305

Becker, George Ferdinand, 1898

"Reconnaissance of the gold fields of southern Alaska with some notes on general geology"

Reconaissance of the gold fields of southern Alaska with some notes on general geology USGS AR 18, 86 p.

CONTENTS.

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Statistics of gold production in Alaska.

[Stated in dollars.]

Year.	Alaska-Treadwell mine.	Mexican mine.	Other quartz mines of south eastern Alaska.	Stream placer mines of south-eastern 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	10.903	--------	--------	20,000	--------	--------	--------	--------	150,000
1883		--------	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

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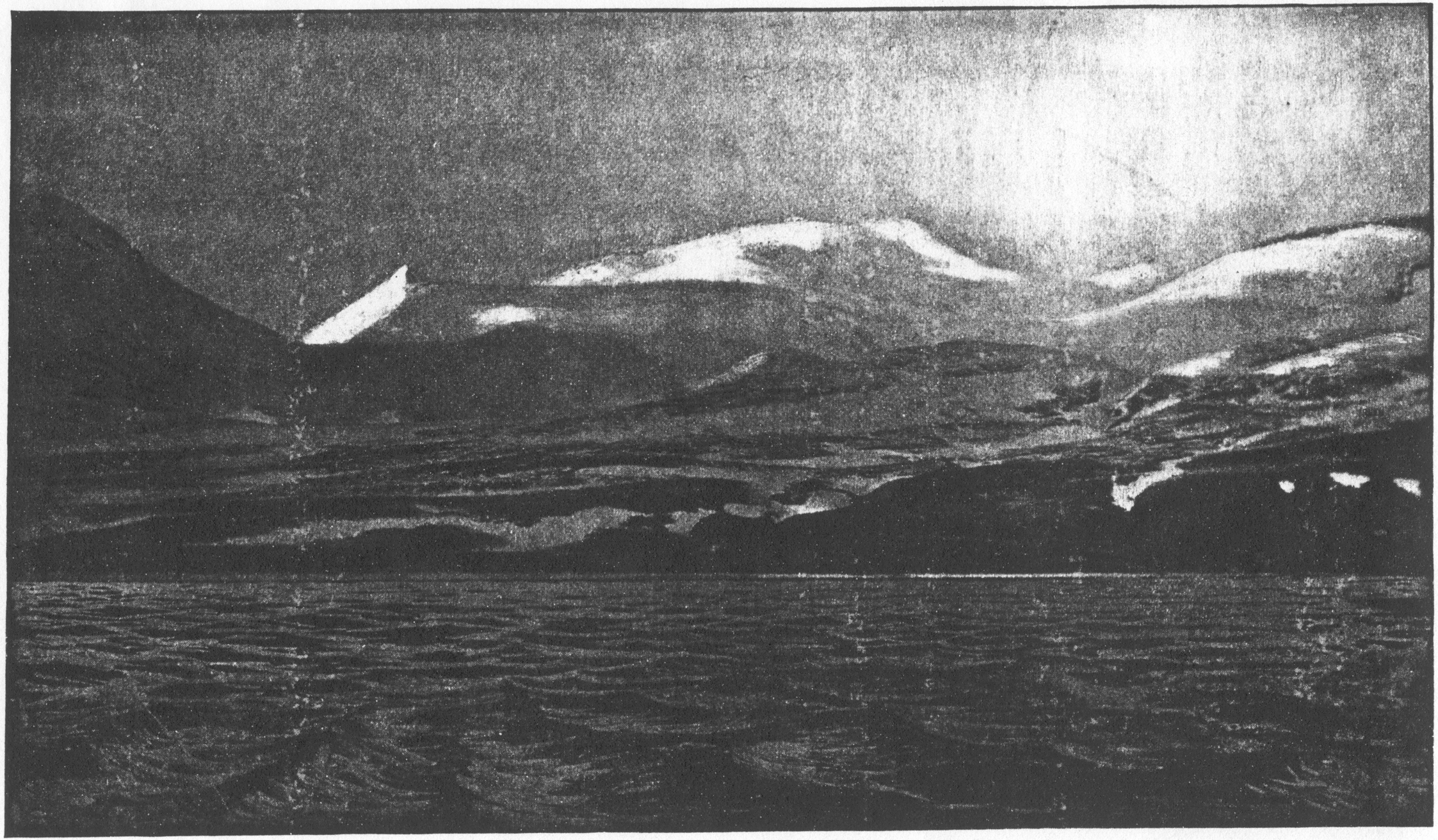
[1] Verh. Rus. min. Gesell. 1848–49, p. 269.

[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 Archiv. 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

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[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

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[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.

