoxene. The rock appears to have chilled rapidly and the feldspar is clearly the youngest constituent. It has a lower index of refraction than balsam and gives extinctions appropriate to albite.

At the Lane and Hayward, and the Bennet properties in Silver Bow Basin, there are three dikes parallel to one another and about 6 feet wide. The rock is a diorite, the feldspars showing an ophitic structure, though there is no augite present. Hornblende and biotite are the ferromagnesian silicates, and magnetite and quartz in small grains fill the spaces between the larger crystals. Chlorite, epidote, and muscovite are present as decomposition products. The feldspars are not well twinned and do not show good crystal outlines; a few, however, are in a position to be determined and prove to be more or less calcareous labradorite.

The diorite from the Bear mine, in Berners Bay, is coarse and granular, and bears considerable resemblance in hand specimens to the

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 276.



DIORITE CLIFFS AT KARLUK.

rock of the Treadwell mine; under the microscope, however, it appears considerably more idiomorphic and the feldspar is much more anorthitic, ranging from acid labradorite toward albite. The ferromagnesian silicate is chiefly hornblende, which is present in very considerable quantities. There is a small amount of original quartz in this rock. Zoisite and the usual decomposition products of ferromagnesian silicates are present. The rock at the Comet mine is similar to that of the Bear.

At Karluk, on the northwest coast of Kadiak Island, there are magnificent cliffs of an interesting hypidiomorphic diorite. The face of the cliffs, of which a general view is given on Pl. XII, is partly gray and partly black, the two colors manifestly belonging to allied rocks, which, however, are so mingled that it seems impossible to determine by mere inspection whether they represent successive intrusions, imperfectly separated masses, or a partial solution of one material in the other. The rock is extremely fresh, and under the microscope is seen to vary in composition with the color. The gray rock is a quartz-diorite containing hornblende, biotite, and labradorite. The analysis of this rock given below, made by Dr. W. F. Hillebrand, evidently answers to the composition ascertained under the microscope. The dark streaks and patches are more porphyritic than the gray portions just described. They consist of a peculiar reddish feldspar with the optical qualities of anorthite, embedded in a groundmass composed mainly of green hornblende, a little biotite, and quartz mingled with some feldspar. The microlites of the groundmass as well as the phenocrysts are anorthite. Needles of apatite and grains of magnetite are also present. The black diorite contains much more lime and much less soda than the gray material, as the partial analysis given below shows. Considering the relations of the chemical composition, it appears to me probable that the dark material in this diorite corresponds to the blebs so often found in granite and granodiorite, and that while the two materials have always been associated they have never been thoroughly mingled.

Analysis of Karluk diorite.

[By Dr. W. F. Hillebrand.]

	Karluk diorite No. 213.	Karluk diorite No. 211 (ferromagnesian facies).
SiO_2	61.58	54.26
TiO_2	.63	----------
Al_2O_3	15.89	----------
Fe_2O_3	2.19	----------
FeO	5.50	----------
MnO	.20	----------
CaO	6.49	8.88
BaO	.06	----------
MgO	2.69	----------
K_2O	.51	.64
Na_2O	3.04	1.99
H_2O, below 110° C	.16	----------
H_2O, above 110° C	1.26	----------
P_2O_5	.12	----------
FeS_2	.06	----------
Total	100.38	----------

A very handsome diorite occurs abundantly in and about the island of Unalaska. This rock has often been referred to by previous visitors as a granite. It occurs at Captains Bay and on Amaknak Island, and seems to be abundant through the interior of the larger island, occupying a considerable area in the Amber Range east of Makushin Bay. In its typical occurrences this rock is remarkably fresh. The feldspars were found to range from andesine to bytownite, the majority lying between acid and basic labradorite. The ferromagnesian silicates include biotite, hornblende, and augite, of which the first is the most abundant. The hornblende and augite are frequently intergrown. The rock contains a very moderate amount of quartz, most of which occupies interstices between the hypidiomorphic silicates. The various occurrences differ from one another chiefly in minor variations in the relative quantities of the constituent minerals.

On the island of Bogoslof a fragment of granular rock was found included in the andesitic lava. This inclusion is a diorite of the same general appearance as that just described, and showing under the microscope a composition indistinguishable from that of the Unalaska rock. No doubt the andesite broke through earlier intrusions of this rock, which is, of course, allied in composition to the more recent lava. It is probable that the two rocks represent recurrent phases of eruptivity.

Another rock similar to that of Unalaska was collected by Mr. Dall many years since at Nushagak, on the north shore of Bristol Bay. Some of the feldspars in this rock appear to be somewhat more alkaline than the diorite of Unalaska. Mr. Dall's collection also contains a diorite from Saranna Bay, on the island of Attu, the westernmost possession of the United States. It is a fine-grained granular rock consisting chiefly of labradorite, hornblende, and augite.

PYROCLASTIC DIORITE.

A very peculiar rock occurs in the neighborhood of Sitka, and appears also to be of very widespread occurrence throughout the Territory of Alaska. So far as the neighborhood of Sitka is concerned, this rock long ago attracted the attention of geologists. The first description appears to be by E. Hoffman, in his Geognostic Observations, collected on a journey around the world in 1829. He says, in substance: In the neighborhood of New Archangel the rocks consist of a fine-grained, siliceous graywacke, which contains clay-slate in long and short strips, and sometimes alternates with this rock as if interbedded. This remark apparently refers to the occurrences at the mouth of Indian River, on the easterly side of the river, where there are a number of tidal islets upon which the rock can be observed with great facility. At this locality the material is rather fine-grained, and exhibits no schistosity, though showing many irregularly distributed joints. It contains blebs similar to those found in diorites, andesites, and other igneous rocks, distinguished from the main mass by their darker color and finer grain. The rock here contains numerous masses of slate, which is thoroughly cleavable and often coal-black in color. These masses of slate vary in size from 10 or 20 feet in width to the smallest dimensions; indeed, in portions of the rock the mass is peppered with minute chips of slate no more than a quarter of an inch thick. The larger masses of slate strike with very considerable regularity about N. 40° W., true, and they contain stringers of the imbedding material. It is proper to observe that the complete cleavage of the included masses of slate indicates that the intrusion of the pyroclastic mass occurred after the country had been affected by the slaty structure.

The same rock is found in very widely dispersed localities elsewhere. It constitutes the main part of the country near Silver Bay, where it is clearly intrusive. It was found on the little island of Ugak, near Kadiak Island; it is believed to exist at the mouth of Copper River, Prince William Sound; it was found at the head of Cook Inlet, on Turnagain Arm; there is a probable occurrence of it on the northwest side of Red Cove, Popof Island, and a specimen has been inspected from Nushagak, on the north shore of Bristol Bay; it occurs in pebbles on the west shore of Kadiak Island and on the south side of Kachemak Bay, Cook Inlet. It would seem from the descriptions by Mr. H. P. Cushing[1] that the same rock occurs on the north shore of Glacier Bay near the Muir glacier. Specimens of this rock, however, were not submitted to Prof. George H. Williams for microscopic study.

While the field occurrence of this rock seems to leave substantially no doubt of its intrusive character, slides examined under the microscope present an extremely unusual appearance for an igneous rock. Specimen 172, from the mouth of Indian River, has been selected as a type. The hand specimen shows a blackish-brown mass with an almost equal proportion of white grains, which under a lens are seen to be incomplete grains of quartz and feldspar. Under the microscope it is found that this rock contains phenocrysts retaining to a considerable extent the form of dihexahedra.

This mineral is accompanied by striated and unstriated feldspar in small amount, together with relatively few pyroxene crystals and irregular fragments of black slate. The groundmass forms a relatively small proportion of the slide. The augite phenocrysts, which are few in number, have idiomorphic form in only one or two cases. There is also one remnant of dichroic brown hornblende. Biotite existed in the rock when fresh, but it is now almost converted into chlorite. The rock contains chlorite, calcite, and muscovite as secondary products. The feldspars are partly striated, and all such refract more highly than Canada balsam. The feldspars can be determined only with difficulty by their optical characters, but one sharp determination was made for oligoclase. They are faulted to a very great extent, and in one case a very beautiful micropegmatitic structure is visible. They are also to a considerable extent decomposed, and some of their outlines are entirely filled with decomposed products. The unstriated feldspar, if there be any such, is indeterminable on account of decomposition. The most numerous phenocrysts are those of quartz. These have undergone no decomposition, and in some cases have retained their original outline, namely, that of short, doubly terminated prisms. The quartzes are much the most remarkable of the rock components. In a great majority of cases they have been crushed and exhibit a fairly regular dynamic cleavage, the planes being apparently parallel to the pyramidal faces *r* or *z*, these cleavages being nearly at right angles to one another. These appear to correspond to Reusch's Gleitflaechen, which Professor Judd has described as developed in crushed or strained quartz. The groundmass of the rock is difficult to distinguish from areas of decomposition and accumulations of fragments due to dynamic action. Areas of closely packed feldspar microlites with low-angle extinction seem, however, to represent the real groundmass.

[1] Nat. Geog. Mag., Vol. IV, 1892, p. 57.

From the above description it appears that the microscopic character of this rock resembles that of a sandstone almost as much as it does that of an igneous rock. Nevertheless, it presents features which seem to be clearly igneous, and taken in connection with the field occurrence, the only explanation seems to be that the mass has been intruded, not in the condition of an ordinary fluid magma like that of modern lavas, but in a semisolid, more or less pasty state, an emulsion so stiff as to permit of rupture of the minerals in the process of forcible injection. Even on this hypothesis it is difficult to comprehend how such minute comminution can possibly have taken place. That an occasional quartz should be broken is not strange, but that so large a proportion of the quartzes should have a superinduced cleavage is extraordinary. It was only after many tests that I was able to convince myself of the true character of this mineral. Two specimens of the rock have been analyzed by Dr. W. F. Hillebrand. One of these is the specimen 172, from Sitka, already described, and the other was collected on Bear Creek, in Turnagain Arm, some 500 miles from 172. The analyses showed the following composition:

Analyses of pyroclastic diorite.

[By Dr. W. F. Hillebrand.]

	Specimen 172.	Specimen 233.
SiO_2	65.94	62.92
TiO_2	.80	.84
Al_2O_3	13.74	14.29
Fe_2O_3	.49	.84
FeO	5.21	4.66
NiO	trace	trace
MnO	.11	.15
CaO	2.87	2.72
SrO	trace	trace
BaO	.12	.10
MgO	2.33	3.14
K_2O	1.63	1.39
Na_2O	2.80	4.30
Li_2O	trace	trace
H_2O below 110° C	.21	.22
H_2O above 110° C	2.59	2.84
P_2O_5	.21	.13
FeS_2	.41	.32
CO_2	.59	1.24
Carbon from carbonaceous matter	.20	
Fl	?	
Total	100.25	100.10

It will be seen that these analyses show a strong likeness to each other. When reduced to molecular terms it appears that No. 172 should contain an average feldspar intermediate between andesine and oligoclase, but nearer the latter than the former. The metasilicates and free quartz should be present in about equal molecular proportions. In No. 233, from Bear Creek, Turnagain Arm, the feldspar is, or should be, oligoclase. The metasilicates and free quartz are present in about the same proportions as in the Sitka rock. The extent of the occurrence represented by No. 233 is quite unknown and may be great.

A few notes may be made on other specimens of this pyroclastic diorite. No. 174 is from a dark, elongated bleb in the rock near Sitka. Its dark color appears to be due to an accumulation of brown hornblende accompanied by very small amounts of augite. The unstriated feldspars in this specimen are less refracting than balsam, and must, therefore, be either albite or orthoclase. In one section a feldspar appears with rectangular cleavages and extinctions parallel to the cleavages, determining it as orthoclase. At least one striated albite also occurs in this slide. There are, furthermore, areas which remain nearly dark between crossed nicols and which seem to represent a partially devitrified glass. Specimen 32 is from the same locality and is chiefly remarkable for the number and variety of the forms of perthitic intergrowths. Micropegmatitic and granophyric structures are not uncommon in this slide. Among the larger feldspars some were found to be oligoclase, and one was determined as andesine. The slides from Silver Bay and its neighborhood call for no special remark, being in general extremely similar to those from the mouth of Indian River. The microgranitic, microperthitic, and granophyric structure of the groundmass in some of these slides is, however, more pronounced than in the Sitka specimens.

The more western occurrences of this rock do not differ in any noteworthy sense from those near Sitka and on Silver Bay. While the pyroclastic diorite at the mouth of Indian River shows little or no evidence of a secondary schistosity, and the included slate is evidently of a totally different origin and greater age, on Silver Bay a considerable proportion of the diorite in question has been reduced to a schistose condition by movements subsequent to this intrusion. The same is true of the occurrence on Cook Inlet and elsewhere; and in many cases, although the diorite seems to alternate with slate, the slate is merely an altered form of the diorite itself. In all cases where the rock could be collected in a state fairly free from induced schistosity, the microstructure was found similar and gave evidence of a very intense comminution prior to the final solidification of the mass.

Concerning the age of the pyroclastic diorite there are few data. That it is pre-Tertiary is certain. On Cook Inlet it certainly appears much older than the almost unmetamorphosed Jurassic rocks of Tuxedni Harbor. Carboniferous strata are now known to exist at several points in the Alexander Archipelago, and such may be the age of the slates associated with the pyroclastic diorite. This rock may also be as young as the Jura.

GABBRO.

One of the important rocks of the Treadwell mine is a heavy intrusion or dike of a green, granular material, regarded in the field as a gabbro. All of this rock is in so advanced a stage of decomposition that a satisfactory examination is impossible. It is composed chiefly of augite and plagioclase, the feldspar, however, being so clouded that its species is indeterminable. While a majority of the specimens must be classed as granular or hypidiomorphic, a few are distinctly porphyritic. In these last the groundmass has ophitic structure, so that taken alone the term porphyritic diabase would fitly describe them. Considering their relation to the mass as a whole, these specimens must be regarded as a porphyritic facies of the gabbro. The analysis, by Dr. W. F. Hillebrand, given below, is clearly that of a basic rock with feldspars, probably belonging to the labradorite series. The augites are largely decomposed to chlorite and epidote, while the feldspars are replaced by aggregates of muscovite, calcite, etc. The amount of magnetite is, on the whole, small. In some specimens hornblende occurs as an original constituent associated with augite. At one point in the Mexican there is asbestos in the greenstone. In portions of the mine this rock has assumed a somewhat schistose structure.

Analysis of gabbro from the Treadwell mine.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	48.18
CaO	8.71
K_2O	1.99
Na_2O	3.11

A float rock was found in Sheep Creek Basin which bears much resemblance to the gabbroitic material of the Treadwell mine. It contains some hornblende, as is the case with some of the Treadwell rock.

A gabbro occurs as the southerly bounding wall of the Grewingk glacier on Kachemak Bay. The structure is granular, and the ferromagnesian silicates are olivine and augite. The former predominates, but is largely converted into serpentine. The feldspars in this rock are so clouded with decomposition products as not to be capable of identification. Doubtless fresher specimens might have been collected in the neighborhood. These were taken at the glacier wall on account of the relations of the glacier to the disintegration of the mass.

DIABASE.

