SULPHUR ON UNALASKA AND AKUN ISLANDS AND NEAR STEPOVAK BAY, ALASKA.

By A. G. MADDREN.

INTRODUCTION.

Sulphur claims have been recorded at three localities in southwestern Alaska—in the crater of Makushin Volcano on Unalaska Island, on Akun Island, and near Stepovak Bay on the Alaska Peninsula. (See Pl. VII.) The deposits covered by these claims have not yet been mined, but during the last year they have received considerable attention with a view to production.

These sulphur-bearing deposits are of the volcanic type termed solfataras—that is, they are surface deposits formed by sublimation from hot sulphurous volcanic vapors. They are situated in the belt of active and quiescent volcanoes that extends throughout the Alaska Peninsula, the Aleutian Islands, and Japan. Similar deposits undoubtedly occur at other localities in this belt.

Unalaska and Akun islands are near the east end of the Aleutian Islands, in latitude 54° N. and longitude 166" W. They lie west of Unimak Pass, the chief thoroughfare for vessels to Bering Sea. Stepovak Bay is on the south coast of the Alaska Peninsula, about 200 miles northeast of Unimak Pass, in latitude 55° 50' N. and longitude 159° 40' W., about 1,600 miles from Puget Sound.

The only regular access to southwestern Alaska is by a small mail steamer that sails from Seward once a month. Unalaska is about 1,150 miles from Seward and about 1,750 miles from Seattle in an air line or 3,000 miles by way of Seward. During the summer steamers from Seattle to Nome and St. Michael enter Bering Sea through Unimak Pass but seldom call at Unalaska or near-by ports because of lack of trade. However, they would be available for shipment of freight to Puget Sound. Fishing vessels and Government patrol and supply steamers make irregular cruises along the coast during the summer and occasionally replenish their coal bunkers at Unalaska. A Navy wireless station at Unalaska is available for transmitting commercial messages.

The following descriptions of the sulphur-bearing deposits are based upon examinations made by the writer during August and September, 1917.

MAKUSHIN VOLCANO.

TOPOGRAPHY.

Makushin Volcano, about 6,000 feet in altitude, is in the northern part of Unalaska Island, about 12 miles west of Dutch Harbor. (See figs. 7, 8.) It is 5 to 6 miles from the northwest coast and about the same distance north of Makushin Bay.

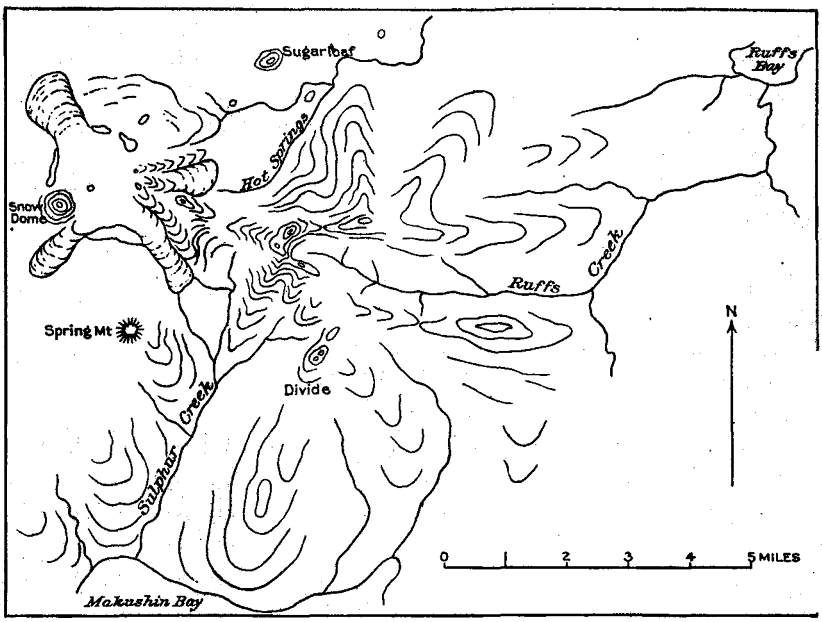
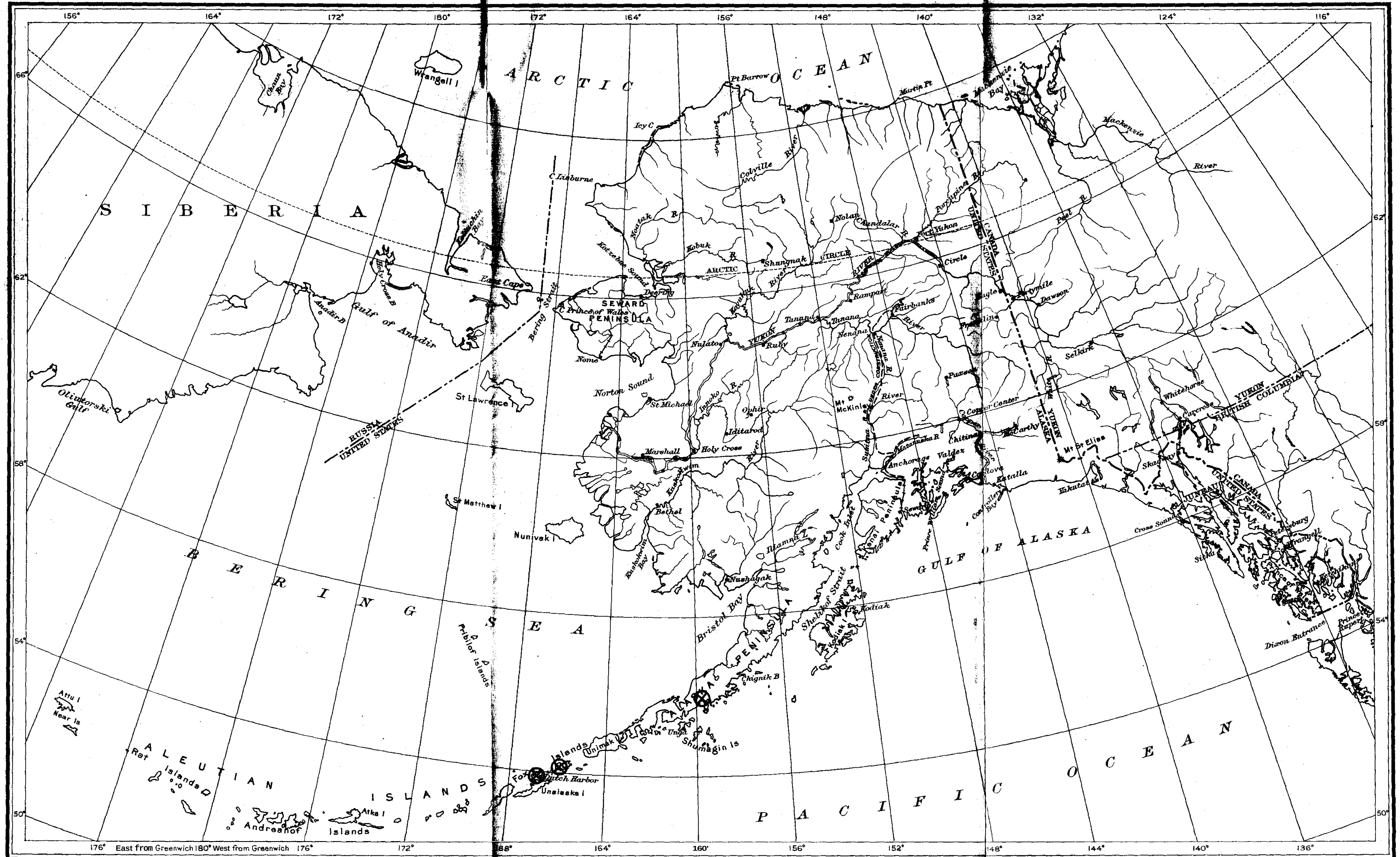