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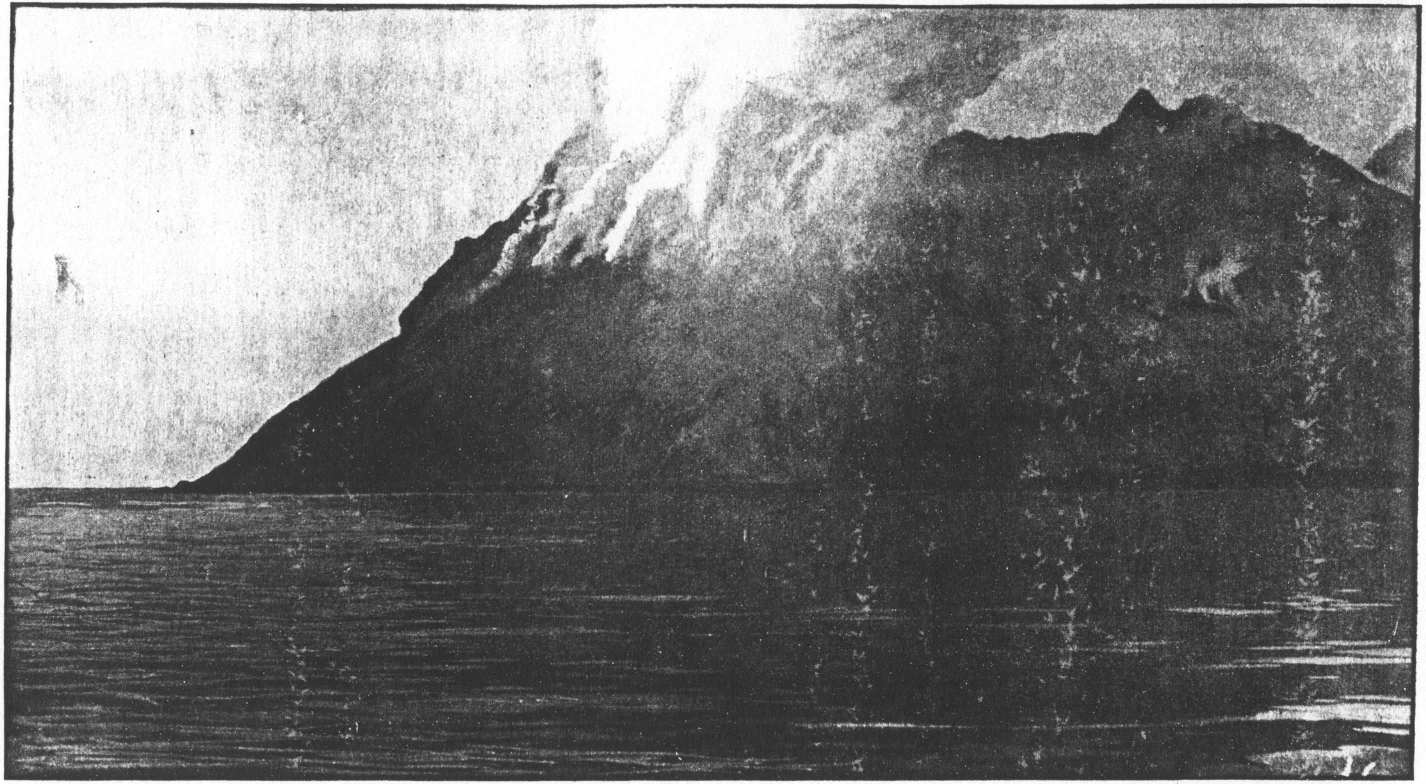
[1] Coast and Geodetic Survey Rept. for 1880, App. 16.



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

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[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,

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

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

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

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

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

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

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

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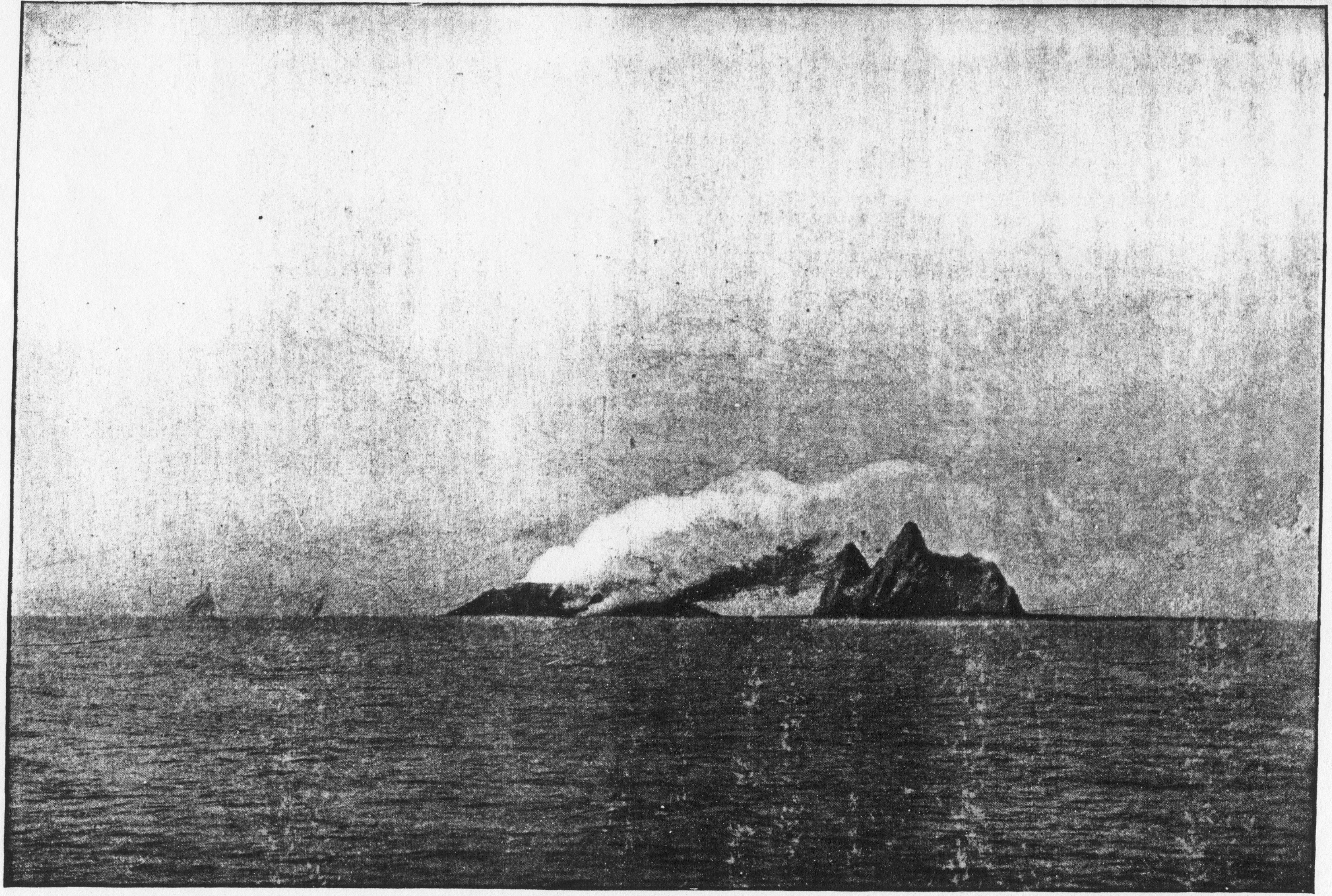
[1] It is not worth while to regard σ as variable; for, excepting near the summit of a volcano, the cubical compression will be nearly uniform and for such material as rock the variation of density is extremely small within the elastic limit.