The only porphyritic pre-Tertiary pyroxene rock collected was found on the dump of the Tellurium mine at Funters Bay. The country at that point is so covered in with vegetation and moss that the exposed rock is almost a vanishing quantity, and even the excavation from which this specimen came was filled in. This diabase is in all probability a dike. It shows large porphyritic crystals, recognizable with the naked eye as pyroxene and under the microscope as augite. The rock is somewhat remarkable for the extreme decomposition of the feldspars in connection with the very fresh augites. The feldspars are recognizable only by their outlines, now filled with sericite, calcite, secondary quartz, and other decomposition products. The outlines, however, are entirely similar to those of labradorites in fresh diabase dikes, and there need be little hesitation in asserting that the feldspar phenocrysts belong in the labradorite series. The groundmass still contains augite, but it is naturally more decomposed than the phenocrysts, and shows a considerable amount of epidote and chlorite. This fact and the state of the decomposition of the feldspars make it difficult to study the groundmass, but it appears to me that the last material to consolidate was pyroxene. The slide contain some magnetite.

SCHISTS.

Eruptive schists.—A few schistose rocks were met with which seem to be of unquestionable eruptive origin, though now so thoroughly metamorphosed that the original character of the rock is obscured. The best of these occurs on Bear Bay, an arm of Silver Bay, Baranof Island. It is a saussuritized, plagioclase rock, and the ferromagnesian silicate is hornblende, probably of paramorphic origin. The feldspars which remained intact are labradorites of both varieties, but most of the feldspathic constituents are disintegrated with the development of zoisite and muscovite. Some garnet is also probably secondary. The hornblende is green, coarsely fibrous, ragged, and strongly pleochroic, decomposed in large measure to chlorite. The rock carries magnetite and some pyrite. As is manifest from this description, this schist strongly resembles many hornblendic schists derived from augitic intrusive or eruptive masses. In this case no direct evidence is at hand that the original rock was pyroxenic.

A somewhat schistose rock occurs on the northeast side of Gastineau Channel, along the beach about 2 miles to the southeast of Juneau. As seen in the field, it is a brownish-green rock with veins of calcite, indicating alteration. Under the microscope the schistose structure is less evident than in the hand specimens. The feldspars, however, are much disintegrated and are determinable only in a few cases. These seem referable to oligoclase. The most prominent constituent is a colorless amphibole (tremolite), occurring in short, rather well-developed prisms which extinguish at about 15°. Nearly every one of these crystals contains flakes of biotite, varying in tint from nearly colorless to deep brown. The amphibole and mica seem to me to be coeval, secondary minerals. The slide contains much calcite and other ordinary decomposition products. The original rock may very probably have been diabasic.

At the Taku mine, Silver Bow Basin, a large mass of pyrrhotite is accompanied by schistose rock similar to that just described, but in a more decomposed state. The amphibole in this rock is light green in color, but is associated with biotite in the same way as in the beach rock. Quartz and magnetite are also intimately mingled with the hornblende. There are remnants of plagioclase, but they are not determinable.

At the site of old Sitka, some 6 miles to the north of the present settlement, a little prospecting was in progress at the time of my visit. The quartz stringers were in an extremely fine-grained, greenish rock, which is composed of minute hornblende needles mingled with tiny grains of quartz. Such schists are known to occur as the result of the alteration of eruptive rocks, and it seems on the whole more probable that this material is igneous than that it is sedimentary.

Sedimentary schists.—The main mass of the country rock in Silver Bow Basin is of sedimentary origin. It is a schistose material, the greater part of which consists of quartz grains. Some of them are probably of granitic origin and are full of inclusions; others have recrystallized. Brown flakes of biotite occur along what I suppose to have been surfaces of relative tangential motion. A carbonate, which is certainly in part calcite, is distributed through the slides in patches. This carbonate probably contains a certain amount of magnesia, corresponding to the magnesian mica. A small quantity of magnetite is present, and a few grains of garnet, partially decomposed. The mica has decomposed in part to chlorite, and the rock carries a little pyrite irregularly disseminated. It is not improbable that this sulphide is due to the action of sulphydric acid on magnetite or biotite.

A specimen of sedimentary schist from the Gould and Curry property in Sheep Creek Basin is amphibolic. Rays vibrating parallel to $\mathfrak{c}$ are of distinctly bluish tinge. The cleavage of the amphibole is very strongly marked, but it can not be called fibrous in the mass of the rock. The slide contains a beautiful little vein, which is filled with quartz, calcite, and fibrous amphibole. All of these minerals seem to have crystallized at the same time, and the amphibole penetrates the others much like the rootlets of a plant, in sinuous lines, which converge to fairly well-defined centers. This vein amphibole is less blue than is that in the mass of the rock.

A schist collected at Funters Bay resembles that from Silver Bow Basin in its microscopical character.

ANDESITES.

Under the term andesite I understand an effusive plagioclase-porphyry in which the groundmass is composed of plagioclase microlites and magnetite, while the phenocrysts are ferromagnesian silicates and triclinic feldspars. The most important difference between an andesite and a basalt lies in the character of the groundmass, or of that portion of the magma which is the last to consolidate; for the fluidity of the lava and its capacity to form extensive sheets depends wholly upon the properties of this portion of the mass. In basalts the residual fluid, the mother liquor, is augitic and has the properties of a basic slag. In the andesites it is a relatively very viscous mass and the lava flows with much greater difficulty. In my opinion any system of classification which should ignore this distinction in the capacity to flow would be very artificial and inexpedient.

All the specimens of lava collected in the expedition of 1895 from Cook Inlet westward turn out to be andesites. Some of them were regarded in the field as possibly basalts. Grewingk mentions basalts at the Pavlof volcano on the mainland, and on Atka. Dr. Dawson notes the basaltic structure of volcanics on Akutan and the basaltic appearance of little islands in Nazan Bay, Atka Island. Columnar structure is not infrequent in andesites, and in Grewingk's time a confusion between dense andesites, von Gümbel's "basaltic" andesites, and basalt would not have been strange. Nevertheless, there seems no inherent improbability in the occurrence of basalt in the volcanic belt of Alaska. To the northward it is known to occur.

The andesite of this region may be grouped as augite-andesite, augite-bronzite-andesite, and hornblende-andesite. There is also a pyroxenic dacite which is closely affiliated with the andesites. They appear to represent substantially the same magmas as the diorites of the region, and it is interesting to note so close an approach to uniformity in composition extending over something like 1,000 miles in distance and over several geological periods in time.

The feldspar most characteristic of the Alaskan andesites, as seen under the microscope, is basic labradorite, which seems to be present both as phenocrysts and as microlites in every slide. On the whole, the augite-andesite contains somewhat more calcareous feldspars than the augite-bronzite-andesite, while the hornblende-andesite of Bogoslof shows less calcareous feldspars. Nevertheless, in all three varieties anorthites have been found. In hornblende-andesite elsewhere pure lime-feldspar is considered a rarity, and details of these feldspars will be given below. The phenocrystic feldspars are scarcely ever all of the same species in any slide of the Alaskan andesites, though one species generally predominates very greatly over the others. Careful examination of the square sections of microlite shows that these too vary, and indeed between much wider limits than the phenocrysts. The majority of the microlites in all these andesites lie within the range of the labradorites $Ab_3 An_4$ and $Ab_1 An_1$, but in almost all there are also microlites of andesine and of oligoclase. The average microlite is always more alkaline than the average phenocryst. Both phenocrysts and microlites often show pronounced zonal structure, and in such cases the exterior portion is as a rule more alkaline than the interior; but there are exceptions to this rule both among the larger crystals and among the microlites, showing a very fundamental heterogeneity in the composition of the fluid rock. While the crystals are conveniently classified as phenocrysts and microlites, several distinct sizes may often be observed, and sometimes there seems to be a complete gradation in size, from phenocrysts some millimeters in length to microlites say 0.005 millimeter square. It may be proper to note that most of the slides of andesites afford much irreproachably good material for the determination of feldspars by optical methods.

The pyroxene of the andesites is present in very much smaller quantity than the feldspar; and though pyroxene microlites occur, they are of much less relative importance than the phenocrysts. A large part of the phenocrystic pyroxene is always augite, and no rhombic pyroxene microlites were found. The rhombic pyroxene shows scarcely noticeable pleochroism, and the axial dispersion has its smaller angle perpendicular to the prismatic axis. This characterizes the mineral as bronzite instead of the more usual hypersthene. Basaltic hornblende, with black borders, occurs sparingly in a few of the augite-andesites.

Olivine is rare in the andesites. It occurs in one slide out of five from St. Augustine, and remnants of this mineral are found in the andesite from Makushin.

Primary quartz is rarer than might be expected in the andesites. A few small crystals were found in the rock from Cape Douglass and in an agglomerate from Amelig Harbor. A specimen from the west side of Amaknak Island also shows a few ill-defined grains. Tridymite was detected with certainty in only one specimen, an augite-bronzite-andesite from Coal Harbor, Unga Island (No. 278). Mr. G. P. Merrill also notes it in the Bogoslof lava.

Glass occurs in greater or less quantity in many of the andesites, but it is not always easy to decide on the amount of this substance present. Many areas which between crossed nicols appear black show faint changes of tint when the gypsum plate is employed. It is possible that this behavior merely indicates strain in a mass, which in a state of ease would be isotropic, or it may be that an incipient crystallization of certain components of the glass has given the mass an optical character.

The order of succession of the phenocrysts appears to be bronzite, augite, feldspar. The feldspars include pyroxene, and when the two pyroxenes are crystallized together, as often happens, the outer portion is augite. The bronzite appears to resist decomposition better than the augite.

The following is an analysis, by Dr. W. F. Hillebrand, of specimen 244 from St. Augustine. The slide shows phenocrysts of augite, bronzite, and plagioclase in a groundmass containing glass, plagioclase microlites, and some magnetite. The feldspar, optically determined, is almost exclusively calcareous labradorite, but there is also a little alkaline labradorite. There is no free quartz.

Analysis of St. Augustine andesite, No. 244.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	60.40
TiO_2	.61
Al_2O_3	16.89
Fe_2O_3	1.88
FeO	3.72
NiO	.02
MnO	.12
CaO	7.25
SrO	ft. tr.
BaO	.06
MgO	3.82
K_2O	.77
Na_2O	3.80
Li_2O	ft. tr.
H_2O, below 110° C	.09
H_2O, above 110° C	.20
P_2O_5	.16
FeS_2	.08
	99.87
S in FeS_2	.04

It is not easy to offer a satisfactory discussion of this analysis. The calcareous character of the feldspars as determined by optical methods does not seem borne out by the analysis, and although microscopic examination would lead one to expect a fairly high percentage of silica in the thoroughly andesitic groundmass, a silica content of over 60 per cent would not be suspected. By converting the analysis into terms of molecular weights the difficulties are not diminished. If the alkalies are reckoned as polysilicate feldspars, and nearly all of the residual alumina is regarded as going to form anorthite, then the feldspars would be nearly expressed by Ab_5An_3, or andesine. The microscopic observations must be greatly strained to answer to this result; for all the determinable phenocrysts and nearly all the determinable microlites are more calcareous than andesine. The only possible conclusion seems to be that the glass is very alkaline. The tendency of alkalies to accumulate in the glass is not unknown; but the difficulty does not end here, for after the maximum amount of feldspar and the ferromagnesian silicates are allowed for, there remains a surplus of silica amounting to over a fifth of the total silica, or about one-eighth of the entire weight of the rock. There is no visible free silica in the slides, and the excess must either be present in the glass or possibly in part in a free state, but so finely disseminated as to escape observation.

As a check upon the microscopic work, specific gravity determinations were made of the phenocrystic feldspars in the St. Augustine lavas. Such examinations on specimen 244 gave in mean a density of 2.684. Specimens 241, 237, and 238 were also examined. The densest feldspar found had a specific gravity of 2.694, and the lightest 2.661. All of these feldspars, judging from their density, were thus labradorites, in entire accord with the microscopic examination. A separation of 244 by the Thoulet solution and analyses of products could hardly throw valuable light on the composition. It is substantially certain that the phenocrysts would prove normal and that the inseparable groundmass would show a large amount of sodium and a great deal of silica.

The composition of this lava is so peculiar that I procured from Dr. Hillebrand the following partial analysis of specimen 241, which is nearly or quite holocrystalline, contains no visible free quartz, and no olivine. The essential components as determined by the microscope are pyroxene, labradorite, and magnetite.

Partial analysis of St. Augustine lava, No. 241.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	58.98
Al_2O_3, Fe_2O_3, FeO, TiO_2, P_2O_5	24.97
CaO	7.65
MgO	4.15
K_2O	0.93
Na_2O	3.25

Supposing the alumina in this specimen to be present in the same ratio to the iron, titanium, and phosphorus as in specimen 244, the alumina here would be 18.13 per cent. The partial analysis would indicate a sodic labradorite, according in so far approximately with the microscopic examination; but there is again a large excess of silica which one would expect to find separated out as quartz. Thus, supposing all the soda and potash to form polysilicates, there remains a mass in which there are about 3 molecules of SiO_2 to 2 molecules of oxides; in other words, the residue would have the mean composition of a polysilicate. The visible minerals, on the other hand, are ortho-, meta-, and sub-silicates. The only mode of reconciling the analysis with the microscopic work seems to be to assume that films or submicroscopic grains of quartz are present, or perhaps more probably scales of tridymite, so distributed in the mass as to escape detection. Tridymite is a fairly frequent ingredient of andesites, and occurs in some at least of the Alaskan lavas. When this mineral is present in small patches it is not easily detected on account of its low polarization colors and lack of definite form. It might therefore be present as disseminated scales in considerable quantities without betraying itself.

The similarity in chemical composition between the Karluk diorite and the St. Augustine lava is so great as to render it probable that slow cooling would have produced from the lava substantially the same minerals as the Karluk rock shows. The structure is another matter. In the lava, slow cooling would not have robbed the mass of its porphyritic structure, though a granular groundmass might have resulted. I can not believe that the hypidiomorphic structure of the diorite could result from the consolidation of any truly fluid mass, though it might perhaps be produced by the slow cooling of a mixture of solids with fluids, such as mortar.

An andesite (No. 268) from Delarof Harbor, near which the Apollo mine is situated, forms in some respects a transition between the lava of St. Augustine and the more usual type of pyroxene-andesites. It is a greenish-black, somewhat vesicular porphyry, in which the microscope shows phenocrysts of augite, a rhombic pyroxene, which in this case seems to be enstatite rather than bronzite, and labradorite. The groundmass consists of "felted" feldspar microlites, a little augite, a little magnetite, and a considerable amount of glass. The feldspathic microlites are mainly alkaline labradorite, while the phenocrystic crystals are more calcareous, approaching $Ab_3 An_4$; but some of the microlites have angles of extinction appropriate to oligoclase. The slide shows decomposition products, especially chlorite, but not in important quantities.

The following is an analysis by Dr. Hillebrand of specimen 268:

Analysis of andesite from Delarof Harbor, No. 268.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	56.63
TiO_2	.67
Al_2O_3	16.85
Fe_2O_3	3.62
FeO	3.44
NiO	trace
MnO	.23
CaO	7.53
SrO	trace
BaO	.09
MgO	4.23
K_2O	2.24
Na_2O	3.08
Li_2O	trace
H_2O, below 110° C	.80
H_2O, above 110° C	.51
P_2O_5	.16
FeS_2	.06
Total	100.14

When computed in terms of molecules it appears that the feldspars should approach andesine. After deducting the feldspar there remain about 4 molecules of silica to 3 of oxides, indicating that there is either free silica or that the glass is very acid. If about a tenth of the silica were free, the rock after subtraction of the albite and free silica would approach a metasilicate in composition. Thus, although the rock has only the rather moderate silica contents of 56.63 per cent, it is still needful to assume the existence of free silica or a highly siliceous glass.