FIGURE 7.—Sketch map of Makushin Volcano and vicinity.

Makushin Volcano is a composite volcanic pile built up of alternating accumulations of basaltic lava, scoria, lapilli, and dust. In shape it is a broad dome, which forms a prominent feature of the landscape on account of its snow and ice capped summit and flanks. Glaciers descend its slopes to points about 2,500 feet above sea level, and rugged radiating ridges lie between the glaciers. A ring of ragged peaks surrounds a broad depression which marks the crater of a large extinct volcano. The mountain topographically dominates the part of the island it occupies over a radius of 5 or 6 miles.

The crater of Makushin Volcano, as defined by its rim ridges, is broadly oval or horseshoe-shaped in plan and is nearly 2 by 1½ miles in dimensions. Nearly continuous ridges form the crater rim except



MAP OF ALASKA SHOWING LOCATION OF SULPHUR DEPOSITS

100 0 100 200 300 400 500 Miles

100 0 100 200 300 400 500 Kilometers

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on the northwest side, at Big Gap, and at lesser gaps in the south and southeast sides.

The floor of the crater is 300 to 500 feet below the higher crags of the rim, but the floor of the basin is exposed only in an area of 20 to 30 acres, where the sulphur deposits occur. Except in this bare area, the basin is occupied by glacial ice and snow that probably is several hundred feet thick in the central part of the basin. This ice and snow sags away from the walls of the crater and presents a concave surface that slopes northwestward to the Big Gap. This gap is the chief outlet of the crater, and the flow of ice toward it is indicated by the crevasses.

THE SOLPATARA.

POSITION AND CHARACTER.

The sulphur deposit of Makushin Volcano is situated a short distance southwest of the center of the crater and is the only part of the crater that appears to be permanently free from snow and ice. The bare area comprises a main southern portion about 1,200 feet long and 700 feet wide and a narrow tongue-like strip that extends north from the main area for about 1,500 feet and has an average width of 200 feet. (See fig. 9.) The area of these tracts is estimated to be 20 and 10 acres respectively. Some minor marginal patches extend beneath the overhanging edges of the ice. These marginal areas are, however, a variable quantity and are inaccessible, because they comprise the floors of grottoes or caverns and tunnels melted from the under surface of the snow and their roofs collapse from time to time.