BOGOSLOF AND GREWINGK, BEARING N. ¼ 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]

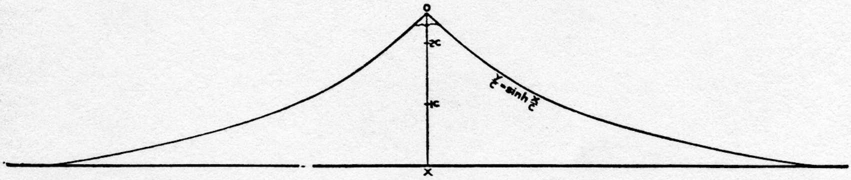


FIG. 1.—Form of volcanic cones.

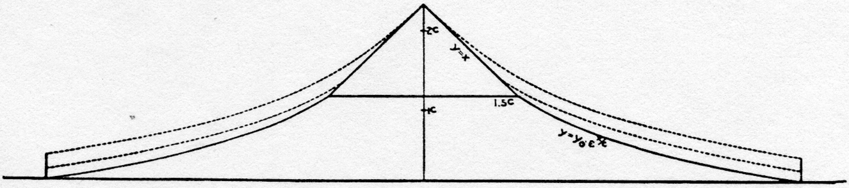


FIG. 2.—Form of volcanic cones.

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

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[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

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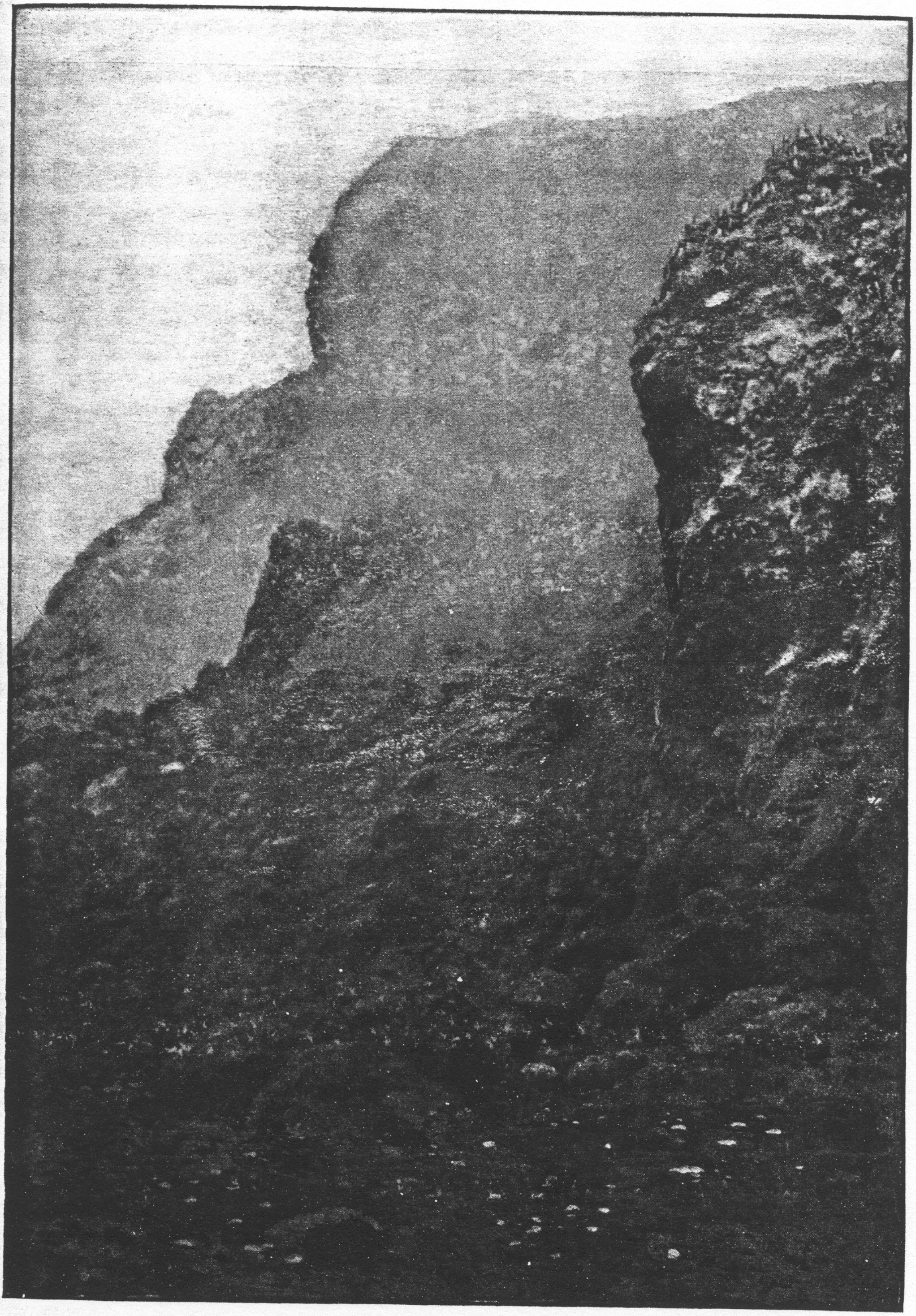
[1] A graphic comparison of the continuous curve with the outlines of Fujisan and several other volcanoes will be found in the Am. Jour Sci., vol. 30, 1885, p. 289. Prof. John Milne has also made such comparisons, Trans. Seism. Soc. Japan, vol. 9, part 2, 1886, p. 179.