The only well-developed dacite met with in Alaska occurs at Delarof Harbor, Unga Island, near the Apollo Consolidated mine. As appears from the notes above, dacites are to be expected in the volcanic belt, and some at least of the andesites have a dacitic chemical composition. The rock at Delarof Harbor is much altered and highly "propylitic" in appearance. Only one specimen (collected long ago by Mr. Dall and numbered 28064) is fresh enough to show the ferromagnesian silicates, which are deep-brown hornblende accompanied by a little biotite. In other slides there are patches of decomposition products which suggest original pyroxene. The quartz grains are often large and seem to be corroded dihexahedra. They are full of inclusions of glass and gas. The feldspar phenocrysts are usually indeterminable from decomposition, but andesine and oligoclase were identified among the larger crystals and oligoclase among the microlites. Some unstriated feldspars occur in the dacite slides. Of these some at least have a higher index of refraction than balsam and are probably oligoclase, but it is possible that some of the unstriated grains may be orthoclases, the optical tests for potassium feldspar being rather negative than positive and unsatisfactory in their character. The groundmass is in part feldspathic and in part spherulitic. The very beautiful spherulites in Mr. Dall's specimen are partially devitrified, and are stained with a brown pigment, probably limonite. The decomposition products are chlorite and epidote, so characteristic of "propylites;" and calcite, too, is abundant.

In comparing this dacite with the andesites it will be observed that the feldspars in the quartzose rock are much more alkaline than in the other lavas. Doubtless there is a connection between the appearance of the quartz phenocrysts and the preponderance of sodium over calcium.

A partial analysis by Dr. Hillebrand of a dacite specimen (271) gave:

Partial analysis of dacite, No. 271.

[By Dr. W. F. Hillebrand.]

	Per cent.
SiO_2	62.32
CaO	3.03
K_2O	2.33
Na_2O	3.92

As compared, in terms of molecules, with the andesite from Unga, No. 268, this dacite contains about the same amount of potassium, more sodium and silica, and less calcium. It would seem to point to a more albitic rock but not to an admixture of orthoclase.

The hornblende-andesites are, so far as is known, much less common in Alaska than the pyroxenic variety. Specimens are at hand only from Bogoslof and Grewingk and from Kiska, one of the Rat Islands. These rocks are for the most part yellowish-gray porphyries with a rough fracture, outwardly resembling trachytes. They belong among the trachytic andesites of von Gümbel, the same group for which I proposed the name asperites. The ferromagnesian silicates are chiefly deep-brown, black-bordered hornblendes accompanied by a very subordinate amount of augite, while orthorhombic pyroxenes were detected only in the specimen from Kiska. The feldspar phenocrysts are chiefly calcareous labradorite, $Ab_3 An_4$, but in some cases they are anorthite. Thus, in specimen 310, a Carlsbad-albite twin phenocryst gave albite extinctions of 18° and 22° and the Carlsbad lamella extinguished at 43°. This corresponds to anorthite cut at 10° to the zone of symmetry. In specimen 295 there are also unquestionable anorthites, showing Carlsbad and albite twinning and giving characteristic extinction angles. The microlites are also surprisingly calcareous; in one slide (292) 10 square microlites gave an average extinction of 38°, showing that they were calcareous labradorite. A few square microlites in the same slide gave angles characteristic of sodic labradorite. Some of the lath-shaped microlites show Carlsbad twinning, and all such that were examined proved to be $Ab_3 An_4$. The rock contains no visible free quartz. Prof. G. P. Merrill, however, mentions tridymite as one of the components of the rock. The groundmass consists of feldspar microlites, a few augite grains, magnetite, and glass, possibly with more or less admixed tridymite.

Other slides of the Bogoslof lava are very similar to 292, which was selected as a type. The proportion of augite to hornblende, and of the ferromagnesian silicates to feldspars, varies considerably. In some slides apatite and zircon are rather abundant. Most of the feldspars show pronounced zonal structure, and this is the case even with the microlites.

Professor Merrill has described two specimens from Bogoslof, and they were analyzed by Mr. T. M. Chatard. One of them is a gray rock representing the main mass of the islands, and its analysis is given under I, below (p. 58). In mineralogical composition and external appearance it corresponds to the description given above, excepting that according to Mr. Merrill[1] it contains tridymite. The average feldspar may be interpreted from Mr. Chatard's figures as $Ab_2 An_1$, yet basic labradorite is certainly present. The residue, after subtracting the feldspars, contains about 3 molecules of SiO_2 per molecule of basic oxide. Hence it would seem that about an eleventh part of the silica must exist in the free state. Mr. Merrill also examined a dark variety of the lava, which contains more hornblende. The analysis is given under II (p. 58). This analysis does not indicate any free silica.

[1] Proc. U. S. Nat. Mus., vol. 8, 1885, p. 31.

Analyses of Bogoslof lava.

[By Mr. T. M. Chatard.]

	I.	II.
Ignition	.99	.34
SiO_2	56.07	51.54
TiO_2	1.24	.32
Al_2O_3	19.06	20.31
Fe_2O_3	5.39	4.64
FeO	.92	3.56
MnO	.23	.32
CaO	7.70	9.55
MgO	2.12	3.16
P_2O_5	.16	.57
Na_2O	4.52	4.29
K_2O	1.24	2.47
Total	99.64	101.07

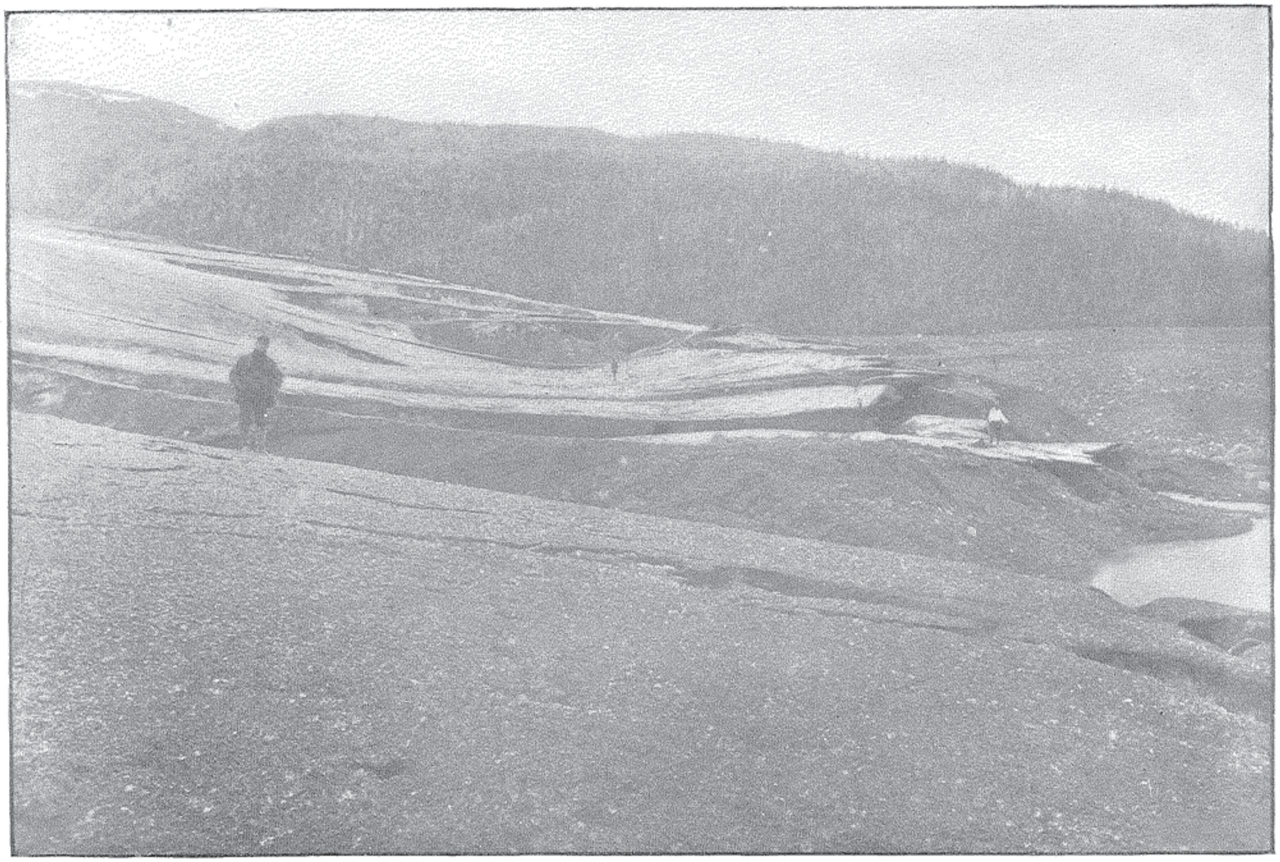
The following is a list of the andesite localities in Alaska known to me by specimens:

List of known andesite localities in Alaska.

	Locality.	Longitude.
		° ′
Augite-andesite	Cape Douglas	153 30
	Belkofski	162 55
	Unga Island	160 30
	Popof Island	160 20
	Unalaska	163 00
	Amaknak Island	163 00
Augite-bronzite andesite	St. Augustine Island	153 30
	Amelig Harbor	154 30
	Unga Island	160 30
Hornblende-andesite	Bogoslof Island	168 00
	Kiska Island	177 30

BASALTS.

Only two basalts were met with in this reconnaissance. One of these is a dike in the Treadwell-Alaska mine; the other occurs on Kruzof Island near Mount Edgecumb. Edgecumb forms a fairly well-developed cone. Of what material the cone itself is composed, I can not say. It is so guarded by a broad strip of forest of almost



GREWINGK GLACIER MOUNTING A MORAINE.

impassable density that no attempt was made to reach the cone. The southeastern shore of Kruzof Island is a beautiful exhibit of basaltic flows, so recent as to show superficial flow structure, scoriaceous masses, and pumice. It is evident that the rock has been of a high degree of fluidity, and hand specimens show abundant olivine phenocrysts.

Under the microscope the rock is seen to be a normal basalt both as to composition and structure. The feldspars are anorthite and labradorite, the microlitic crystals being more alkaline than the phenocrysts. The olivine is very fresh, and several of the specimens show a large amount of glass.

The dike in the Treadwell is less ordinary and more important, since it is seemingly associated with the genesis of the ore body. Though much decomposed, this rock can be fairly well studied under the microscope. It consists of augite, some olivine, a little feldspar, mostly zeolitized, and sensibly isotropic minerals.

A partial analysis of specimen 87 by Mr. George Steiger showed—

	Per cent.
K_2O	2.12
Na_2O	2.39
Water above 110° C	2.41

From these figures it would appear that analcite and leucite are both present, the analcite perhaps resulting from the decomposition of the leucite, perhaps being an original constituent, as in the analcite-basalt first described by Mr. Lindgren. Under the microscope some arrangements of inclusions may be seen which remind one of the symmetrical disposition of such bodies so often seen in leucite, but the minerals do not occur in the slides in such a way as to make it practicable to discriminate the hydrous silicate from the anhydrous one. Mr. Lindgren informs me that the general appearance of the slides is extremely similar to that of his analcite-basalt.

SOME NOTES ON GLACIATION.

Prior to 1895 glacial action on Kadiak and the adjacent smaller islands had not been observed. The topography of Woody Island and the islets which lie between it and the port of St. Paul, however, is strikingly glacial. In particular, the surface shows hummocks and tarns such as unglaciated areas do not exhibit. The rock beneath the grass roots is undecomposed and sometimes nearly smooth, but neither here nor along Narrow Straits was I able to find actual scratches on the rock. Mr. Dall, however, found on Woody Island, in the Mission garden and elsewhere, erratics showing groovings. At the entrance of the southeast arm of the Uyak Bay, about a mile to the westward of the Wamburg and Boyer prospect, there is topography similar to that about Woody Island, but in addition there are scratches and grooves which have been perfectly protected where covered by moss. The principal set of scratches strikes N. 83° W. (true), and a subordinate one N. 68° W. The steeper surfaces of the roches moutonnées are turned toward the head of the arm.

In considering the glaciers at various points it occurred to me that disintegration must be extremely rapid along the edge of the ice; for the temperature of the ice being zero centigrade, the number of days in the year must be great upon which the adjoining rock is chilled below the freezing point at night and raised above the melting point during the day, and such alternations form a most efficacious means of breaking up solid rock. In such a position, too, the local precipitation of dew must often be sufficient to wet the wall rocks daily.

I had an opportunity of examining such effects on the westerly wall of the Grewingk glacier in Kachemak Bay. The rock here is a gabbro. Within a few yards of the glacier it is full of gaping cracks, dividing the mass into fragments of an average volume of a cubic inch or less, and these are so loose that although nearly in place they can be pulled down with the hand by the bushel. Fifty or a hundred feet away from the ice, on the contrary, the rock was smooth, hard, and so tough that it was difficult to get specimens. It appears to me that all along the edge of a glacier, and along its névé field as well, frosts must be more frequent than, ceteris paribus, at a distance from them, and that disintegration must be correspondingly rapid. The U-shape assumed by glacial gorges and the cirques at the névé basins may be in part explicable in this way.[1]

A somewhat similar action seems to be produced in many parts of Alaska by the ocean spray or the lapping of wavelets. Along many of the shores above high water a groove may be seen in the cliffs which is perhaps a couple of feet deep and in which the rock is cracked and disintegrated, but not in the least waterworn. It seems probable that frequent wetting in frosty weather has caused the disintegration.

The ability of a glacier to excavate beneath the level of its course depends on the fact that it is a solid and not a fluid. For this reason it can move up hill for a certain distance, depending upon its "solidity" or on the elastic limit of the material. The Grewingk glacier at one point is mounting a moraine, and Pl. XIII shows the ice advancing on a rising grade.

Pl. XIV shows the foot of one of four superb glaciers at Cape Douglas. These, like most Alaskan glaciers, are remarkably free from moraines, and in the clear, dust-free air display their structure in a most diagrammatic fashion.

REMARKS ON DISTRIBUTION OF GOLD IN SOUTHERN ALASKA.

The data which are available concerning the gold are too meager to permit of any very important generalizations. There is a distinct zonal development of the deposits in the Alexander Archipelago,

[1] I am told that Mr. Willard D. Johnson, in an unpublished lecture, gave expression to somewhat similar views, but I am not acquainted with his precise opinion on this subject.

NORTHERN GLACIER AT CAPE DOUGLAS.

including Sumdum, Juneau, and Berners Bay, and the general direction of this belt is that of the schistosity of this part of the country. Pls. I and XV show the general geographical relation of these localities. The great mine of this belt is the famous Alaska-Treadwell. The ores are normal gold ores, except that calcite is unusually abundant, and there is a sufficient reason for connecting their genesis with eruptive phenomena. The deposits of this belt are so similar in position and character to those of British Columbia and California that, in the absence of direct evidence, they may be regarded as contemporaneous with them and probably of early Cretaceous age.