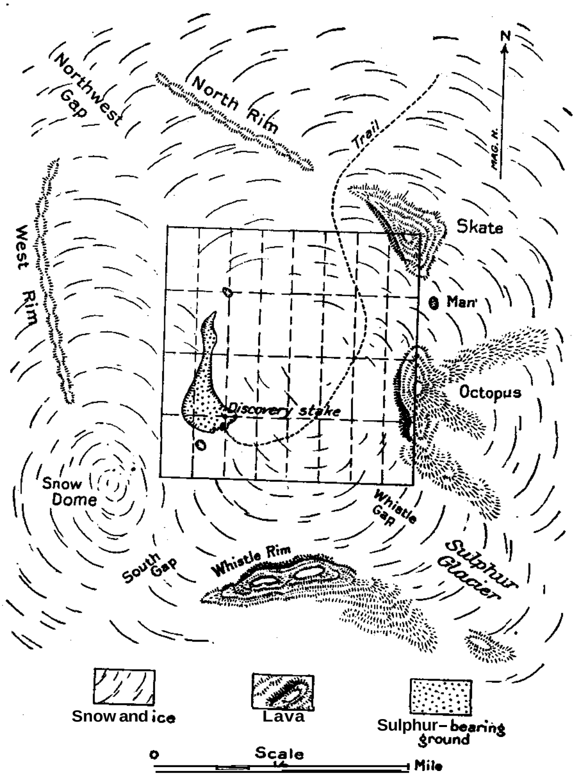

FIGURE 8.—Sketch map of part of Makushin Volcano showing location of sulphur claims.

The southern part of the solfatara is a hummocky hill or ridge which rises about 100 feet above the comparatively smooth surface of the surrounding snow and ice. On the southwest flanks of this ridge are several grottoes or tunnel-like caverns. These grottoes appear to lead toward a large chimney-like hole in the ice, about 150 feet in diameter, from which hot vapor discharges. This hole evidently marks a cleft in the rock from which hot vapor has melted the ice, and the grottoes are irregular passages that were melted in the ice by the circulation of hot vapor. The sulphurous character of the vapor is indicated by the sulphur that is deposited about the mouth of the hole, which stains the snow slightly yellow.

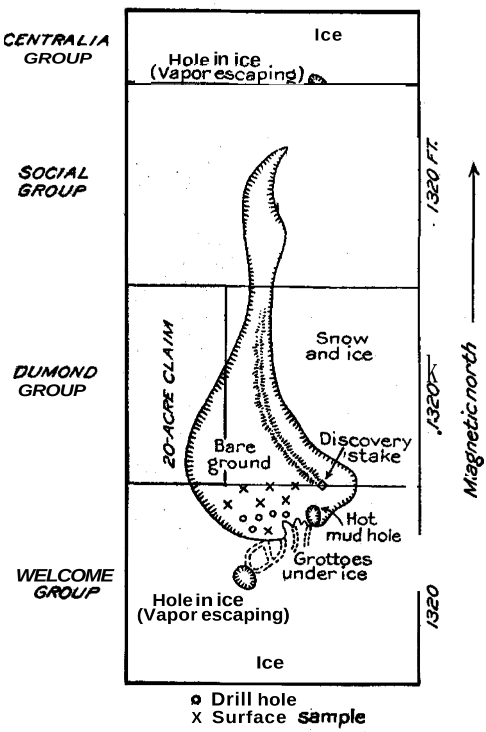

FIGURE 9.—Sketch map of sulphur area on Makushin Volcano.

It is evident that the main solfataric area is kept bare by subterranean heat. The heavy persistent clouds of condensed vapor indicate that the radiation of heat is active and fairly constant. In calm weather the condensed vapor rises many hundred feet and resembles smoke from a great chimney or a forest fire, but as violent winds are common the heavy clouds of vapor are usually swirled and eddied along the surface of the ice in different directions. If the wind blows from one direction for some time there often is a perceptible yellowing of the snow with sulphur. At such times the solfatara is approachable only from the direction of the wind, as the sulphur fumes are strong and the thick vapor obscures the way over the crevassed surface. Probably the smokelike grayness of the vapor is due to finely divided particles of sulphur, and the precipitation of these particles causes the yellow film on the ice.

LITHOLOGY.

As a whole the sulphur-bearing deposit is earthy and appears to be composed chiefly of siliceous residual products of rock decomposition that have resulted from the highly corrosive chemical actions of the hot solfataric vapors on the basalt. No outcrops of the basalt rock that are certainly in place could be closely examined, because the only exposures are in the walls of the deeper fissures and down the throats of fumaroles from which vapors issue at temperatures too high to allow near approach. The firm, massive character of the walls of such openings probably confines the escaping vapor, so that it issues with a loud, roaring sound. The country rock is seen only in blocks, slabby fragments, and kernel-like pebbles and scaly flakes, in various stages of decomposition, that are scattered about on the surface and disseminated throughout finely divided residual material. The larger and least-altered blocks of basalt, from 1 to 2 feet in dimensions, have somewhat pitted light-gray surfaces but within are dark and of compact crystalline texture, similar to the non-vesicular portions of the lava flows on the flanks of the mountain. The underlying rock of the solfatara area is thus chiefly compact crystalline basaltic lava, but it probably includes also some porous vesicular lava and possibly some fragmental volcanic material such as lapilli and dust, which are present in the old crater rim.

The olivine is considerably decomposed throughout the compact crystalline lava, but the other minerals are not extremely altered except near the surface. The leached surface layers of these blocks show the faded texture of the original lava and have a tendency to exfoliate or spawl off as concentric shells, especially when struck with a hammer. Some of the blocks have the form of roughly rounded boulders and cobbles and thus resemble volcanic bombs, and the residual earth suggests, at first sight, a light-colored volcanic ash. However, none of the boulders show the vesicular texture that usually characterizes bombs, and the earthy deposit appears to be mainly residual in origin.