[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-

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[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 2½ 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.

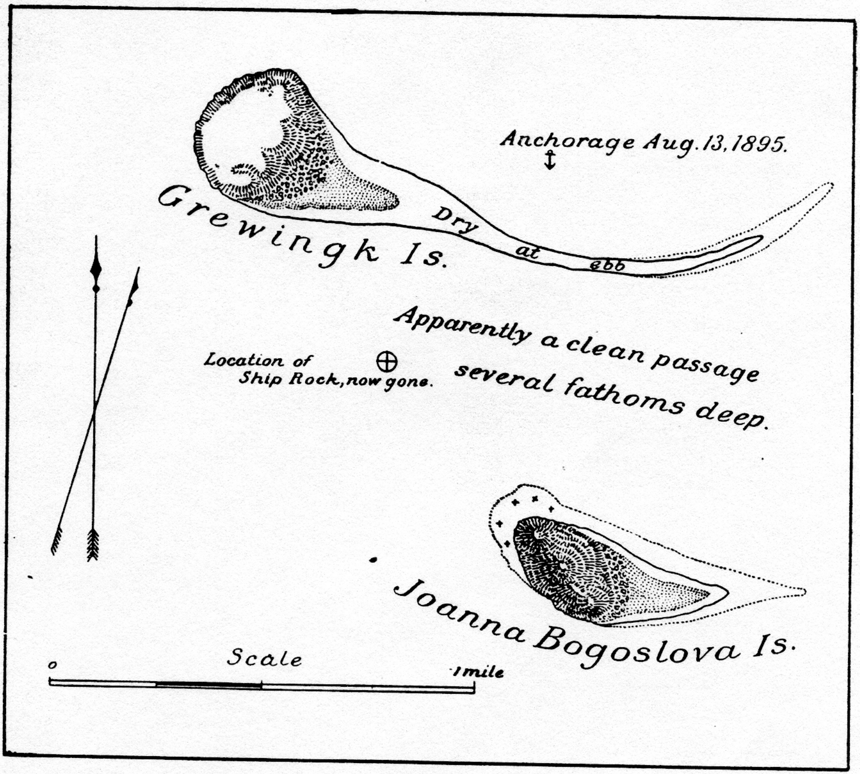

FIG. 3.—Sketch map of Bogoslof and Grewingk.

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

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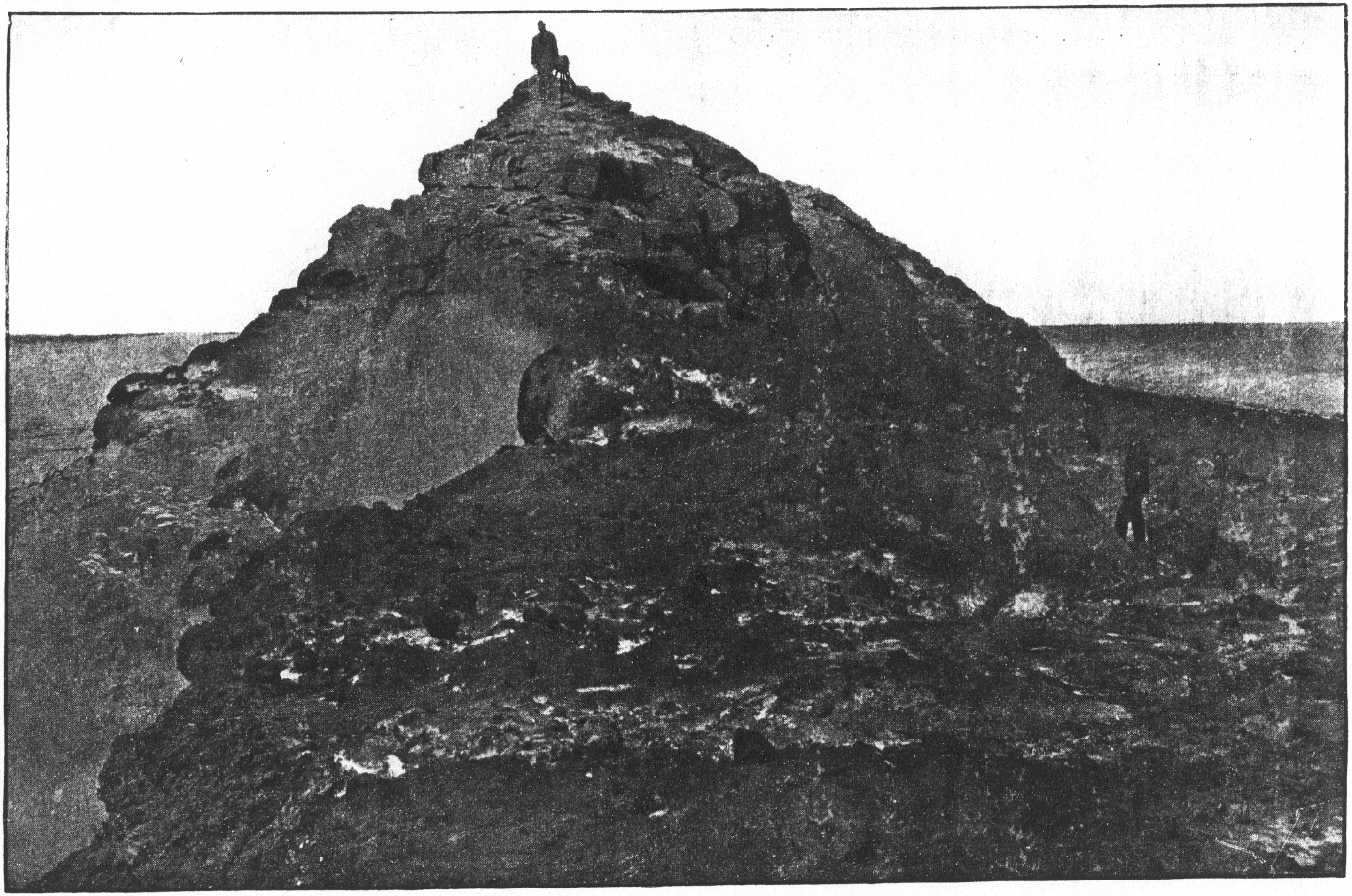
[1] Science, Jan. 25, 1884. Prof. Geo. Davidson also described it in the same journal, March 7, 1884.