Further westward occur the deposits near Sitka on Baranof Island, and very possibly the source of the gold of Lituya Bay, in west longitude 137° 30′, may be a prolongation of this group. The mineralizing action on Baranof Island does not appear to have been very vigorous. It seems to be quite as old as the more easterly belt.

At the head of Cooks Inlet, some 14° west of Sitka, are the placers of Turnagain Arm and the Kaknu River, indicating the presence of gold veins which may or may not be strong enough to be worked singly.

The veins on Uyak Bay, Kadiak Island, are few, so far as yet known, and not important.

Next to the Douglas Island deposits the Apollo Consolidated, on Unga Island, in west longitude 160° 30′, is the most important mine in the Territory. It is an extremely interesting occurrence in andesite of Tertiary age, and represents a relatively very modern repetition of the conditions of gold genesis in the northwest. Though there is as yet but one working mine here, it would be strange indeed if no other valuable deposits exist in the same region.

A memoir on the gold deposits of the Yukon region has been prepared by Mr. J. E. Spurr, who made his examinations in 1896, and will appear in the same volume with this report. While together these reports will represent most of what is yet known of the gold resources of the Territory, the reader may be reminded that the area of Alaska is greater than that of all the States north of Tennessee and east of the Mississippi River, more than half a million square miles, and most of it is peculiarly inaccessible. It will be long before any fairly complete view of the resources of this vast region can be presented.

GANGUE MINERALS.

The list of gangue minerals known to occur in the Alaska mines is not a long one. Quartz and pyrite are found everywhere with gold in place. There is possibly an exception in the case of the Taku mine, where pyrrhotite in uncommonly abundant and where I observed no pyrite, but very likely a methodical search for this mineral would reveal it at this locality. Worthy of note is the native copper at the Apollo Consolidated. This metal occurs also in the Smuggler vein, Telluride, Colorado,[1] and was reported long ago (1847) in the property

[1] Mr. Purington saw a specimen at the mine.

of the Orange Grove Mining Company, Virginia.[1] Prof. Henry Howe also mentioned the occurrence of native copper in the gold mines of Nova Scotia, at Oldham and elsewhere.[2] While the list of gangue minerals is not a long one, it includes most of the minerals usual in gold mines. Tellurium and the tellurides are fortunately absent, so far as is yet known.

The following is a list of the minerals, other than quartz and pyrite, thus far detected in the Alaska gold deposits:

List of minerals, other than quartz and pyrite, detected in the Alaska gold deposits during this expedition.

Mineral.	Mine.	Locality.
BIOTITE	Alaska-Treadwell	Douglas Island.
CALCITE	Apollo	Unga Island.
	Bear	Berners Bay.
	Comet	Do.
	Bennet	Silver Bow Basin.
	Liberty	Silver Bay.
	Lucky Chance	Do.
	Mexican	Douglas Island.
	Thetis	Baranof Island.
	Treadwell	Douglas Island.
	Willoughby mines	Funters Bay.
CHLORITE	Apollo	Unga.
	Glacier	Sheep Creek.
	War Horse	Admiralty Island.
COPPER, NATIVE	Apollo	Unga.
COPPER PYRITE	do	Do.
	Bear	Berners Bay.
	Comet	Do.
	Eureka	Silver Bay.
	Glacier	Sheep Creek.
	Gould & Curry	Do.
	Hague	Unalaska.
	Silver Bay	Silver Bay,
	Silver Queen	Sheep Creek.
	Treadwell	Douglas Island.
GALENA	Apollo	Unga.
	All mines of mainland belt except Funters Bay and Taku.	
	Calaveras	Uyak Bay.
	Thetis mine	Baranof Island.

[1] Gold fields of the Southern Appalachians, list of gangue minerals: Sixteenth Ann. Rept. U. S. Geol. Survey, Part III, 1895, p. 275.

[2] Mineralogy of Nova Scotia, 1868, pp. 39-61.

List of minerals, other than quartz and pyrite, detected in the Alaska gold deposits during this expedition—Continued.

Mineral.	Mine.	Locality.
MISPICKEL	Bear	Berners Bay.
	Bennet	Silver Bow Basin.
	All the mines of Uyak Bay	Kadiak Island.
	Duncan's prospect	Douglas Island.
	Glacier	Sheep Creek.
	Haley & Rogers	Silver Bay.
	Liberty	Do.
	Lucky Chance	Do.
	Silver Queen	Sheep Creek.
	Stewart	Silver Bay.
ORTHOCLASE	Apollo mine	Unga.
PYRRHOTITE	Bald Eagle	Sumdum.
	Bennet	Silver Bow Basin.
	Gould & Curry	Sheep Creek.
	Silver Queen	Do.
	Taku	Silver Bow Basin.
	Tellurium	Admiralty Island.
	Thetis	Baranof Island.
SIDERITE	Treadwell	Douglas Island.
	Lane & Hayward	Silver Bow Basin.
	Lucky Chance	Silver Bay.
SERICITE	Apollo	Unga.
	Glacier	Sheep Creek.
	Lucky Chance	Silver Bay.
	Mexican	Douglas Island.
	Taku	Silver Bow Basin.
	Treadwell	Douglas Island.
	Willoughby	Admiralty Island.
SILVER	Occurs in alloy wherever gold does.	
PYRARGYRITE	Silver Queen	Sheep Creek.
	Glacier	Do.
ZINCBLENDE	Apollo	Unga.
	Bald Eagle	Sumdum.
	Glacier	Sheep Creek.
	Gould & Curry	Do.
	Lane & Hayward	Silver Bow Basin.
	Silver Queen	Do.
	Taku	Do.
	War Horse	Admiralty Island.

THE ALASKA-TREADWELL MINE.

The Alaska-Treadwell and the Alaska-Mexican mines lie on the same lead and are worked under the same superintendence. They are separated by the Alaska claim, 700 feet in length, upon which little work has been done. The Alaska-Treadwell is justly famous both for its large yield and for its economical working. Thus, for the year ending May, 1894, the profit was nearly 60 per cent of the total yield; yet the ore ran only $3.20 per ton; but the total expense of treatment was only $1.35. Such results could not be attained were the mine not situated as it is. The deposit runs nearly parallel to the shore of Gastineau Channel, at a distance of a few hundred feet from it, leaving just convenient space for offices and storage. Thus, coal, machinery, and other supplies can be procured with ease. Water power is also available for a portion of the year, but it must be supplemented by steam power, involving the consumption of two or three thousand tons of coal annually, at some $9 per ton. On the other hand, the climate is severe (450 inches of snow fell in the winter of 1893–94) and wages are high. The pay of some of the men is as follows: Blacksmiths, $5; amalgamators, $4; roasters, $3.50; miners, $3.50; Indians, $2. That the expense per ton should, nevertheless, be so small is a real triumph of intelligent organization and labor, largely due to Mr. Thomas Mein, who was formerly superintendent. The total product of the Alaska-Treadwell, as shown in the statistical notes in the earlier part of this paper, amounted to $7,028,649 up to the end of 1896.

A plan and section of the Treadwell as it was developed in 1895 are given on Pls. XVII and XVIII, and a view of one of the pits is shown on Pl. XIX.

The Alaska-Treadwell deposit has been described by Dr. George M. Dawson, and his specimens were examined under the microscope by Prof. F. D. Adams.[1] The following quotations from Dr. Dawson's paper give his opinion of the origin of the deposit:

> The impression formed from such examination of this remarkable deposit as I was able to make is, in fact, that it represents the upper portion or "feather edge" of a granitic intrusion, probably contemporaneous and connected with the characteristic granites of the neighboring coast ranges, but which, owing to peculiar conditions, has become decomposed and silicified by solfataric or hydrothermal action, to which the concentration of gold in it and the deposition of pyrites are also due. * * *
>
> It is conceivable that the hydrothermal action which has affected this part of the original granitic magma may have been due to the water included by the mass itself while in a state of "aqueo-igneous" or "granitic" fusion, the escape of such water through the substance of the upper part of the intrusive mass being rendered possible by the relief from pressure consequent on the approach of the intrusion to the actual surface.

[1] Am. Geologist, August, 1889.

> It may, however, perhaps with greater probability, be supposed that the water included in the adjacent sedimentary deposits became vaporized by the heat of the intrusive mass, and found its way to the surface, in the form of steam, through the substance of that mass. It will be noticed that Mr. Adams finds evidence, in the microscopical character of the rock, of much crushing and fracture, so that in any case it must have afforded a convenient channel for the passage of heated waters or steam; and this appears to have been one of the more important circumstances leading to its mineralization. * * * This deposit therefore affords an interesting example of the manner in which intrusive masses may directly give rise to ordinary metalliferous veins.

As I understand him, Dr. Dawson supposes the formation of the ore body to have followed immediately upon the intrusion of the granitic mass, without any interval of time, and either just before or just after its solidification. Professor Adams, on the other hand, seems to consider the ore as consisting of a mass of fractured rock, filled with veinlets in the ordinary manner, and finds in the slides no indication of a genetic connection. He concludes his remarks upon the slides as follows:

> It may therefore be stated that the ore of the Treadwell mine is a granite, probably belonging to the class of the hornblende granites, much crushed, altered, and impregnated with secondary quartz, calcite, and pyrite; that the "kernels" are portions of the rock in which alteration is less complete than in the mass of the granite, and that at least a considerable portion of the gold present in the ore is contained in the pyrite as free gold.

It has already been shown in the portion of this report dealing with the rocks that this rock is to be regarded as a sodium-syenite or, more logically, as an albite-diorite. It will be shown below that the ore deposition occurred much later than the intrusion of this syenite, two other intrusive masses having followed it before the deposition of the ore was complete.

The main mass of the country at this locality and the oldest rock is a carbonaceous slate of very uniform texture. While it is unquestionably sedimentary in origin, it does not display any variations in lithological features, such as calcareous or sandy facies, sufficient to mark the original lines of bedding, and it was found impracticable to discover whether or no the bedding and principal cleavage coincide. At Juneau Island, close by, slaty cleavage and bedding do not coincide. At many points in the mine the slate passes into what I term a schist, being affected with more than one pronounced cleavage of less regularity than that of true slate. The strike of the slate is N. 50° W., true, being nearly the same as that of Gastineau Channel and coinciding with one of the two fissure systems which affect nearly the whole of the Alexander Archipelago. The cleavage dips steeply to the southeast. The age of the slate was thought by Dr. Dawson to be very probably Triassic, from its analogy with rocks on the coast of British Columbia. There is no direct evidence as to age yet available.

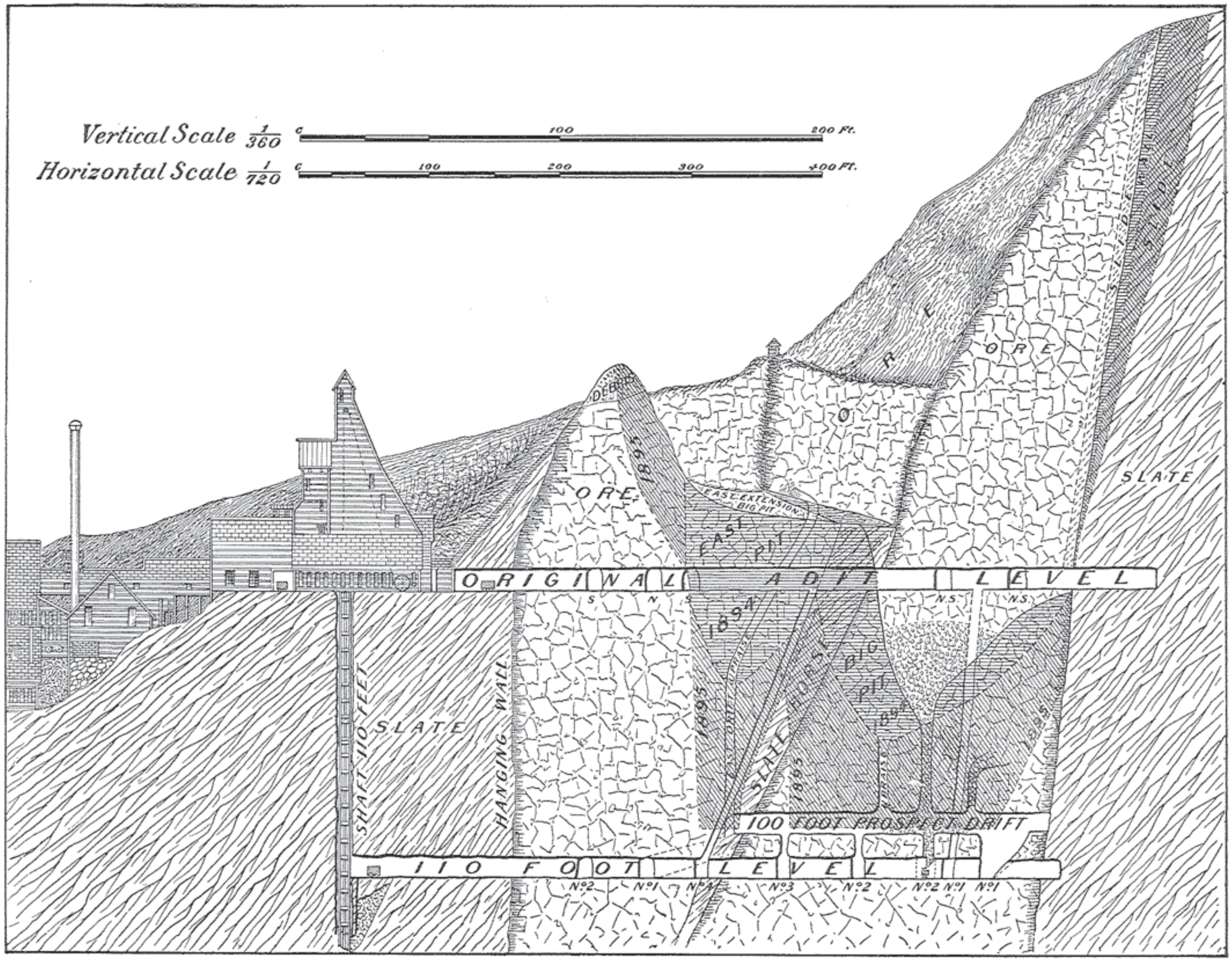
After the sediments had been reduced to the condition of slate, the syenite was intruded into them. This intrusion was of a very irregular character, although it may be called a dike. In the Alaska-Treadwell it swells out to 450 feet in width, including, however, large "horses." To the northwest and to the southeast it narrows, and is sometimes reduced to a system of parallel dikes divided by slate. The lithological character of the syenite has already been described in sufficient detail.

After the syenite intrusion came one of gabbro. It forms a dike a couple of hundred feet in width and follows the northeast wall of the deposit pretty closely, though sometimes separated from it by slate. This rock has been turned to "greenstone" by the action of solutions, seemingly those attending the ore deposition. The color, due to chlorite and epidote, and the granular structure, make its identification easy. At some points it is porphyritic or semiporphyritic, and would then, strictly speaking, be known as a diabase, but the granular modification seems to be the prevailing one. This gabbro contains some fragments of the granite. Though decomposed and intersected by a considerable number of quartz stringers carrying a little pyrite, it is nowhere converted into profitable ore, and relatively to the syenite it is but slightly mineralized. Calcite is more abundant in the gabbro than in the syenite. The gabbro appears as a cropping on the northerly side of Glory hole, or the northwesterly of the open pits. It appears again in the adit level and on the 110-foot level of the Treadwell, in the south pit of the same property, at a watercourse on the Alaska claim, and in both levels of the Alaska-Mexican. It is always on the hanging-wall side of the deposit.