The residual earth that constitutes the bulk of the surface mantle of the solfataric area is light gray to creamy white. As explained above, most of it was formed in place, although naturally some has been shifted locally by winds and rains, both of which are violent and frequent, and no doubt much of the finer clayey material has been washed away. Test holes drilled into the deposit show that the earthy mantle in places is fully 16 feet thick and that it changes little in character to that depth, although some thin layers are dark brownish red. The deposits were not bored to a greater depth than 16 feet, but below that depth they are believed to grade into less decomposed phases of the country rock. For the most part the deposit has a coarse mealy texture, but some of it resembles loosely compacted sandy clay. In general the material is quite porous and comparatively light weight when dry. It resembles kaolin, although its aluminous content is low.

Although the earth is highly siliceous no sinter deposits were observed. Slight cementation occurs, but the somewhat crusty character of the surface zone seems to be due in part to the drying out induced by the warmth of the ground and also to the deposition of sulphur in the upper 1 or 2 feet of porous ground, especially on the immediate surface of the tracts that are more or less constantly bathed by sulphurous vapors.

SOLFATARIC ACTION.

The most striking feature is the rather vigorous solfataric activity of the greater part of the bare ground. This activity may be divided into two phases that are somewhat distinct but nevertheless closely related. The most manifest activity is the discharge of hot sulphurous vapor that deposits sulphur in the cooler part of the deposit. The other phase of solfataric activity is the corrosive chemical action upon the rock in the zone of oxidation, which has caused the formation of a highly decomposed earthy residue that includes the bulk of the sulphur-bearing deposit and that rests upon the volcanic rocks from which the hot vapor emanates. Sulphurbus and sulphuric acids probably are formed in small quantities in this surface zone.

The most active escape of hot vapor seems to be in the southern part of the area of bare ground near the highest part of the ridge. At this place vapor at relatively high temperature issues with a roaring sound from several openings. The largest vent is at the southeast end of the ridge in the lower wall of a pit, about 75 feet in diameter and 40 feet deep, the bottom of which is filled with steaming gray mud. The sound from this fumarole can be distinctly heard for a distance of half a mile. The temperature of this fumarole was not measured, but that of a smaller one on top of the ridge was 310° F. at a point 2 feet down its throat. Temperatures of 170° and 180° were observed in crevices from which the escape of vapor was much less active, and fragments of ice were boiled in about 10 minutes in a kettle placed over one of the openings after the crust of sulphur that partly sealed it was broken away.

The temperature of 310° F. indicates that the vapor is far hotter than the melting point of sulphur, which liquefies at about 240°. It was noted that no sulphur was being deposited where the temperature was 310°, although near the cooler border of the opening was a thin incrustation of sulphur.

Several test holes that were drilled into cooler parts of the deposit tapped hot sulphurous vapor at depths of 4 to 8 feet, indicating that the porous earthy mantle is more or less charged with hot vapor. Thus it appears that except for a comparatively thin superficial zone the solfataric deposit as a whole is probably too hot at a short distance below the surface to permit the deposition of sulphur, or conversely that the heat of the deposit below the surface is sufficient to keep most of the sulphur that may be present in a molten or vaporized state until it reaches the surface. In this connection it may be noted that sulphur may be extracted from ores of this character by melting it with steam under a pressure of about 60 pounds to the square inch. Steam under this pressure has a temperature of about 292° F. No field evidence was noted, however, of any of the sulphur having been melted after its deposition by sublimation.

The commercial bodies of sulphur in this deposit are clearly superficial. The percentage of sulphur at the surface does not indicate that rich deposits exists at depth, as is usually believed by the optimistic prospector.

THE SULPHUR DEPOSITS.

OCCURRENCE.

The richer deposits of sulphur occur within 2 feet of the surface, but there is also more or less finely divided sulphur disseminated to a depth of at least 16 feet, the greatest depth from which samples were obtained. Some of the finely divided sulphur may be redeposited, especially in. the earthy accumulations along the lower flanks of the ridge, but most of it was undoubtedly sublimed from the vapor where it is now found.

The most conspicuous deposits of sulphur occur along crevices or large clefts that intersect the surface of the ground in many directions and around the holes from which large volumes of hot vapor issue continuously. Some of the larger holes axe true fumaroles. The cracks in the surface might be attributed to shrinkage of the earthy mantle, but as they have no geometrical arrangement it is more probable that they lie just above open fissures in the underlying rock.

The largest masses of sulphur occur as irregular pieces, some of which are 8 to 10 inches in diameter. These pieces have more or less completely sealed the vents. Incrustations of sulphur an inch or more thick are being deposited on the lips of crevices and about the open vents. Hot sulphurous vapors issue from these openings in considerable volume, but only small amounts of vapor escape from sealed crevices. There may be a circulation of the sulphurous vapors from one set of crevices to another or from one part of a crevice to another part as the sealing progresses, the vapors seeking an outlet along passages of least resistance. In this way the sulphur may become distributed over the solfataric area.

At present the most abundant deposition of sulphur appears to be in the crevices and vents which have temperatures of about 170° to

180°. Comparatively little sulphur is being deposited about the hot fumaroles, such as one whose temperature is approximately 310°.

In addition to the sulphur that may be brought from primary sources in the hot vapors and deposited directly at the surface, it is probable that sulphur is revolatilized from the hot lower zones of the deposit and recondensed in the cooler surface zone. Thus there may be a migration of the sulphur from deeper parts of the deposit to its surface. It also seems possible that some of the sulphur reaches the surface dissolved in superheated water vapor and is directly sublimed upon condensation of the water vapor in the cool atmosphere.