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 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.

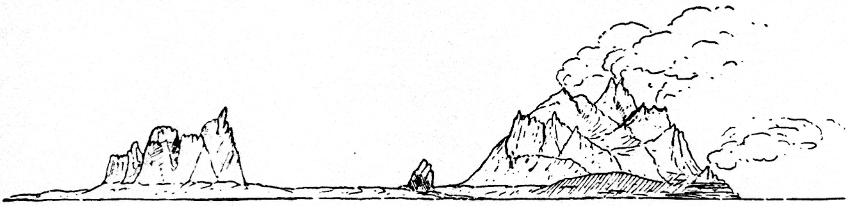


FIG. 4.—Sketch of Bogoslof and Grewingk in 1887, by Mr. William C. Greenfield.

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

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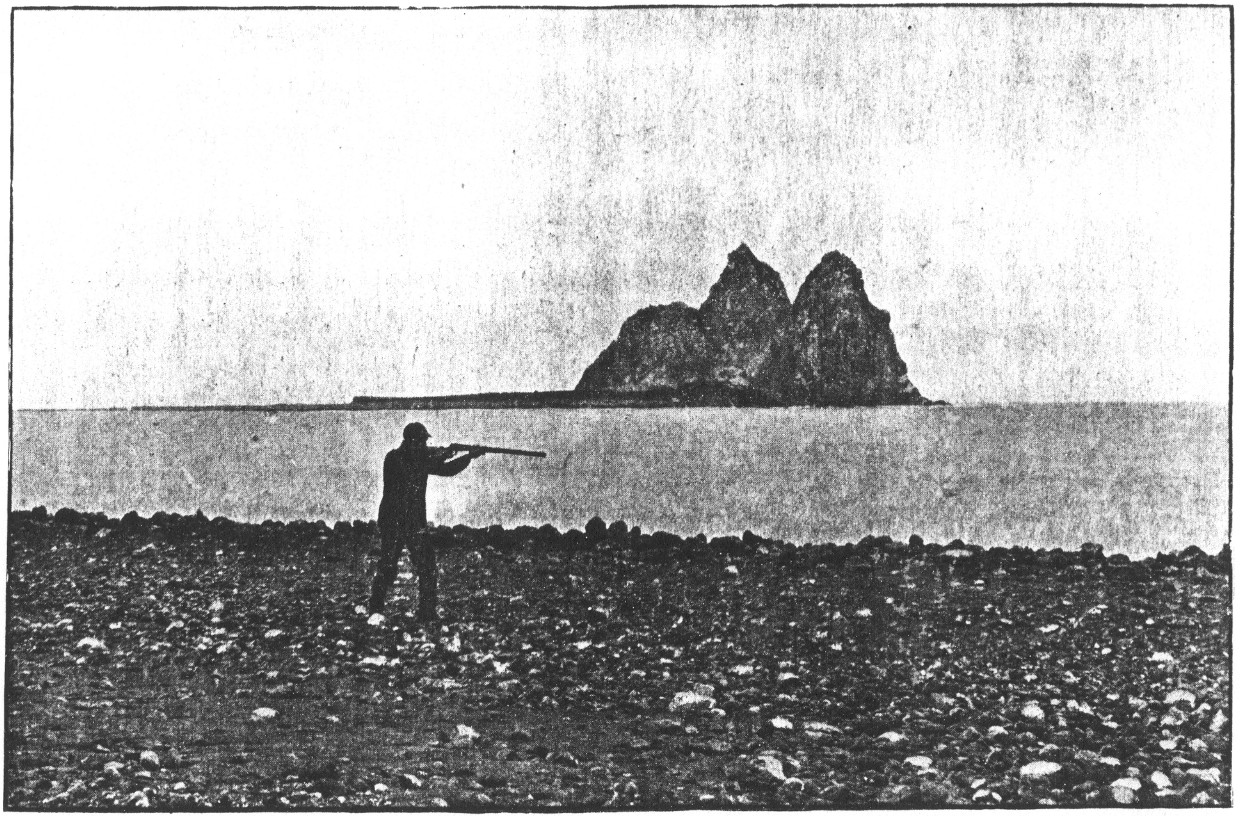
[1] A Voyage of Discovery to the North Pacific Ocean, book 5, chapter 5.