Latest of the intrusions is the analcite-basalt, of which a petrographical description has been given. This dike is seen in the south pit of the Alaska-Treadwell, which it crosses at a moderate angle, striking N. 20° W. and dipping steeply to the northeast. This dike is very regular and from 4 to 6 feet in width. It cuts slates, diorite, and gabbro, and at one point contains numerous slabs of the diorite. The rock evidently chilled rapidly and has a fine-grained selvage. For the most part the dike rock is decomposed to a brown-black earthy mass, which can be crumbled in the fingers. Portions of it, however, are fresher, and the fine-grained selvages are less decomposed than the body of the dike. At some points it contains hard, bean-shaped bodies, which look as if they might be spherulites, but under the microscope there seems to be no essential difference between these bean-shaped masses and the fresher specimens of the solid rock. I infer that they have been formed by decomposition of the basalt, starting on shrinkage cracks and acting more rapidly upon the edges and corners than upon flat surfaces. I have discussed the effects of such decomposition on a former occasion.[1]

The structure of the Treadwell is complex in detail, but shows some

[1] Mon. U. S. Geol. Survey, Vol. XIII, 1888, p. 68.



SECTION OF ALASKA-TREADWELL MINE.

distinct general features. The slates, which are the oldest rocks, acquired their slaty structure prior to the intrusion of the igneous rocks; for the fragments caught up by the intrusions have as well-developed slaty structure as the walls of the deposit. The slaty cleavage is thus an ancient feature of the general structure of the country. Under external pressure the slates have yielded mainly along the cleavage planes, opening up into lenticular spaces, many of which are now filled with ore. These lenticular masses are arranged in overlapping groups, and form ore bodies similar to some in the gold fields of California and the southern Appalachians, for which I have proposed the name stringer lead.[1] The faulting on these slates has been normal, as is shown by the character of the stringers. These have an average dip greater than that of the slate, and the steepest portions of the stringers are the widest.[2]

The gabbro is in some places in contact with the granite, while in others it is separated by more or less slate. In the Alaska-Mexican a considerable amount of slate intervenes. In places the gabbro has been rendered schistose, and near the south pit of the Treadwell the sinuosities of the schistose surfaces seem to follow the undulations of the contact with the syenite.

The syenite has yielded to pressure much more completely than the other rocks. At first glance it seems to have been reduced to mere rubble, but on good exposures it can be seen that the initial yielding has gone on methodically along planes at nearly 90° to one another and at nearly 45° to the horizon. They strike with the lode, and were probably caused by nearly horizontal forces. Crushing, however, was carried beyond the rupturing point, so that the fragments after separation were ground together and some faults were produced in the broken mass.

Such conditions might naturally influence the distribution of ore. While crushing of the mass opens the way for solutions and leaves space for auriferous quartz, the faulting in the crushed rock might give rise to layers of finely packed attrition products, which would affect the course of the solutions and make against uniformity of distribution. Inequalities in richness are known in the mine and are said by some of the miners to be related to such surfaces of motion. A detailed study of this subject with an assay plan would be interesting, but I had not time to make it.

The gangue minerals of the Alaska-Treadwell are not numerous. Quartz is the chief gangue, but it is frequently accompanied in the interstitial stringers by calcite, sometimes ferriferous. In the impregnated rock these carbonates are in excess of the quartz. Pyrite is by far the most abundant associated sulphide or metallic gangue. Professor Adams found free gold in his slides embedded in pyrite,

[1] Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, Part III, 1895, p. 283.

[2] Ibid., p. 271. Compare von Cotta, Erzlagerstätten, 1859, p. 161.

but I was unsuccessful in a similar search. From the assayer, Mr. Booth, I learn that chalcopyrite is more frequent in the Treadwell than in the Mexican, while mispickel is found in the latter mine but not in the former. Pyrrhotite, galena, and zincblende are rare, but are not confined to any particular portion of the deposit.

The ore associated with the syenite is separable into two distinct varieties. Of these one consists of stringers of quartz carrying some calcite and occupying interstitial spaces between more or less decomposed syenite fragments. In such ore the pyrite is often grouped in bunches and at other times is disseminated through the quartz. The distribution of the pyrite seems to be without effect upon the tenor of this variety of ore, which is usually rich in proportion to the quantity of pyrite. The other variety of ore consists of fragments of the syenite which have been, as it were, *soaked* in the auriferous liquid. They are impregnated chiefly with carbonates and pyrite, only a little silica penetrating where there were no open fissures. The pyrite in this variety is also either bunched or disseminated, and all the mine foremen assert that where this pyrite is scattered the ore is nearly or quite worthless. It appeared to me that the disseminated pyrite represents ferromagnesian silicates attacked by sulphydric acid or soluble sulphides, and study of the ore under the microscope lends strength to this hypothesis, though without absolutely proving it.

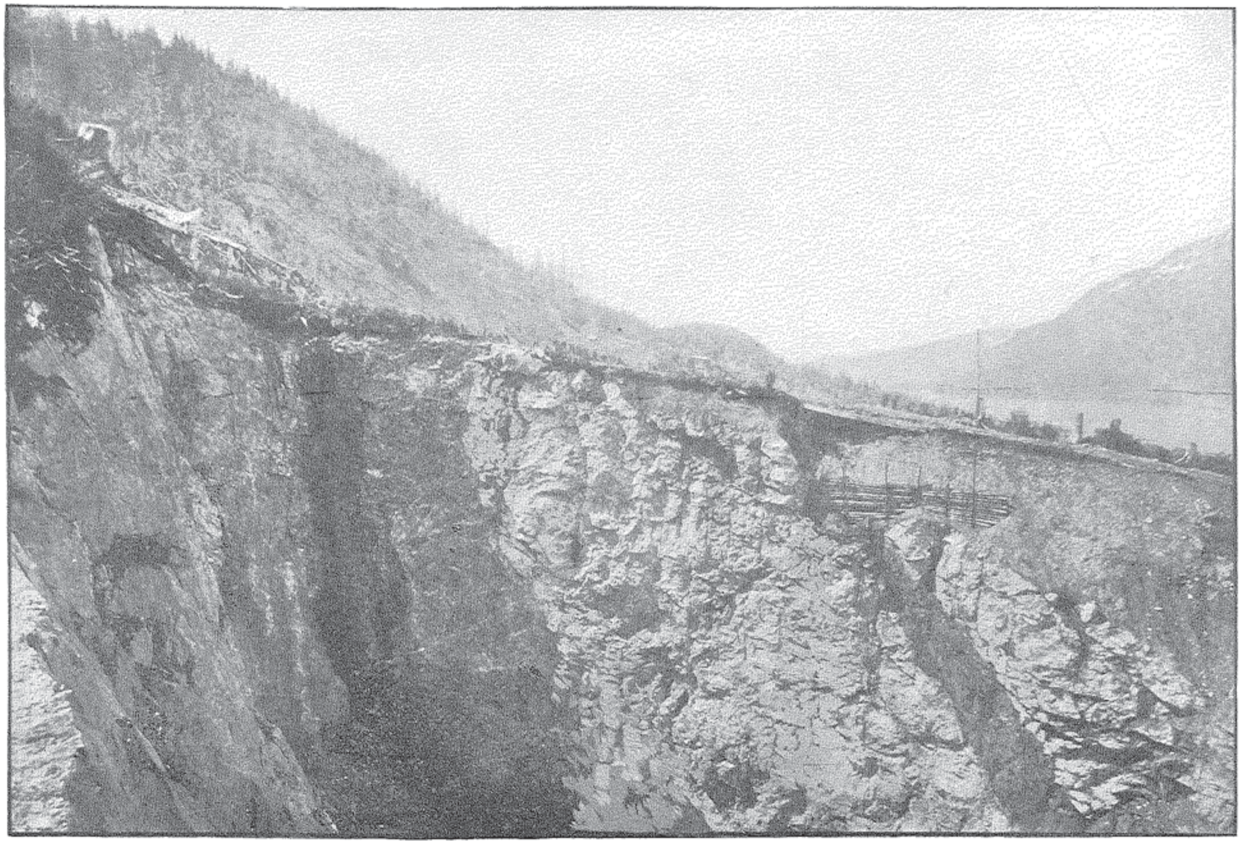
Wherever the ore is strongly mineralized the ferromagnesian silicates have totally disappeared from the syenite, and the pyrite is scattered in it in about the same manner as the iron-bearing silicates in the fresher material. On the other hand, as the bunches of pyrite are accompanied by much calcite, they could not have been produced from any ordinary accumulation of ferromagnesian silicates, and I think such pyrite must have entered the rock in a state of solution. The association of calcite and pyrite in the wall rock of gold veins in California has been studied by Mr. Lindgren.[1] It appears to be very similar to the association of pyrite with fibrous silica which I have described from the gold mines of the southern Appalachians.[2] Sericite and a secondary green mica are common in the ore.

The impregnation of rocks with various substances seems to be accompanied by a separation of substances, as if certain compounds in solution permeated the rock more rapidly or more completely than others. This would be equivalent to an osmotic separation, and a tendency to such a separation seems almost inevitable when solutions are in contact with dense rocks. I have before called attention to this action,[3] and the theory finds considerable support in the recent investigations of Mr. Lindgren on the alteration of wall rocks.

[1] Gold-quartz veins of Nevada City and Grass Valley: Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, 1896, p. 147.

[2] Loc. cit., p. 308.

[3] Quicksilver ore deposits: Mineral Resources U. S. 1892, p. 156.



WEST WALL OF EAST PIT OF ALASKA-TREADWELL MINE.

The genesis of the Treadwell-Mexican deposit is probably connected with the intrusion of the dike of analcite-basalt. This dike must either have accompanied the mineralization of the deposit or have followed close upon it. The dike is not crushed or impregnated with ore to any notable extent, though here and there a few crystals of pyrite are visible. Fragments of the syenite included in the basalt show much crushing, but only a slight amount of mineralization. On the other hand, along portions of the dike small pyritous quartz seams lie between the dike and the surrounding mass, and I was informed that rich ore and free gold are usually abundant near the dike.[1] The preceding intrusion of gabbro has evidently been subjected to intense dynamic and chemical action, and must have antedated most or all of the auriferous injections. Thus, the crushing of the country rock and the deposition of the ore seem to have taken place mainly between the two intrusions, but ore deposition had not entirely ceased when the basalt dike was formed. The basalt was injected after mineralization began, but before it had ceased. The phenomena are not absolutely incompatible with the hypothesis that after the main ore deposition and a period of quiet the basalt was intruded and a fresh, relatively unimportant mineralization ensued, but there is no evidence of such a recrudescence, and the character of the included syenite fragments does not support this more complicated hypothesis.

So far as I know, this is the first known case of an association of analcite-basalt with ore generation. It is worth while to note that in a certain way the gabbro is intermediate in chemical character between the syenite and the basalt. The sodium is least and the potassium greatest in the basalt, which probably came from the deepest couche with the ore-bearing solutions.

The date of the mineralization is uncertain. There is no basalt of any kind known within a long distance of Douglas Island. On the other hand, no analcite-basalts are known to be older than the Laramie, and both in Alaska and California gold deposition has accompanied neovolcanic rocks; but all analcite rocks are not relatively recent, and the general aspect of the deposits in eastern Alaska indicates Mesozoic rather than Cenozoic age. It may be that this basalt is connected with some eruptions concealed from view by the forests, which are of more than tropical density.

The basalt dike occurs near the center of the ore-bearing ground. The most probable hypothesis at the present time seems to be that the ore chute follows downward nearly in the track of the basalt, keeping for the most part to the syenite on account of the superior fragility of that rock, and not because of any chemical influence of the albite rock on ore deposition.

[1] Rich ore, running up to more than $100 per ton, is occasionally found in small quantities.

THE ALASKA-MEXICAN MINE.

This mine is on the same deposit as the Alaska-Treadwell and shares most of its characteristics. The syenite is much narrower in the Mexican and much of the ore is in "stringer leads" in the slate. The slates show undulating and carunculated surfaces, and are marked by incised grooves caused by the relative motion of the slaty sheets at the time of dislocation. These grooves pitch to the northwest, and the result has been to produce pipes pitching downward to the southeast, which is the pitch of the ore chutes according to the information obtained at the mine. The richest ore is said to occur on the foot wall, or southwestern side. In the proper sense there can not be said to be any foot wall, since the deposit in the slate is a series of imbricating lenses of quartz, and in the syenite a reticulated vein. More generally the deposit occurs on a zone of distributed fracture and not on a single fissure.

The ore of the Mexican has about the same tenor as in the Treadwell, and the gangue minerals are nearly the same. The slate at some points is impregnated with pyrite, which, however, I understand to be of very low grade. The deposit is not so wide, but reaches 100 feet at some points and is amply large for convenient economical working.

OTHER DEPOSITS OF DOUGLAS ISLAND.

Some excitement was once created by the Bears Nest property on Douglas Island. The ground was not accessible at the time of my visit. I was informed that it was opened on the same sodium-syenite dike as the Treadwell, but that the rock was too poor to pay expenses.

On the shore of the island about 2 miles to the northwest of the Treadwell a very little work had been done on a quartz vein about 3½ feet in thickness, from which some fine specimens are said to have come. The exposure as I saw it was quite insufficient to justify any opinion on my part. The vein carries pyrite and pyrrhotite. Juneau Island is a mere rock near the Treadwell wharf. It is of true granite, containing masses of stratified slate and some quartz veins said to carry a little gold.

SILVER BOW BASIN.

Silver Bow Basin lies about 3 miles from Juneau, a little to the north of east, near the head of a stream called Gold Creek. Its position is shown on the map, Pl. XVI, the topography of which was supplied approximately from local surveys by Mr. C. W. Garside. This basin is the site of considerable mining activity and is a locality of no little geological interest. In the hills to the southeast lies a glacier which formerly extended to the mouth of Gold Creek and

NOWELL PLACER MINE, SILVER BOW BASIN.

built up the moraines, a part of which is now occupied by the outskirts of Juneau. This glacier excavated, or at least swept out, a considerable depression in the position of Silver Bow Basin. The depression was subsequently occupied by a lake separated from the lower stretches of the creek by a solid rock divide.

The excavation of a depression by glacial ice is sometimes referred to as if it implied a paradox in mechanics. Were a glacier a slowly moving fluid mass, however viscous, like sealing wax or asphalt, it could never excavate beneath the level of its course. Ice, however, is not a fluid, but a solid; and it is entirely practicable for a glacier to move uphill provided that the back pressure thus produced does not exceed the limit of solidity of the ice. An opportunity was afforded during the expedition here described of observing the fact that ice may move upward at the Grewingk glacier on Kachemak Bay. The action at Silver Bow Basin was no doubt entirely similar. I was informed that the solid rock of the divide is about 100 feet above the bottom of the lake basin.