Some of the sulphur may be precipitated from mixtures of hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), two compounds which presumably can not exist together and which when commingled set sulphur free. To judge by the odor, small quantities of both these compounds seem to emanate from the solfatara, but they undoubtedly constitute a very small percentage of the total vapor. The odor of hydrogen sulphide was evident but not very marked. As one ten-thousandth part of sulphur dioxide in air is intolerable to human beings there probably is not much sulphur dioxide in the vapor, for no particularly suffocating effects were experienced upon breathing the vapor, even near the hot fumaroles. Water vapor is by far the most abundant emanation. It contains some dissolved sulphur which it deposits when it is condensed on the ice.

AMOUNT.

The sulphur deposit has not been sampled comprehensively, and it is very doubtful whether ordinary methods of sampling will give sufficiently accurate results to serve as a reliable basis for estimating the content of sulphur.

The deposit may be divided roughly into two zones on the basis of percentage of sulphur—a richer zone that forms a surface layer from 1 to 2 feet thick that seems to owe its crusty character chiefly to the sulphur deposited in it, and a poorer subsoil zone that consists in greater part of moist, hot, porous, decomposed material in which a small percentage of sulphur is disseminated as grains and blebs to a depth of at least 15 to 20 feet at some points.

The surface crust of the solfatara is rather irregular in general contour and quite uneven and hummocky in relief. Its minor ridges, hollows, and hummocks seem to owe their form partly to uneven deposition of sulphur along the intricate mesh of crevices and vents and partly to subsequent erosion by wind and rain. The higher tracts along the main ridge of the solfatara appear to owe their general prominence to the proximity to the surface of the lava, which probably underlies the whole solfataric area at no great depth, for all the blocks that are scattered about on or protrude from the surface of these tracts are of a uniform crystalline basalt and the walls of the fumaroles and larger openings appear to be similar solid rock to a level within a foot or so of the surface.

No definite data regarding the thickness of the lower layer or zone are at hand, and it can not be assumed that the earthy mantle has a uniform thickness throughout the solfataric area. It is assumed to be thickest along the lower flanks of the area, where it has been tested to a depth of at least 16 feet. Over some of the higher tracts it is generally thin and in places is entirely absent.

The sulphur is very irregularly distributed even in the crusty surface zone of the deposit. Although practically pure masses of sulphur occur as fillings in some of the dormant and semidormant crevices and vents and seal their outlets it does not extend down these openings very far. Some of these masses are estimated to contain several cubic feet of reasonably pure sulphur that could be mined by careful hand methods. The aggregate crevice and vent space thus occupied with sulphur is relatively small. Although a few of the crevices are 10 to 12 inches wide, most of them are not more than 2 or 3 inches wide, and the cracks and crevices in which sulphur has been deposited are about the same size. The sulphur-bearing crust between the crevices averages about 12 inches in thickness, although in some places it is as much as 2 feet. In many places the upper half of this crust is composed chiefly of sulphur, and the lower half contains a large percentage of earthy material. The amount of sulphur in the solfatara is not so striking as the area of gray earth, streaked and dotted here and there by the sulphur deposited along discontinuous cracks and about small vents that are irregularly distributed over the surface of the ground in more or less definite tracts.

Of the approximately 20 acres of bare ground that comprise the main area of the solfatara probably not more than 5 acres, in the southern part of the area, may be classed as containing a good grade of sulphur-bearing material, the remainder being of inferior grade, and only certain rather small tracts in the 5 acres of better ground contain high-grade material, even in the surface crust zone. Probably the average sulphur content of this surface crust is about 60 per cent of the material that would be handled in mining. If this estimate is correct it indicates about 260,000 cubic feet of sulphur, on a basis of 2 feet of depth, which is 12,500 tons at 125 pounds to the cubic foot.

The high-grade sulphur deposited at the open vents is about 98 or 99 per cent pure and is estimated to constitute about 5 per cent of the surface material as a whole. It is estimated that about 70 per cent of this surface material, to a depth of 1 or 2 feet, is composed of material of which four analyses show a sulphur content of 86.3

to 89.6 per cent and average about 88 per cent. According to these figures, the average sulphur content of the surface material to a depth of 1 or 2 feet is about 60 per cent. If the weight of the dried material is about 70 pounds to the cubic foot, as is indicated by the determination of the specific gravity of a sample that was assumed to be representative, the 5 acres of better ground should contain about 1,800 tons of sulphur to the acre within 2 feet of the surface.

It is difficult to make even a rough estimate, like that just given, for the sulphur content of the remainder of the deposit, especially of the earthy portion beneath the surface crust. In the first place this earth can not be assumed to be of uniform thickness, and secondly, in the absence of comprehensive sampling over the whole area, the quantity of sulphur that may be disseminated in it is a matter of conjecture. Five samples taken in the southwestern flanks of the deposit from depths of about 4, 8, 10, 12, and 16 feet contain, respectively, 47, 29.8, 14.7, 13.8, and 9.5 per cent of sulphur, averaging about 23 per cent. If this average holds the zone from 2 to 16 feet below the surface should contain from 716 tons of sulphur for each acre-foot at a depth of 4 feet to 145 tons for each acre-foot at a depth of 16 feet, or a total for the entire 14-foot zone of 4,900 tons to the acre.

PURITY.

The chief impurity of the sulphur is the earthy material in which it is deposited. In the small samples collected by the writer this impurity ranges from 1.5 or 2 per cent in selected pieces of solid sulphur to 75, 80, and even 90 per cent in the poorer earthy material. This finely divided earthy impurity is composed chiefly of silica and lime and is comparatively light in weight. The separation of the sulphur could be accomplished by heating the ore, for the sulphur would melt at a relatively low temperature and be drained off, making a commercial product of nearly pure sulphur.