[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

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[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

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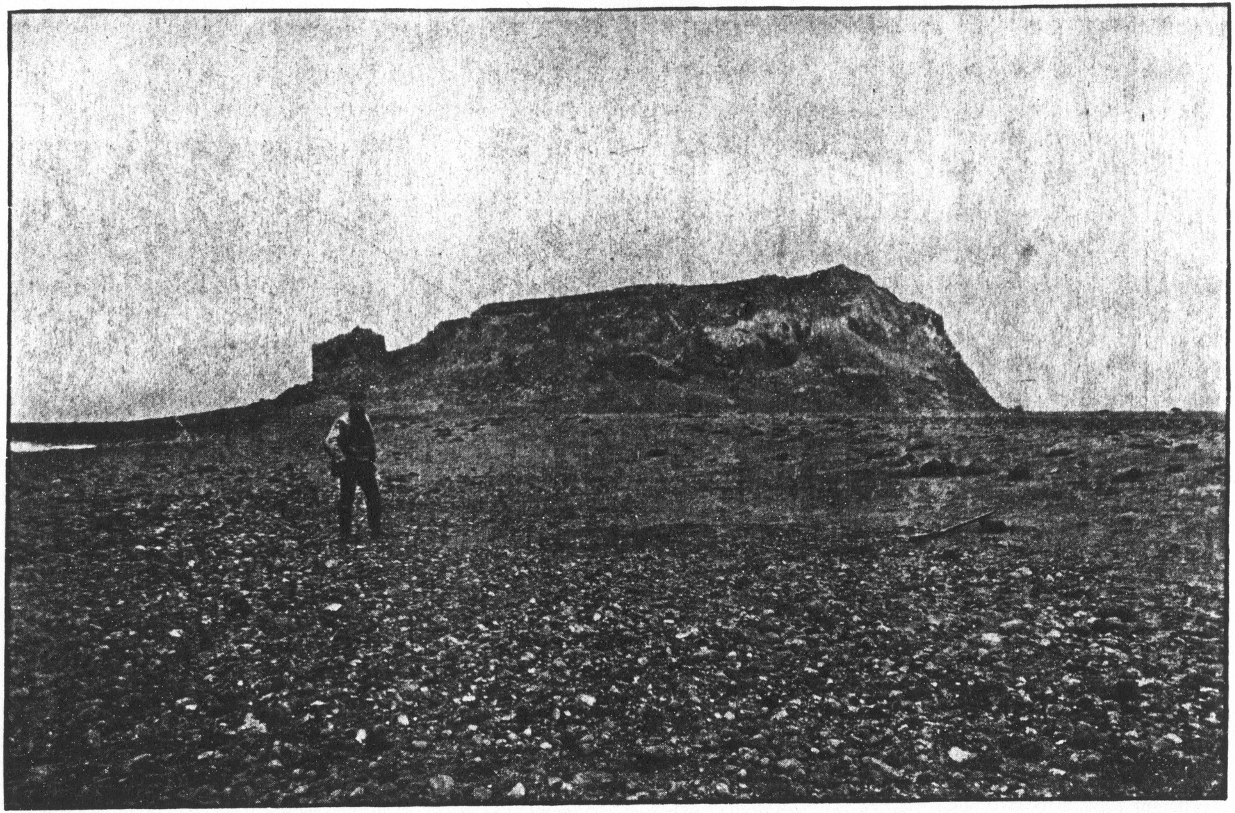
[1] Étude sur la détermination des feldspaths, 1894. Same, second fascicle, 1896.



GREWINGK, FROM THE SOUTHEAST, IN 1895.