The lake-beds of Silver Bow Basin are auriferous, and that to a very considerable extent. It is asserted that no less than $250,000 was extracted from these beds prior to 1895 by the hydraulic process, drainage being secured by a tunnel 3,500 feet long through the schists. The mining operations have made an excellent section of the deposit, a general view of which is given in Pl. XX. Directly upon the bed rock occurs a fine, muddy sand, a foot or more in thickness; next comes a few inches of a black vegetable mold containing a great quantity of leaves which, though blackened, are still tough. Upon this mold rests a layer of large bowlders, some of them 2 or 3 yards in diameter, more or less rudely mingled with gravel and muddy sand. This is illustrated by Pl. XXI. The topmost layer is in some portions a peaty mass, and the entire deposit averages some 50 feet in thickness. The gravel is extremely little rounded and many of the rock fragments are almost sharp cornered. The pebbles are of the most diverse character and many of them are gold-bearing quartz. It is probable that the bowlders in these beds were deposited at a time when the glacier ended in the lake, perhaps after having already once retreated to a higher level. The period during which the glacier supplied the lake with bowlders was probably brief, since otherwise the bowlder layer would be heavier. The upper portions of the beds seem to have been filled in, in the ordinary way, by wash from the surrounding slopes. It is believed to be only the southwestern side of the lake deposit which is auriferous, this side having received the drainage from the area containing the gold-bearing veins to be described presently. This is almost the only case known to me in which lake-beds have proved auriferous to a remunerative extent, though gold-bearing lake-beds are not very uncommon.

It is a remarkable fact that although ice has filled Gold Creek, patches have been left near Silver Bow Basin which have never been subjected to glaciation; in fact, in the higher portion of the Lane and Hayward property there are left considerable areas of decayed rock, or saprolite, exactly similar to those so abundantly found in the southern Appalachians. This saprolite also is auriferous, deriving its gold from a very great number of quartz veins, many of them of the most tenuous description. It is the wash from this saprolitic mass which seems to have furnished the gold to the lake-beds.

The saprolite on the Lane and Hayward property has been worked for years as a placer deposit. The best of it is no doubt gone, but enough remains amply to illustrate its character. A little lower down the hill than the saprolite deposit are a couple of open cuts and a short tunnel, also on the Lane and Hayward property, known as the Fuller No. 1 mine.

The country rock is a micaceous schist of sedimentary origin, carrying garnets. The schists strike N. 60° W. (true) and dip about 60° to the northeast. These schists are cut by at least three dikes of a fine-grained diorite. The dikes are nearly vertical, strike north, and are each about 6 feet in thickness. They occur near the western limit of the ore-bearing ground, but do not seem to cut off the ore entirely in this direction. Another and similar parallel dike occurs somewhat farther east in the Aurora claim. There appear to be no large veins on this property; the quartz occurs in innumerable stringers and lenses, varying in width from 2 feet or more to the thickness of a sheet of paper. Many of the veins, especially the smallest of them, are intercalated in the schists in perfect conformity to the cleavage, and many considerable lenses occur in the same manner. Still more numerous and of greater average width are seams cutting upward into the schist and very strikingly displayed on the surface of the smooth rock. The stringers have been opened by normal faulting.

There seems to be no large body of quartz on this property which would pay for underground development; but the rock lies in a position very favorable for quarrying, and it is believed by the owners that a large amount of material carrying $4 or $5 a ton can be cheaply extracted. The maximum value of the ore obtainable in commercial quantities is said to be about $8 per ton. The fineness of the battery plate gold saved is about 0.856. The gangue minerals are calcite, siderite, pyrite, mispickel, galena, and zincblende. As nearly as I could learn, this property has produced by milling something like $40,000 worth of gold. The product of the saprolite workings is entirely unknown.

The Aurora or Bennet mine lies directly north of or down the hill from the Lane and Hayward, and is opened on a portion of the same deposit. The peculiar feature of this mine is that it possesses a well-developed cross-fissure vein from 2 to 6 feet in width, striking at 15° west of north and dipping at about 70° to the southwest. I was

BOWLDERS IN THE NOWELL PLACER MINE.

informed that there is no sensible difference between the ores of this vein and those of the lenses or stringers, and I see no indication that its age or its origin is different. It has an advantage over the stringers in the fact that it lends itself to underground mining with more facility. The gangue minerals are the same as those of the Lane and Hayward, but include also pyrrhotite and muscovite. The ore is reported as milling about $13, and the concentrates are shipped to Puget Sound to be smelted. The vein has been followed for about 200 feet underground, and is said to have been followed on the surface for 200 feet more.

About a mile and a half down Gold Creek from Silver Bow Basin is the Taku mine. The rock at this point is a dioritic schist and has been intruded among the slate, horses of which are included in it. The schistosity of the dioritic mass is of course due to subsequent movements. The ore consists of very irregular quartz stringers intersecting both diorite and slate; they strike about N. 30° E. (true) and dip eastward. This ore is remarkable for the unusual quantity of pyrrhotite which it contains, this sulphuret often occurring in masses several pounds in weight. I had a special test made for nickel in the pyrrhotite, thinking this worth while on account of the very usual association of nickel with pyrrhotite, but none was detected. No other sulphuret was observed at the Taku mine, and the only other gangue mineral noticed was muscovite. The gold is said to be very free, as is usual in pyrrhotite ore, so that the sulphurets after milling have no considerable value.

SHEEP CREEK BASIN.

Sheep Creek Basin lies to the southeast of Silver Bow Basin, at a distance of about 3 miles, and the two areas are separated by a divide. The direction of the mines of the two localities from one another is the same as the strike of the schistosity of the country, or as the course of Gastineau Channel. They are, in fact, on a continuous belt of quartz deposits. Sheep Creek Basin is a picturesque little valley lying 750 feet above sea-level, and it seems to represent a glacial cirque. Even in June masses of snow heavy enough to interfere somewhat with mining remain upon its declivities. A view of the Sheep Creek Mountains, taken from the Treadwell Mine, is shown on Pl. XXII.

In Sheep Creek Basin there are three mines from which there has been a considerable output—the Silver Queen, the Glacier, and the Gould and Curry. Besides these, there are several prospects of minor importance.

The Silver Queen mine is that on which there is most development. It is situated on the northwest side of and about 600 feet above the floor of the basin, which is itself about 750 feet above the level of the channel. A wagon road 2 miles in length runs from the beach to the foot of the steep slope on which the mine is situated. A track tramway, working by gravity, serves to transport ore from the mine to the end of the road.

The rocks of the basin consist of carbonaceous and micaceous schists, whose strike is 50° west of north and dip 70° north. There are also possibly dikes of gabbro similar to that accompanying the Treadwell ore deposit. At the Silver Queen the carbonaceous slate forms the country rock of the vein, while the gabbro is perhaps represented by a decomposed greenstone, which occurs on the foot-wall side a few feet away from the vein. The vein is 5 feet in widest dimension, is intercalated with the laminæ of the slate, and corresponds to the schistosity in strike and dip. It pinches and swells in the manner characteristic of such intercalated veins. Vein minerals consist of quartz, pyrrhotite, zincblende, copper pyrite, galena, mispickel, a little iron pyrite, and, it is reported, native silver and a little ruby silver. The galena is argentiferous. In fact, the product of this mine and that of the Glacier above has been mostly in silver, and has contributed the major part of the silver hitherto obtained from the Territory. Up to the end of 1895 the Silver Queen had produced about $100,000 in silver and $20,000 in gold. The mine workings consisted of about 800 feet of drifting on the vein, represented by three tunnels of 200 to 300 feet in length. The ore is milled in the basin below, and the concentrates shipped for smelting.

The Glacier mine, situated 800 feet above and to the northwest of the Silver Queen, on the same slope of the basin, has workings on three parallel veins, one of which is the same vein as that worked in the Silver Queen. The most westerly of these three veins is on a contact between two varieties of schist. Its foot wall and the country rock of the two veins lying to the east is the carbonaceous slate seen in the Silver Queen. The hanging wall is, however, a micaceous schist, containing scales of muscovite and of light-green chlorite. The veins all correspond in strike and dip with the inclosing schist, but differ from the veins of Silver Bow Basin in that they do not have so much the character of stringer leads. Faults have been noted in the veins, the fault plane being nearly vertical and directly across the strike. The throw is in each case about 5 feet, the southeast side having slipped downhill. Detailed observations on these dislocations were not practicable, but it seemed more reasonable to refer them to the subsidence of blocks or scales of the rock which had been loosened by surface weathering. Such phenomena are probably much more common than has been generally noted hitherto, especially in regions subjected to the violent action of frost, such as the one under consideration.

The veins of this mine average 3½ feet in width, and are said to have a lenticular character, the long axes of the lenses having a pitch in the plane of the strike downward toward the west. Like the

SHEEP CREEK MOUNTAINS, FROM THE TREADWELL MINE.

Silver Queen, this mine carries more silver than gold, but the ratio between the two is variable. The average tenor is about $40. Minerals found in the vein here, besides quartz and some muscovite, are iron pyrite, argentiferous galena, zincblende, copper pyrite, pyrrhotite, mispickel, argentiferous tetrahedrite, pyrargyrite, and native silver. The mine has been worked for six years and has 1,500 feet of development. No complete statistics as to its product are available. Thirty to forty thousand dollars will probably represent its output.

The Gould and Curry, in the north end of Sheep Creek Basin, at about 2,500 feet above the sea, was a mere prospect in the summer of 1895. Considerable development has since been done on it. The rock, although schistose, appears to be of igneous origin and of dioritic type. The strike of the schistose laminæ is N. 70° W.; dip, 80° to the north. There were three veins exposed in a small crosscut 30 feet long, each vein being about 15 inches in width. Stringers of quartz were seen in the schist between the veins. These cut slightly upward into the schistosity. They are barren of any value. The vein minerals consist mostly of quartz, containing zincblende of the black-jack variety, accompanied by small amounts of pyrrhotite and iron pyrite. The veins are said to show free gold frequently, and specimens containing it were found on the dump. According to the United States Mint report for 1895, the product of this mine for that year was $26,000 in gold.

SUMDUM BAY.

The only mining in progress on Sumdum Bay in the summer of 1895 was at the Bald Eagle, in longitude 133° 30′. The mine is at an altitude of about 1,000 feet above sea-level and $2\frac{1}{2}$ miles from shore. The rocks are green slate, black bituminous slate, and dikes of a massive rock seemingly granite, but too decomposed for satisfactory study. The schists strike and dip very irregularly from N. 45 E. to N. 70 W., and have been greatly disturbed.

The deposit is a stringer lead, following the schistosity with so much regularity in dip that I was unable to observe in the exposures momentarily visible whether the stringers cut upward across the schistose surfaces or not. The foreman, however, asserted that they do so, which would indicate normal faulting. In strike they often break across laminæ, and the lead shows a divergent stringer, so that the deposit clearly occupies an opening due to fracture. The lead lies for the most part along the contact between the two varieties of slate.

The main lens of ore being worked is from 5 feet in width downward. The ore consists of quartz, galena, zincblende, pyrite, and mispickel, and is richest on the foot wall. At the cropping I observed copper stains, so that there is probably some chalcopyrite in the lead. The ore is said to be very rich, averaging, according to the superintendent, Mr. Trowbridge, $40 to $50 per ton. The data obtained indicate that the ore contains about equal quantities, by weight, of gold and silver.

At the time of my visit this property could be regarded only as a promising prospect, but the ore was good and the disturbed condition of the country rock was a favorable indication for further development. From the Director of the Mint I learn that the product of the mine for 1896 was nearly $96,000, so that the favorable impression produced is confirmed.

BERNERS BAY.

The Comet and Bear mines belong to the Berners Bay Mining and Milling Company, but the landing, called Seward City, is on the west side of Sherman Point and not in the bay. The 40-stamp mill is about 2 miles from the landing and 700 feet above tide-water.

The Bear mine is about 500 feet above the mill and a third of a mile away. The country rock is a diorite, which is described on an earlier page. It is irregular in texture and much fissured, but I detected no system in the partings. There are three small tunnels cutting several quartz veins, all of which strike in a westerly direction, but do not seem to be parallel. They also dip at various angles to the northeast. The widest of them is known as the Bear vein. It strikes due west (true) and dips at 60° or 70° to the north. In width it varies from 2½ to 11 feet. The vein contains quartz, calcite, sericite, pyrite, chalcopyrite, and mispickel. The vein also incloses many fragments of wall rock, often sprinkled with pyrite, though embedded in white quartz not visibly charged with sulphurets. The quartz is much broken and disturbed, no doubt by movements of the ground. The direction of movement seems to be indicated by the groovings on the walls, which pitch westward at about 30°. While portions of the Bear ore look fairly well, much of it is sugary, dead, and barren-looking. The mine at the time of my visit had produced no ore.

The Comet is said to be 7,000 feet eastward of the mill, and is about 1,000 feet above it. It lies at least approximately in the strike of the Bear deposit. The development consisted of three small tunnels and one winze down about 100 feet below the lowest tunnel. The country rock is the same as that at the Bear. There are several small veins besides the Comet, and the structure is as irregular as in the other mine. The strike of the Comet varies from N. 15° E. to N. 75° E., but the former course seems to be the more characteristic. The dip also varies from about 70° to 45° to the north. The vein varies in thickness from 8 feet downward, and averages about 3 feet. The quartz, which is usually somewhat broken, carries pyrite, chalcopyrite, and galena. In some portions of the mine there is much free gold accompanied by an unusually small amount of sulphurets, and, judging from the statistics, some of the other quartz must be richer than it looks; the deposit, however, is apparently somewhat "pockety." I was informed that the mine had produced over $200,000 in the year preceding June, 1895, and that the ore averaged $50 or $60. It is said that only 1 per cent of the ore is sulphurets, and that these run about $160 per ton. If so, 97 per cent of the gold recovered is obtained by direct amalgamation, a very unusual state of things. The fineness of the bullion is 0.840 to 0.800. The Berners Bay Mining Company, according to the Director of the Mint, produced $125,000 in 1896.

FUNTERS BAY.

There were two prospects on Funters Bay at the time of my visit, both seemingly on the same series of veins. The more easterly was known as the Tellurium mine, and the other, about a mile distant, as the War Horse. The strike is somewhat different, but there is evidence of curvature on the exposures along the shore, and the discoverer, Mr. Richard Willoughby, informed me that substantial continuity is established by intermediate croppings and what may be called *soundings*.

The surface of Admiralty Island is deeply covered with decaying timber, overlain by a thick layer of moss, and overgrown with bushes and trees. Mr. Willoughby states that he is in the habit of prospecting through this vegetable layer with a steel rod armed with a "carbon." After a little practice it is easy to discriminate the feeling of quartz from that of less gritty rocks. More than 99 per cent of southeastern Alaska is covered by dense moss and decaying wood, and some such method of facilitating prospecting as that described is highly desirable.

The Tellurium Mining and Milling Company is said to possess six parallel veins, striking a little east of north (true) and dipping southward at 70° or 80°. Of these, four were visible, averaging about 3 feet in thickness, but sometimes swelling to 10 feet and occasionally pinching. The country rock is a schist seemingly of eruptive origin, very probably once a diabase, but rendered cleavable by pressure. The present position of the schistose laminæ is nearly horizontal. On a little dump I found fragments of a diabase which seem to belong to a dike not visible in place. This is the only diabase met with during the trip, though the closely affiliated gabbro of the Alaska-Treadwell might at some points be regarded as diabase.