AKUN ISLAND.

GEOGRAPHY.

Akun Island lies on the western side of Unimak Pass about 23 miles southwest of Unimak Island. (See fig. 10.) The settlement of Unalaska, on Unalaska Island, is about 45 miles southwest of the northern end of Akun Island.

Akun Island is about 12 miles long from north to south, has a very irregular coast line, and the northern part is nearly divided from the southern part by two large embayments that lie opposite each other—Akun Cove on the east coast and Lost Harbor on the west coast. The heads of these bays are separated by a strip of low land about 1 mile wide. Except this narrow strip of land, the island is comparatively high and has a general rolling relief that is marked by rugged ridges. Rugged topography is particularly characteristic of the northern

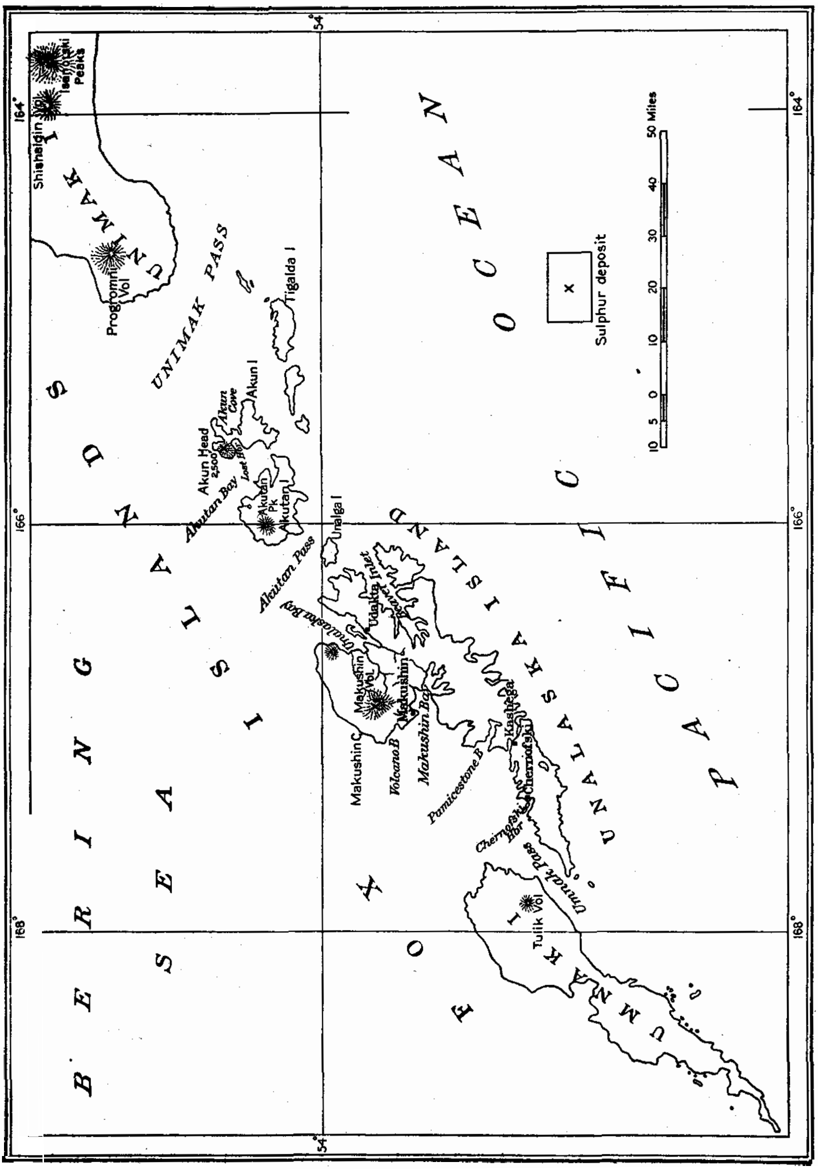

FIGURE 10.—Map of Unalaska and Akun islands showing location of sulphur deposits.

third of the island, the highest point of which is the summit of a roughly conical volcanic mountain 2,500 feet high. This volcanic mountain, locally called Akun Peak, stands near the northwest shore, and its westward and northward slopes terminate as abrupt sea cliffs 500 to 1,000 feet high.

GEOLOGY.

The hard rocks of Akun Island consist at the base of rudely stratified volcanic fragmental materials (agglomerates and tuffs) that are overlain by andesitic lava flows. Each of these formations is 1,000 feet thick where it attains its maximum development. Akun Peak is a typical volcanic cone and appears to have been one of the chief centers of outflow for the lava in the northern part of the island. Its conical form suggests that it is a comparatively recent volcano, and the lavas that flowed from it are little altered except by surface weathering. On the other hand, the basal deposits of agglomerates and tuffs, upon which the lavas rest, are considerably cemented and oxidized, and it is probable that they are considerably older than the lavas. At one exposure on the north side of Lost Harbor, where the contact between the lavas and the agglomerates and tuffs is well displayed, it is evident that the lavas flowed out and buried an old land surface that had been eroded in the agglomerates and tuffs.

THE SULPHUR DEPOSIT.

LOCATION AND AREA.