lamellæ is cut at an angle of 180°–φ 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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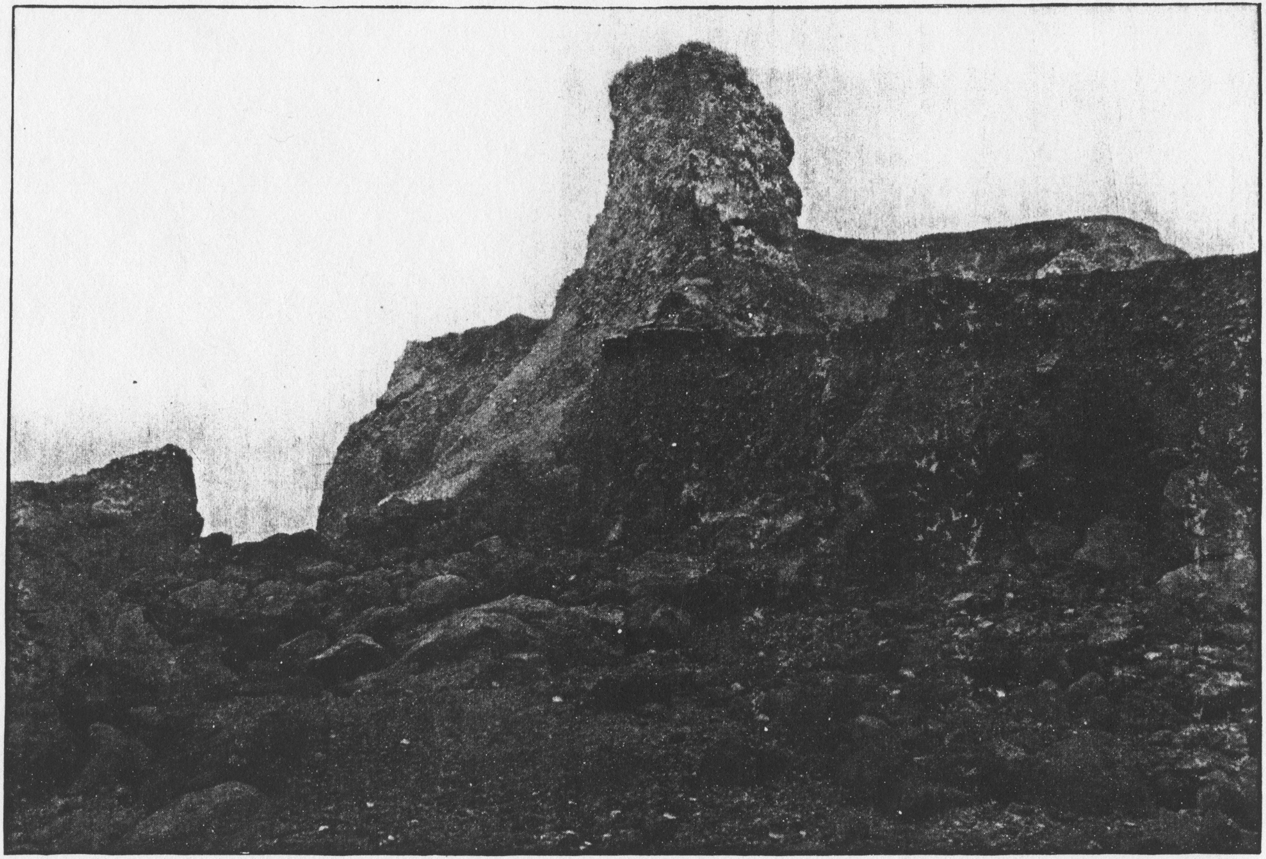
[1] Taking albite as $NaAlSi_3O_8$, molecular weight 263.36, and anorthite as $CaAl_2Si_2O_8$, molecular weight 279.09, I find the following percentages of anorthite in the several feldspars. Michel-Lévy gives somewhat different values in his second fascicle, page 107.

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]

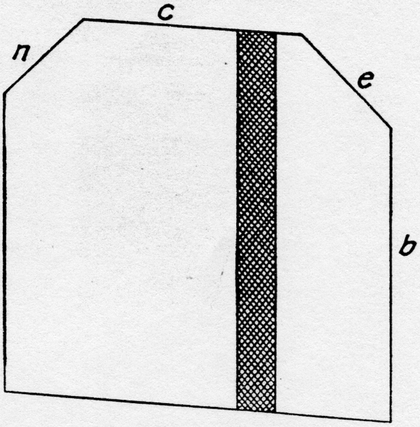


FIG. 5.—Cross-section of bacillar feldspar microlite.

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

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[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.

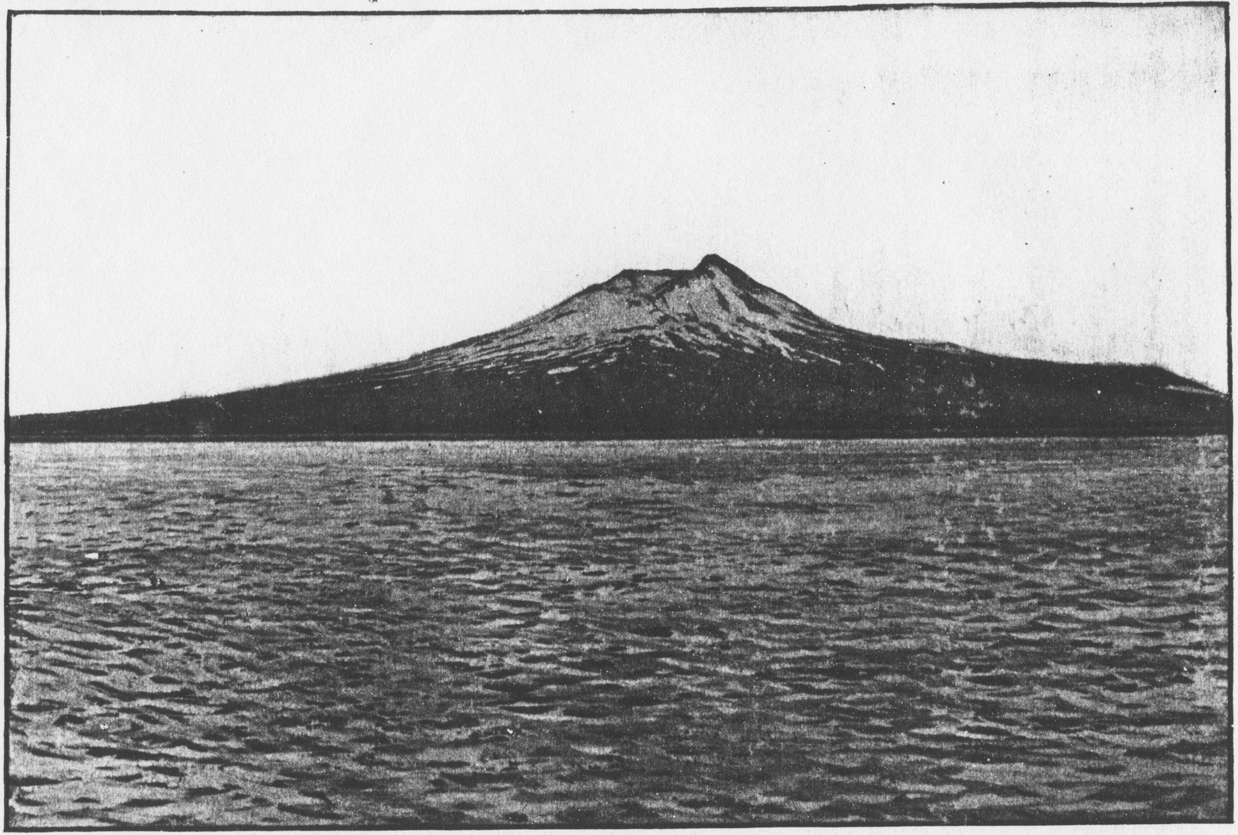
Orthoclase microlites would be exactly square; they would not show polysynthetic twinning, and the index of refraction is much lower than that of oligoclase, which, like orthoclase, extinguishes at 0°.