The veins fill cross fissures in the schists. They consist of quartz, a little calcite, and a fair amount of pyrite and pyrrhotite, accompanied by an unusual quantity of chlorite. The chlorite is often intergrown with the quartz so as to produce a somewhat regular mottling. Free gold is sometimes found in the chlorite. Mr. Willoughby asserts that some telluride occurs in the ore in thin silvery streaks, but the specimen given me to illustrate this occurrence contains no tellurium. Free gold is sometimes seen in quartz carrying inappreciable quantities of sulphurets.

It is stated that the pyrite contains $150 per ton, while the pyrrhotite carries only $10 or $15. The ease with which gold entangled in pyrrhotite is extracted is well known, and this fact tends to throw a doubt on the favorite hypothesis that gold in pyrite is altogether free. However, pyrrhotite is so much softer than pyrite that, other things being equal, the monosulphide should be more easily treated. The ore is said to average $10, and there is nothing incredible in this assertion. The proximity of the veins to the water and their nearly vertical position will facilitate the working of the property.

The War Horse veins strike about N. 15° E. (true), and the geological conditions seem similar in nearly all respects to those of the Tellurium property. The veins on the War Horse often send off sheets of quartz into the schists, these sheets following the cleavage surfaces. In this way very pretty illustrations on a small scale of "pipe and rake" veins are produced. It is said that, as one would suppose, the intersection of pipe and rake is often much richer than the average ore. Besides these pipes, there are portions of the slate which show numerous small lenses and stringers of pyritous quartz, and some of the ground thus impregnated is believed to be worth extraction.

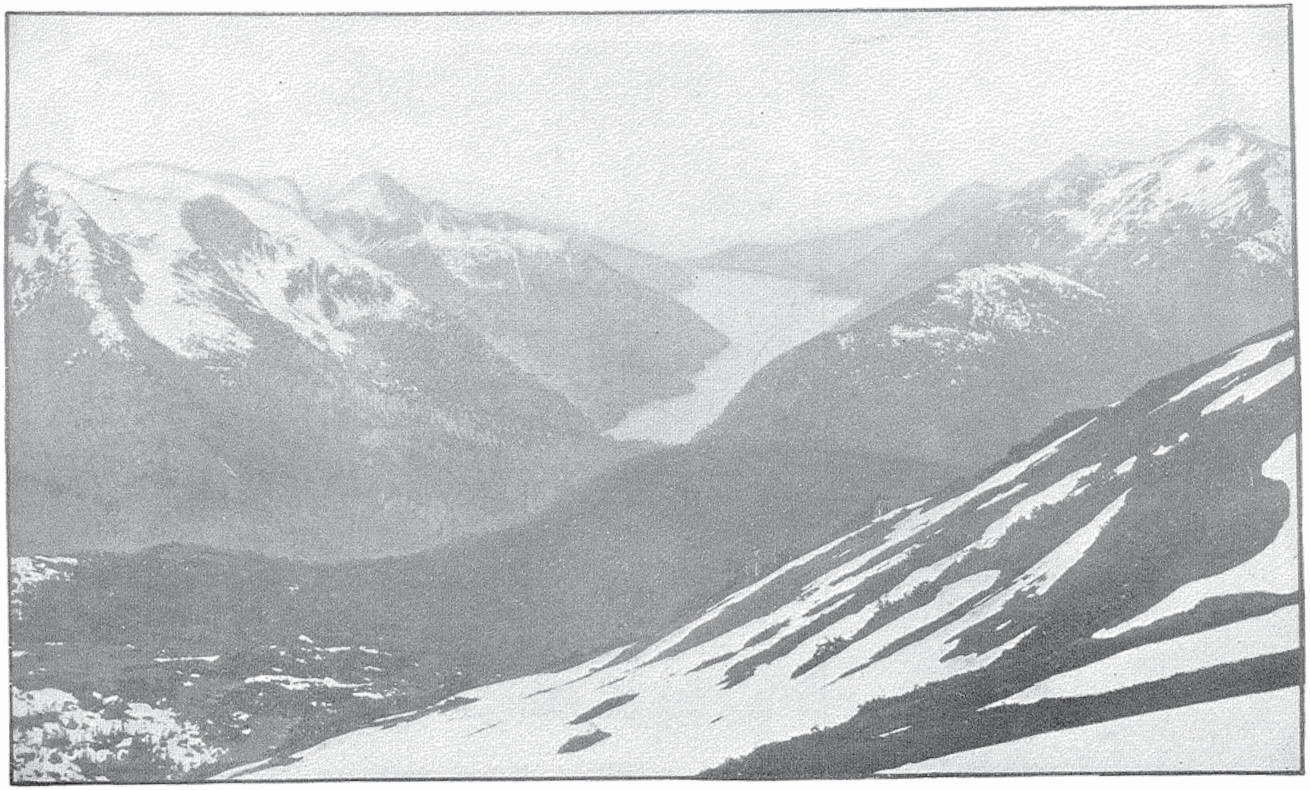
The Director of the Mint reports $16,000 from Funters Bay in 1896 credited to the Boston and Alaska Company. Whether this company has acquired the Tellurium claim I am not informed.

REGION NEAR SITKA.

There is a very considerable number of prospects within a few miles of Sitka. Most of these occur about Serebrennikof Arm or Silver Bay, but the Thetis lies to the eastward of Sitka, and a little (so far as I could see, hopeless) prospecting has been done at the site of Old Sitka on Katliana Bay. Pl. XXIII is an approximate map of this region, the general position of which may be seen on Pl. XV. The rocks associated with ore throughout this region, so far as observed, are carbonaceous slates and the curious pyroclastic diorite described in the earlier portion of this report. The cleavage of the slates antedates the diorite, which is itself more or less schistose at many points. At the hot springs, however, not very far away from Silver Bay, there is granite and a dike of sodium-syenite, and Mount Edgecumb is at least in part basaltic. No product is reported by the Director of the Mint from this region for 1896.

The Liberty mine, owned by Major Turner, lies on the south shore of Silver Bay, about three-quarters of a mile from the indentation called Bear Bay. The country rock is slate, but near by are intrusions of the diorite in the form of dikes varying in width from a few inches to several feet. The slides from these dikes are among the most characteristic of this pyroclastic rock. The slates strike N. 70° W. (true) and dip 80° southward. The ore forms a series of imbri-

VIEW OF THE LUCKY CHANCE MINE.



VIEW OF DEEP LAKE FROM LUCKY CHANCE MINE.

cating lenses, or a stringer lead, in the slates, the quartz conforming as a rule to the caruneulated schistose structures, though occasionally breaking across laminæ, and sometimes the slate is so broken as to form a reticulated deposit. The slate fragments are angular, and there is no evidence of substitution. The width of the lead is variable, but reaches 7 feet in maximum so far as explored. The ore consists of quartz, calcite, chlorite, pyrite, chalcopyrite, and mispickel. The ore is said to average $2.50, half of it "over the plates." Milling tests have yielded as much as $5.

The Silver Bay property is nearly on the strike of the Liberty, on the other side of Silver Bay, and shows a vein 8 feet in width in pyroclastic diorite, with the dip and strike of the Liberty lead. Ore on the dump showed pyrite and chalcopyrite. No work was in progress.

The Eureka prospect is about 2 miles southeast from the Liberty, on the westerly side of the bay, and about 500 feet above the water level. It is a stringer lead of pyritous quartz inclosed in slate, but lying close to masses of the diorite, which forms both dikes and brecciated masses. The strike is the same as that of the preceding deposits. The amount of development is insignificant.

The Haley and Rodgers lies east of Salmon Creek, about two-thirds of a mile from the southerly extremity of Serebrennikof Arm, at an elevation of 675 feet. The country rock is slate. The vein is several feet in width, strikes N. 60° W., and dips 70° to the northeast, not conforming to the schistosity of the sedimentary rocks. The vein as a whole is white and unpropitious, but there is said to have been a rich streak on the foot wall. Pyrite is present in the vein, and on the dump fragments of mispickel carrying free gold were observed.

The Stewart is near the last prospect, a little farther from the bay, on the same creek, at an elevation of about 1,000 feet. The deposit is a stringer lead, sometimes developing into a nearly solid vein. A little of the ore is brecciated, and much of it is mingled with slabs of slate. The lead is 15 feet wide at one point, and may average 8 feet in width. It carries pyrite and mispickel. There is a ruined mill at the Stewart, but how much bullion it has turned out I was unable to ascertain.

The Lucky Chance is $2\frac{1}{2}$ miles from the southerly end of Silver Bay as the crow flies, but 7 miles by the wagon trail. It lies on the crest of a ridge, 2,500 feet above water and far above timber, in a very picturesque position. The main country rock is the pyroclastic diorite, carrying, as usual, numerous included fragments of slate. The property is opened by two tunnels, but the entrances to both were deeply buried under snow (June 26), and it was only with much effort that an entrance was effected into one of them, the lower one.

As there seen, the ore forms irregular stringers, each a few inches in width, sometimes massed and sometimes scattered through the country rock, which here consists of diorite mingled with slabs of slate. If the deposit were a solid vein, it would be perhaps 3 feet in thickness. The strike is irregular, but is approximately N. 45° W. (true), and the dip 80° NE. A peculiarity of the ore seems to be that the sulphurets are massed in contact with the walls or horses, the body of the quartz being nearly free from sulphides. At one point the stringers were so crowded that a stope could be and was carried up to the upper level. The ore contains, besides quartz, calcite, siderite, chlorite, mica, pyrite, and particularly abundant mispickel. Free gold associated with mispickel occurs. A sample taken by a disinterested person is said to have assayed $30 per ton. The upper tunnel is said to look better than the lower one, and the mine is considered the best in the district. While as at present developed it is a very unsatisfactory property, it might pay to follow the lead somewhat farther. A view of the Lucky Chance claim is given on Pl. XXIV, and a view of Deep Lake, taken from the mine, on Pl. XXV.

The Thetis is about 5 miles north of east from Sitka, and lies in a locality known as Billys Basin. The country rock is somewhat schistose diorite, and the deposit a reticulated zone striking N. 35° W., with a dip of 40° to the northeast. It shows about 2½ feet of quartz carrying calcite, pyrrhotite, and galena. A mill test is said to have yielded $7 gold and $1 silver per ton.

UYAK BAY.

Several small prospects exist on Uyak Bay, Kadiak Island. Their positions are given approximately on the map, Pl. XXVI. The Bear, Dan, and Calaveras claims lie close together, the first two on what is supposed to be the same vein, and the last on a second, nearly parallel, vein. The country rock is a carbonaceous schist or slate, and the fissures cut the cleavage. The Bear vein strikes N. 25° W. (true) and dips in a southwesterly direction at 40°. In width it varies from a few inches to about 6 feet, and averages perhaps 2½ feet. The quartz is usually solid, but is not entirely free from included schist fragments. A number of fine outlying parallel stringers accompany the vein. The sulphurets are arsenopyrite and pyrite, the former preponderating. Free gold is easily panned from the croppings, and some extraction has been effected with an arrastra, but I was not able to ascertain yield or tenor.

The Dan is about 500 yards from the Bear and on its strike, but the deposit has not been traced through the heavy timber. The vein is about 2 feet in width, and contains the same sulphurets. The mispickel here is well crystallized, and the general appearance of the quartz is good. No work was in progress and scarcely any has been done. The Calaveras lies to the northeast of the Dan, on a similar vein of the same strike. It is about 20 inches wide, and shows pyrite, mispickel, and galena.

The Lake claim is about 4 miles north of the Bear and on the east

VIEW OF RILEY'S CLAIM, BEAR CREEK.

shore of the bay. The vein at this point strikes N. 70° E. (true) and dips 80° to the southward, cutting the slate, which is here manifestly of sedimentary origin. The vein is only a foot wide, and the only sulphuret observed in it was a very little mispickel. This vein lies on one of a double series of joints forming a nearly rectangular system. On the shore below the vein is a neat illustration of the mechanism of jointing. The partings cross both sandstone and shale. In the sandstone the joints are from one-fourth to one-half inch wide and filled with quartz, but in the shale the same cracks are so narrow as to be scarcely visible, although sometimes carrying quartz. Evidently the shale yielded far more prior to rupture than did the sandstone.

The Wamberg and Boyer is 10 miles north of the Bear and near the entrance of Uyak Bay. The prospect is on a veinlet 7 inches wide, striking about N. 55° E. (true) and dipping to the southeast at 65°. It lies in sedimentary schist, and conforms nearly in strike, less nearly in dip. Near by excellent glacial modeling and scratches were observed.

TURNAGAIN ARM PLACERS.

At the time of my visit stream gravels had been worked for a year or two on Resurrection Creek and Bear Creek, and prospecting was going on at a locality called Sixmile Creek. These localities are shown in fig. 6 (p. 82). They lie on Turnagain Arm at the head of Cook Inlet, shown on Pl. XXVI. Rich gravels were found higher up the arm a few weeks after my departure. The only profitable workings in July, 1895, were on Bear Creek, but I was informed that a "color" could be obtained in any stream for miles about. On Bear Creek, which is a small brook running northwestward, the pay was confined to a length of about 1½ miles, the lower end of the stretch being perhaps 2½ miles from the mouth. The deposit consists of a mass of moderately coarse gravel, composed of pebbles of the size of cobblestones, mingled with a few bowlders. They extend in some cases a couple of rods from the present bed of Bear Creek. The gravel is evidently the result of modern erosion. The bed rock is exposed at Riley's claim toward the upper end of the productive stretch, and consists of slates striking nearly at right angles to the course of the stream and intersected by heavy dikes of pyroclastic diorite. A view of Riley's claim is given on Pl. XXVII. A description and analysis of this diorite have been given on a preceding page. Most of the pebbles are diorite, and this is said to be the prevailing rock at the headwaters of the creek. The rocks, where seen, contain a limited quantity of small quartz veins, and it is probable that the gold is derived from such stringers. Of course, prospecting for remunerative veins would be justified, but the heavy growth of spruce forest renders the search laborious, and hitherto no success in this quest has been attained.

The gold is found mostly in flattened but coarse and slightly worn grains. It is light in color and said to be worth $14 to $16 per ounce. This would correspond to a fineness of about 0.740.

It should be noted that the first discovery of gold in Alaska was made in 1848 by P. P. Doroshin. He found auriferous sands on the Kaknu River, the grains being coarse toward the source, or a region not far from Resurrection Creek, and he speaks of the association of gold with slates and diorite dikes. The miners on the Bear assert that the gravels have been worked to some extent before, and that they find old pick points deep in the gravel. It seems hardly credible, however, that any working in this locality can have antedated the discovery of a couple of years before my visit.