The sulphur-bearing area on Akun Island, upon which mining claims have been located (see fig. 11), is situated on the upper flanks of a rugged mountain ridge, 1,800 feet high, that lies about a mile northeast of Akun Peak. This ridge is a somewhat detached outlying spur

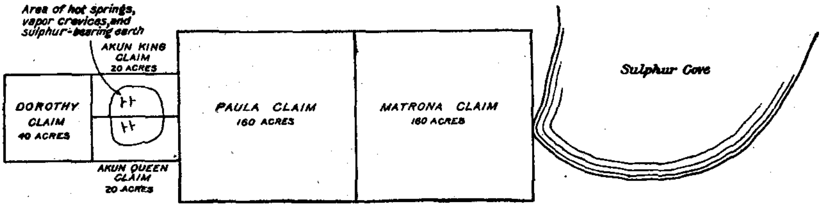

FIGURE 11.—Sketch of sulphur claims on Akun Peak.

of Akun Peak, and divides the northward and southward drainage of this part of the island. The solfatara lies in the broad headwater basin of a steep gulch that descends to a small cove immediately west of Akun Head on the north shore of the island and is about 1 mile from the cove. The southward drainage from this ridge flows to the north shore of Lost Harbor in a gulch about 2 miles long, and the easiest approach to the solfataric locality is by way of this valley. The best route is along its eastern slopes and thence through a small gap, at the head of a tributary gulch, that lies immediately south from the deposit at an altitude of 1,600 feet. The sulphur-bearing area is between 15 and 20 acres in extent and stands from 1,300 to 1,500 feet above sea level, but the part of the deposit that is characterized by 'mild solfataric activity comprises only about 5 acres.

VOLCANIC ACTIVITY.

The solfatara is in rather mild or semidormant activity. Within the smaller area of about 5 acres small volumes of steam and scalding water, accompanied by a small quantity of hydrogen sulphide gas (H_2S), issue from fissures at widely spaced intervals, and the remainder of the area shows no particular evidences of the escape of, subterranean heat. The most striking evidence of solfatarism is of chemical decomposition of the rock.

GENERAL FEATURES.

The surface of the deposit consists of highly decomposed material, apparently of residual origin, that resembles the deposits of the solfatara in the crater of Makushin Volcano but is thinner. This earth is light gray to dull yellowish and forms a mantle from 1 to 4 feet thick. Much of it is essentially in place, but the steepness of the slope on which it rests has caused movement of some of the material and the hot waters that flow from crevices are transporting s small quantity to lower levels.

The earthy deposit is of uniform character throughout the area as is proved by the sections exposed in numerous open cuts that were dug in 1917. Many of these excavations are only 4 to 5 feet deep, but about six of them are from 12 to 15 feet deep and show the nature of the ground. . All these cuts show a highly decomposed, leached, porous surface layer of light-gray earth from 1 to 4 feet thick that conforms to the slope of the ridge.

Beneath the surface layer is a zone of dark-gray semileached decomposed rock which in some places where it is saturated with water resembles massive clay. This zone ranges from 6 to 10 feet in thickness, and in its lower parts, where less decomposed, the joint planes and brecciated fragments may be seen. Along some of the seams in this subsurface zone a small quantity of alum salts is being deposited. This salt indicates that one of the changes which is taking place in the country rock is the decomposition of the feldspars.

In the bottoms of the deepest cuts, 12 to 15 feet below the surface, the highly decomposed rock of the subsurface zone grades downward into a less decomposed compact crystalline rock and although considerably altered shows the mineral constituents distinctly.

The highly decomposed rock and earth within the solfatara appears to be directly derived' from the andesitic lava that composes the body of the mountain ridge, good outcrops of which may be observed on the crest of the ridge immediately above the solfatara. The area of the sulphur-bearing earth is clearly a locality where solfataric vapors have found an outlet and have intensely decayed the rock by highly corrosive chemical reactions.

The present solfataric activity at this locality is of a much mild'er stage than that of the solfatara on Makushin Volcano. In fact on Akun Island the activity seems to be entering into the hot spring stage. The evidence furnished in the open cuts as to the relatively shallow depths to which the solfataric decomposition extends indicates that this solfatara has never been extremely active. This conclusion is further indicated by the comparatively small amount of sulphur present.

THE SULPHUR.

MODD OF OCCURRENCE.

The sulphur in this deposit occurs chiefly in the form of crystalline incrustations one-sixteenth to one-eighth of an inch thick on the walls of narrow crevices and small cavities in the .porous earthly surface zone. Most of the crevices are not more than one-eighth inch wide, and few of the larger ones are as much as one-fourth to one-half inch wide, and usually they are only partly filled with sulphur. Some sulphur is also disseminated through the decomposed material, but there are practically no solid bodies of sulphur, even of small size, in any part of the deposit. Apparently a small quantity of sulphur has also been deposited in the cooler parts of the subsurface zone, as is shown by incrustations observed along the walls of the deeper open cuts at points 10 to 12 feet below the surface, but this sulphur may have been deposited since the excavations were made by small jets of water vapor that now find an easier passage into the excavations. The sulphur-bearing vapor evidently rises through the material of the subsurface zone from a subterranean source by way of rather tight seams that mark joint fractures in the original lava. Where these crevices have been exposed in the excavations the vapor issues from them.

The temperature of the vapor is little above the boiling point (212° F.), and scalding water issues from some of the crevices, indicating that a considerable volume of the vapor condenses before reaching the surface.

AMOUNT.

Most of the sulphur in this deposit occurs in the porous earthy mantle within 1 to 4 feet of the surface. The average thickness of this mantle is believed to be about 2 feet. Two samples, one taken at the surface and the other at a depth of 4 feet, contained 55.5 and 22.8 per cent of sulphur, respectively. If the average thickness of the sulphur-bearing surface mantle is 2 feet, and if its average sulphur content is 40 per cent, it should contain 1,200 tons of sulphur per acre.