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

Feldspar.	Composition.	Extinction.
		° °
Anorthite	$Ab_{11}\ An_{200} = 96\ \%\ An$	$+42\frac{1}{2} \pm 3\frac{1}{2}$
Calcareous labradorite	$Ab_3\ An_4 = 60\ \%\ An$	$+38 \pm 3$
Sodic labradorite	$Ab_1\ An_1 = 47\ \%\ An$	$+26\frac{1}{2} \pm 2\frac{1}{2}$
Andesine	$Ab_5\ An_3 = 34\ \%\ An$	$+16 \pm 2$
Calcareous oligoclase	$Ab_3\ An_1 = 28\ \%\ An$	$+4 \pm 1\frac{1}{2}$
Sodic oligoclase	$Ab_4\ An_1 = 18\ \%\ An$	$+0 \pm 1\frac{1}{2}$
Albite	$Ab = 0\ \%\ An$	$-13 \pm 2\frac{1}{2}$

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.

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 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.

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[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

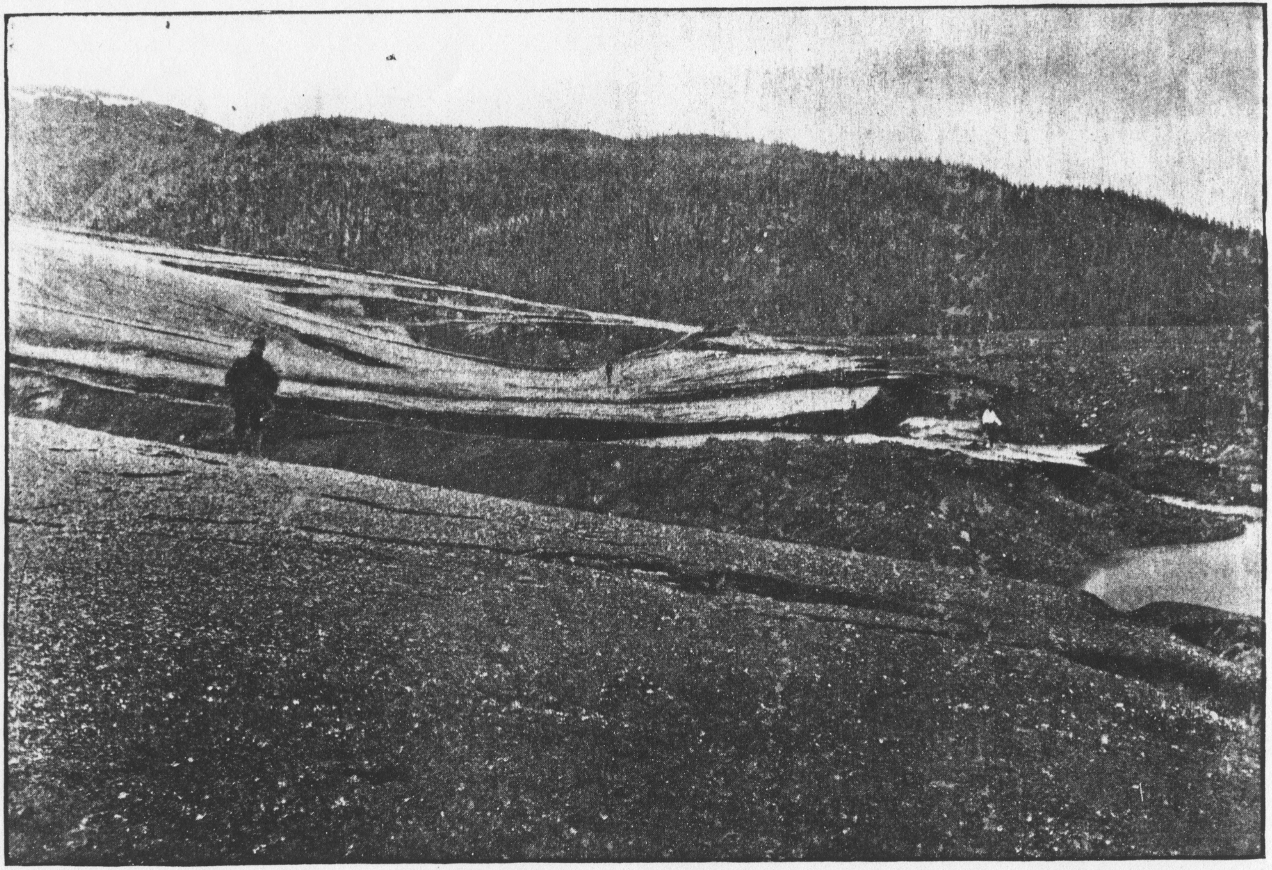
The following is a list of the andesite localities in Alaska known to me by specimens:

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 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,

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[1] Eleventh Census, Pop. and Res. of Alaska, 1893, p. 230.

[2] Nat. Geog. Mag., Vol. III, 1891, p. 196.