Late in August, 1895, fresh finds were made, particularly on Canyon Creek and Mills Creek, shown on the map, fig. 6. This map I owe

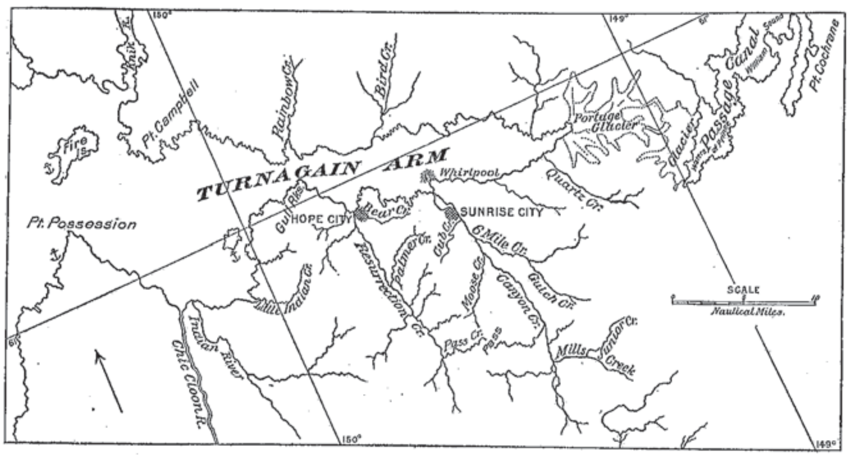
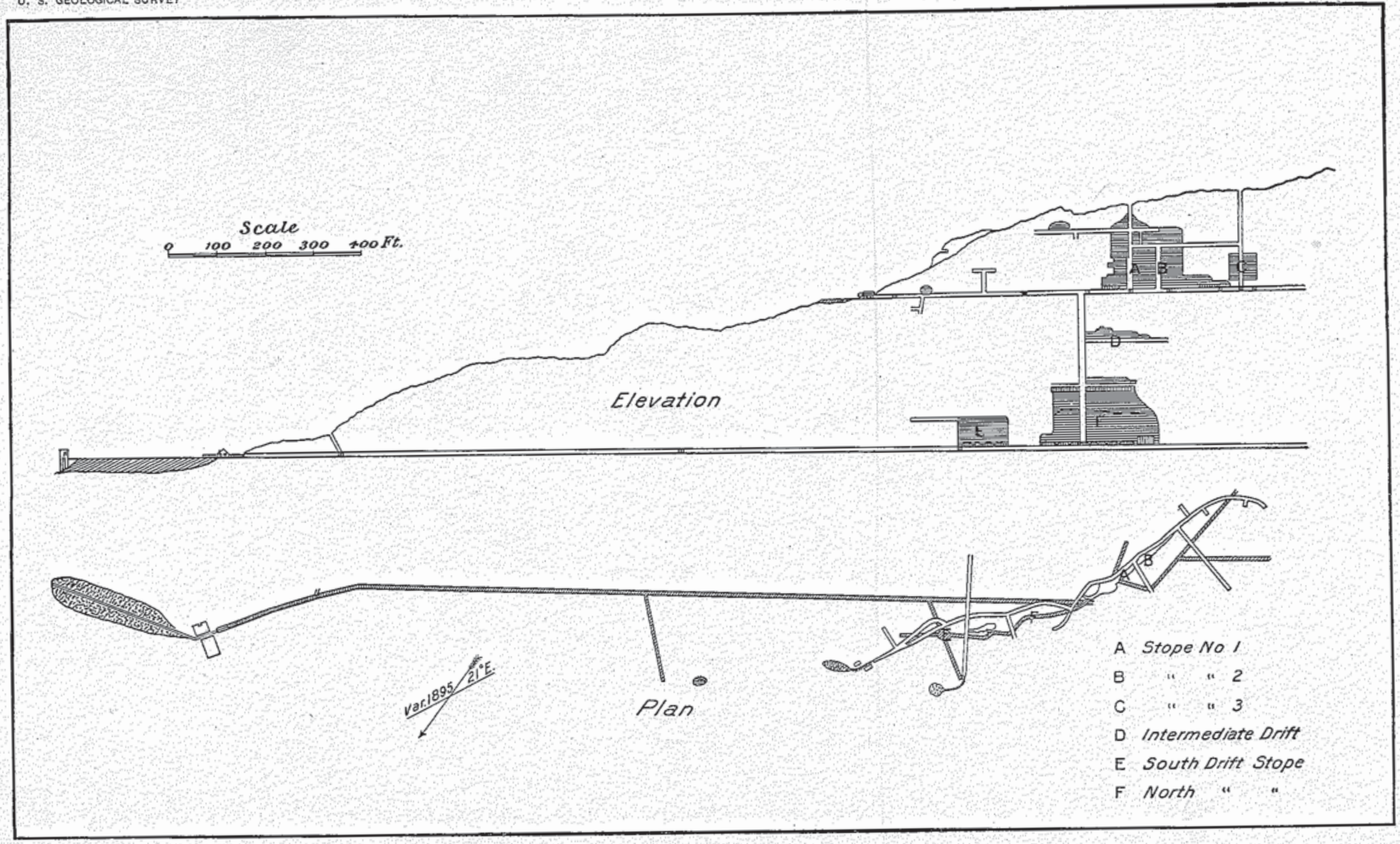


FIG. 6.—Sketch map of Turnagain Arm.

to the courtesy of Mr. J. A. Becker, of Sitka. It is decidedly more accurate than that given on Pl. XXVI. The miners at the new diggings are said to have made over $100 a day, and many slightly worn nuggets were obtained. The richness of the new washings stimulated the placer industry throughout the region, and pay gravel was found on Resurrection Creek and elsewhere. A rush to this region took place in 1896, as one would suppose, and while good diggings were found, not enough auriferous gravel was discovered to supply the needs of the influx of miners, and great disappointment followed. Such a result was sure to occur. Had there been enough gold for last year's crowd, twice as large a one would have sought the fields in 1897.

Access to the region is difficult and dangerous on account of the stupendous tides, which are about as great as those of the Bay of Fundy. For this reason many parties have gone in by way of Prince William Sound and Passage Canal.



PLAN AND SECTION OF APOLLO CONSOLIDATED MINE.

THE APOLLO CONSOLIDATED MINE.

This remarkable and important deposit lies on the island of Unga, about 2½ miles west of Delarof Harbor. Unga is one of the Shumagin Islands, and is shown on Pl. XXVIII. Nearly the whole of the exposed rock in this region is andesite and dacite, but on the north side of the entrance to the harbor there are rocks underlying the andesite which from the deck of a vessel look sedimentary. At Coal Harbor, or Zachareffskaia Bay, similar andesites overlie the Miocene. It is reported that there is a belt of granite farther inland than the mine. This is very probable, and it is certain that granite occurs on the Nagai, an island of the same group as Unga, and one of its nearest neighbors.

I saw nothing to lead me to suppose that there is any considerable geological difference between the dacite and andesite of Unga. They seemed at least associated eruptions, if not merely different facies of the same series of eruption. These rocks at some points show well-marked columnar structure. As the mine is approached the decomposition of the rock increases and there is a large amount of "propylite," or chloritic andesite, as pronounced in character as that of the Comstock lode. At the mine itself the rock is so decomposed that it is nearly impossible to decide whether all of the quartz which it contains is secondary. On the whole, it seems probable that at least a portion of the wall rock is dacite. The walls are highly chloritized and charged with pyrite. There is no sensible amount of sericite, nor any conversion to carbonates. The pyrite would seem to have been formed in part from ferromagnesian silicates, and perhaps also from magnetite. In one case a colony of minute pyrites occupies the position of an augite or hornblende.

The ores of the Apollo Consolidated consist of free gold, pyrite, galena, zincblende, copper pyrite, and native copper. Red oxide of copper and malachite are joined as decomposition products. The occurrence of native copper is remarkable, though not absolutely unknown elsewhere. Its usual form is that of fine filiform aggregates. A large part of the gold occurs in the free state, finely disseminated through quartz, and almost wholly unaccompanied by sulphurites. The quartz there often has a yellow stain, not at once recognizable by those unfamiliar with this unusual mode of occurrence. A large part of the value of the mine is said to depend upon kidneys of this free gold ore. A slide from such a specimen shows a few particles of galena with the gold. In some cases, also, the specks of gold are intimately mingled with tiny shreds of native copper, both being embedded in quartz and manifestly contemporaneous. Most of the surfaces of the gold grains are rough, and the metal tends to filiform and scaly configurations. Only occasionally is a plane face visible under the microscope on a gold grain. It evidently requires peculiar conditions to develop good crystals of gold even on a minute scale.

Much of the quartz is sugary. This condition seems due in part to conditions of crystallization and in part to movements which have taken place since ore deposition. The evidence of such movement is found in thin sections of the ore. One locality in the mine is known as the "Flour Mill," because the ore can be shoveled up as if it were meal. The ore has crystallized on walls and fragments of andesite in a very striking manner. Comb structure appears wherever there were relatively narrow spaces between fragments or along walls. There is not the slightest evidence of substitution; on the contrary, the fragments of rock are as sharp as possible. One of the specimens collected is a piece of andesite with a nearly square cross-section having sides an inch long, the length of the andesite fragment being perhaps 2 inches. The ore has crystallized out from the surfaces of the andesite in all directions, the crystals being arranged like iron filings on a magnet; but the corners of the andesite nucleus are as well defined as if it had been broken but yesterday.

Calcite occurs as a gangue mineral in the Apollo, though in quantities very subordinate to quartz. Much more remarkable is the presence of a mineral believed to be orthoclase. It occurs in small quantities in the stringers of ore, and is of the same age as they. It has a lower index of refraction than the balsam, displays a cleavage like that of orthoclase, and gives a strong reaction for potassium with hydrofluosilicic acid. Mr. Lindgren has more recently found microcline in auriferous veins at Silver Crown, near Cheyenne, Wyoming.

The deposit as a whole is nearly vertical and strikes N. 43 E. (true). It occupies a zone of fracture rather than a fissure, and might be called as a whole a reticulated vein. It is supposed to be bounded by two fissures, often marked by clays. There is often a pay streak at one or both of these fissures, but the pay frequently makes from the easterly fissure into the intermediate ground. So far as I could see, the presence or absence of remunerative ore depends chiefly on the amount of interstitial space present. The included rock fragments often show pyrite, but I could not learn of any more rock which was richly impregnated with gold. The ore-bearing ground is sometimes 40 feet in width, and, on the whole, forms a chute pitching northward. If there are other such chutes, as is to be assumed, they will probably be rudely parallel with this one.

The average yield of the ore is said to be \$8, and about four-fifths of this amount is obtained from the plates. The bullion carries 0.767 gold as collected from the plates. The sulphurite contains \$50 or \$60 per ton, and carries more silver than the plate gold. This is no doubt due to the large amount of galena in the ore. The amount of the production is given in the early portion of this paper under the heading, "Statistics of gold production." In 1896 the Apollo produced over \$400,000 gold and nearly \$40,000 silver, coining value.

Of course the Apollo Consolidated is a very recent deposit, and

VIEW OF EASTERN PORTION OF UNALASKA.

there has been little erosion since its deposition. In its general features it resembles the deposits of Bodie, California, and the irregularity of the fracturing in both cases is due to proximity to the surface as well as to lack of homogeneity in the rock. Such a mine requires careful management and systematic development. The Apollo also deserves careful treatment. A plan and section of the mine appear on Pl. XXIX.

There are other deposits in the neighborhood of the Apollo. The King mine is about half a mile northward, and is believed to be on the same lead. It is reported to have produced $3,000. Gold has been found at various points east and west of the Apollo, as well as northward, and there is said to be a belt of auriferous ground extending through the island on the strike of the Apollo. Nearly in this direction lies Red Cove, Popof Island, where the andesites are intensely decomposed and heavily charged with pyrite.

UNALASKA.

On the island of Unalaska some prospecting has been done, and one of the tunnels near Pyramid Peak is several hundred feet in length. This tunnel follows fissures on which a little quartz is occasionally seen, accompanied by iron and copper pyrite. This is certainly not a valuable deposit, but it is reported that there are other occurrences of sulphureted quartz on the island. A view of the eastern portion of Unalaska, taken from a hill close to Dutch Harbor, on the little island of Amaknak, is given on Pl. XXX.

AURIFEROUS BEACH SANDS.

As is well known, auriferous beach sands have been worked at various points along the Pacific Coast from lower California northward. Gold-bearing sands are especially abundant from Lituya Bay to Yakutat Bay—that is, between longitude 138° and 140°. According to Mr. Henry Boursin,[1] auriferous black sand was first discovered on the western beach of Khantaak, a small island in Yukutat Bay, in 1887. It is said that $3,000 was extracted from the sands near Yakutat in 1891. In 1890 beach sands were worked a few miles east of Lituya Bay, and in 1891 the yield at this locality is said to have been $15,000, obtained by sluicing. According to the reports received by the Director of the Mint, Lituya Bay sands produced $39,000 in 1896.

Sands from the Khantaak Island have been carefully examined by Mr. J. Stanley-Brown.[2] He found, besides gold, magnetite, garnet, hornblende, pyroxene, zircon, quartz, feldspar, calcite, and mica associated with fragments of a slaty or schistose character. Iron,

[1] Eleventh Census, Pop. and Res. of Alaska, 1893, p. 230.
[2] Nat. Geog. Mag., Vol. III, 1891, p. 196.

platinum, and chromite could not be detected, and only a trace of titanium is present. Mr. Stanley-Brown concludes that the sand is derived from the destruction of metamorphic rocks. The rocks surrounding Yakutat Bay seem to be Pliocene or Pleistocene, but as they are composed of the débris of older rocks, the sand derived from them might bear an older character. There is nothing known to me which suggests that the gold of this region is of recent origin, and it is more probable that it was derived from deposits affiliated with those of Baranof Island, though the croppings may now be concealed by Pleistocene beds. In the expedition here described it was impracticable to stop on this shore compatibly with visiting the more western auriferous districts.

Gold washing was in progress during my visit to the western shore of Kadiak Island, at Portage River and Ayakulik River. The beaches here lie along a bluff, averaging 50 feet or more in height, which limits an extensive grassy plain. This represents a very recent uplift which has been general throughout western Alaska, elevating most parts of Kadiak, Chirikof, Tugidak, and other islands. The recency of the elevation is shown by the fact that the little streams draining the low, flat plateaus have made small progress in cutting back into the bluffs. A view of the Portage River locality is given on Pl. XXXI. At the beach washing, the bluffs as well as the beaches carry streaks of black sand, and those in the bluffs are said to be auriferous as well as those at tide-level. The source of the gold is doubtless in the ranges which lie several miles to the east of the bluffs. Pebbles of granite and metamorphic rock are found on the shore, and have accompanied the gold from its original position. The gold-bearing sands do not occur in masses, but in patches, perhaps an inch in thickness and extending over a few square yards. When such a patch is found the material must be gathered and carried out of reach of the waves, which constantly shift the sands from place to place. The Kadiak sands consist of magnetite, garnet, quartz, slate, serpentinoid material, and very light, scaly gold. The gold floats easily and does not seem to amalgamate well. No doubt much of it is lost, and some new process, such as cyaniding, must be adopted before large profits can be made from any but exceptionally rich beach sands.

While on Kadiak and elsewhere the gold is associated with magnetite, I do not regard this as necessarily any evidence of a common origin. The two minerals would be found together, because both are denser than quartz, whenever both gold and magnetite exist in the rock undergoing degradation. As is well known, volcanic rock usually contains much magnetite, so that an area consisting of schists carrying gold-quartz veins, and basalt carrying no quartz, would yield an auriferous magnetite sand.

BEACH WASHINGS AT PORTAGE RIVER, KADIAK ISLAND.

END