MINING AND SHIPMENT.

Although this deposit is of low grade and is not very extensive, it is fairly accessible. If the material should prove to be of sufficient value to justify mining it, there are no engineering difficulties to hinder development.

The sulphur-bearing material can easily be excavated and could then be transported to Lost Harbor by an aerial cable tramway that would be a little more than 2 miles long. The rise from Lost Harbor to the gap in the ridge about 1,000 feet south of the solfatara is 1,600 feet and the descent from this gap to the deposit is only 200 to 300 feet.

The sulphur doubtless could be extracted from its earthy gangue by melting in retorts with steam, but there is no fuel on the island. Oil, however, is now shipped from California to a whaling establishment on Akutan Harbor, 10 miles from Lost Harbor, for use in generating steam, and coal which might be developed for local use is reported to occur on Avatanak Island, about 5 miles southwest of Akun Island. It would probably be unprofitable to ship the sulphur-bearing earth in bulk to a distant point for treatment.

Lost Harbor does not afford good shelter for vessels, as it is open to the heavy southwest swell of Bering Sea and has a rocky bottom. Several vessels have been wrecked on its shores because their anchors failed to hold.

STEPOVAK BAY.

Stepovak Bay is on the south shore of Alaska Peninsula in latitude 56° N. and longitude 160° W. The only important sulphur deposit reported in the vicinity (see fig. 12) is about 7 miles northwest of the head of the bay, at an altitude of 3,000 feet, near the crest of the Aleutian Range, which is glaciated and contains numerous dormant or active volcanoes. This deposit was not visited because of the danger in crossing the crevassed glaciers covered with newly fallen snow that obstruct the only available route to it. As seen from a distance of about 2 miles, the supposed sulphur-bearing bed is a light-colored zone 100 feet thick and half a mile long in the wall of a cirque that may be the site of an extinct crater. A glacial moraine that extends from this cirque consists largely of sulphur-bearing rock that was probably derived from the light-colored band already noted.

The sulphur-bearing rock in the morainic deposits consists of porous volcanic breccia that contains compact crystalline sulphur in the interstices of the breccia and also in the vesicles of the constituent fragments. Some specimens probably contain 20 per cent sulphur (by bulk) in veins one-eighth to one-fourth inch thick and show masses up to 1 inch long at the intersections of the veins. In much of the rock the sulphur is finely disseminated and probably does not constitute more than 5 or 10 per cent of the rock. In regard to the sulphur content of the morainic material as a whole, it may be stated that parts of the moraine may contain 10 per cent

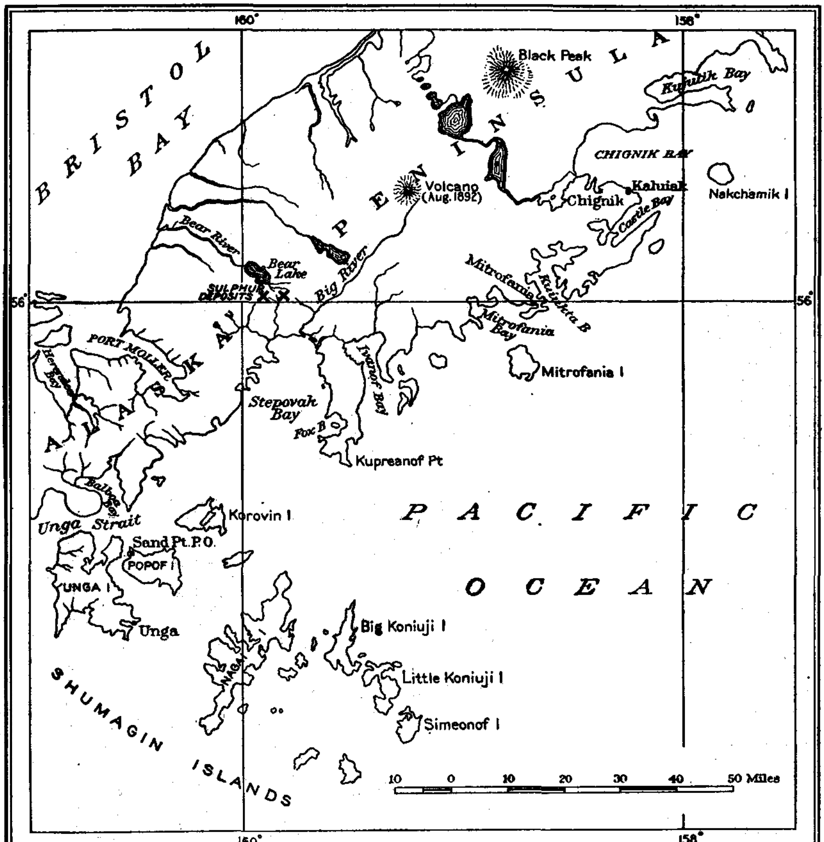

FIGURE 12.—Map of Stepovak Bay and vicinity showing location of sulphur deposits.

of sulphur, but larger parts are practically barren. The material in the moraine is probably poorer in sulphur than the bed from which it was derived and furthermore is a mixture of many different rocks rather than of those from the best parts of the sulphur deposit. Some of the sulphur-bearing boulders are 30 to 40 feet thick, thus indicating a minimum thickness for the bed from which they are derived. The abundance of the sulphur-bearing material in the moraine also indicates that the original source was of considerable extent.