DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 418

INERAL SPRINGS OF ALASKA

BY

GERALD A. WARING

WITH A CHAPTER ON THE

AL CHARACTER OF SOME SURFACE WATERS OF ALASKA

BY

RICHARD B. DOLE AND ALFRED A. CHAMBERS

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ILLUSTRATIONS.

PREFACE.

By Alfred H. Brooks.

Hot springs are widely distributed in Alaska, but they were only slightly utilized by the natives before the coming of the white man. During the Russian occupation of Alaska primitive bathing houses were built at several hot springs, notably near Sitka, and the hygienic value of the springs was recognized. In recent years more elaborate bathing establishments have been constructed at several accessible hot springs and are much used by local residents, and some hot springs that are more difficult of access are occasionally visited by prospectors as health resorts. This local use of the springs has led to a demand for more accurate information about the qualities of the thermal waters than has been available, and for this reason the investigation whose results are here set forth was undertaken.

Though Mr. Waring gave attention principally to the hot springs he examined other mineral springs that lay near the route he traveled. He could not in one field season visit all the springs in Alaska, many of which are in very inaccessible places, but he has compiled for this report all available information about mineral springs.

As Mr. Waring points out, the hot springs may be grouped into several provinces. A larger number have been found in southeastern Alaska than in the interior, perhaps because this part of the Territory is best known. This southeastern mineral-spring province lies adjacent to the great Mesozoic batholiths of the Coast Range and is itself a field of abundant intrusives. Most of the hot springs occur along shear zones within intrusive rocks. Though there are some recent lavas in this field no genetic relation has been established between them and the hot springs. This province, which lies on the western margin of the Pacific Mountain system, has been repeatedly subject to deformation. More directly bearing on the genesis of the springs is the fissuring that has affected the rocks. Though most of this took place in pre-Eocene time, there is some evidence of later movement, and it is in this epoch of later movement that the fissures with which the hot springs are associated were probably formed.

The hot springs of the Alaska Peninsula and the Alaska Islands are all in a field of present volcanic activity, and though they have been but little studied many of them are so near active volcanoes as to leave slight doubt that they are genetically related to the volcanic activity.

The information at hand indicates that there are but few hot springs within the belt of profoundly folded rocks that constitute the Pacific Mountain system. Inland of this system, however, lies another ill-defined belt of hot springs, which is traceable through the central Yukon basin. The springs here are associated with intrusives, in part Eocene and in part probably Mesozoic, that were fractured and locally invaded by metalliferous quartz veins and subsequently, in post-Eocene and perhaps in comparatively recent time, were again fractured and deformed. The fractures with which the hot springs are associated were probably formed during the later epoch of deformation.

The history of the hot springs of Seward Peninsula is probably similar, but the age of the intrusives with which the hot springs are associated in this field has not been determined. It may be Mesozoic or it may be Tertiary.

Quaternary volcanic rocks are widely distributed in both the Yukon Basin and Seward Peninsula. They come from many small vents and possibly from fissures, but the volcanic accumulations are not extensive. There is no evidence that the hot springs are genetically related to these Quaternary volcanic rocks, for the surface manifestations of the two phenomena have not been found in association.

Relatively few hot springs have been found in northern Alaska, possibly because this province has been little explored and possibly because of the scarcity of Mesozoic and Tertiary intrusives and of Quaternary volcanics in this part of the Territory.

The conditions of erosion and ground-water circulation in the subpolar region of northern Alaska are very different from those in more temperate zones. As these conditions probably affect the composition of the surface waters, an investigation of the subject seemed desirable. With this object in mind, a start was made in 1914 by H. M. Eakin, who collected a few samples of surface waters from the Yukon Basin and from Seward Peninsula. Advantage was taken of the opportunity afforded by Mr. Waring's journey in 1915 to collect a larger number of samples of river and stream waters. These have been analyzed, and the results are set forth and discussed in this report by R. B. Dole and A. A. Chambers. Relatively few samples of water were collected, however, and these only in summer; and the meager information they afford does not permit final conclusions. It is, however, the only information thus far available to show the composition of surface waters in subpolar regions.

The conditions pointed out in this report that may influence the composition of the waters are (1) the paucity of erosion over large areas, due principally to the mat of moss and other vegetation which mantles the soil and to the small rainfall, and (2) the permanently frozen condition of much of the subsoil in the Yukon Basin and Seward Peninsula, which prevents the circulation of ground water. In the central plateau province of Alaska but little bedrock is exposed to erosion, as compared with that exposed in temperate regions. Rock outcrops are found on the crests of some divides, but by no means on all, for many rounded or flat summits are covered with moss; and much the larger part of the slopes are gentle declivities that are covered with moss, grass, and timber and that show rock only here and there. Relatively few of the streams are cutting on bedrock, most of the valleys being filled with alluvial material contributed in part by present or recent glacial erosion and in part by surface soil creep or by solar fluction. Some material is also contributed by a very slow mass movement of the heavy frozen talus which mantles the lower slopes of the smaller valleys, notably on the sides not exposed to the sun. Erosion of this type yields the familiar asymmetric valleys which are typical of the streams of this province. By lateral swinging the larger watercourses in places cut the valley walls, and small cliffs at such places indicate bedrock erosion. The amount of bedrock exposed to erosion in the province as a whole is very small.

The wide distribution of ground frost is even more typical of this subpolar region than is the dearth of erosion. In numerous excavations made in placer mining the ground is permanently frozen to great depths, beginning 18 inches or 2 feet below the surface, and the alluvium is frozen down to hard rock. In the Klondike the alluvium is frozen to a depth of about 200 feet. At Fairbanks permanent ground frost has been found at many places to a depth of more than 200 feet and the deepest shaft sunk there penetrated 318 feet of frozen alluvium. In Seward Peninsula many holes in permanently frozen alluvium are more than 75 feet deep and one is nearly 200 feet deep. These shafts are all in flood plains, but at many places on north-facing hill slopes ground ice can be found within a foot or two of the surface.

Some ground in the province is not frozen, for causes not determined. Underground channels of water have been encountered in some mine workings and have played havoc with the operations, but these appear to be exceptional. When the moss is stripped the ground thaws, and with open-cut mining or cultivation the upper level of permanent ground frost seems gradually to descend. It therefore appears that this ground frost is a survival of a climate colder than the present and is preserved by the nonconducting mat of moss and other vegetation. It is natural to attribute it to the climatic conditions that brought about the last glacial advance in Alaska, during which but little of the central region was ice covered, though glaciers advanced into it from the higher mountains on the north and south.

Although the conditions described are general within the central plateau region, they by no means prevail throughout the Yukon and Kuskokwim basins. Many of the larger tributaries of these rivers, such as White and Tanana rivers, flowing into the Yukon, have their sources in the high ranges bordering the plateau province, in headwater basins, where the conditions of erosion are normal except in so far as they are modified by permanent fields of snow and ice. The waters of these streams would therefore probably not differ from those of normal streams working on similar bedrock in more temperate zones. Mr. Dole and Mr. Chambers point out that certain marked differences in the composition of Yukon waters taken at different localities may be due to the influx of tributary rivers whose sources lie in the high ranges outside of the plateau province, where the abnormal subpolar conditions of erosion and underground-water circulation persist.

MINERAL SPRINGS OF ALASKA.

By Gerald A. Waring.

INTRODUCTION.

Geologists and engineers of the United States Geological Survey, who for a number of years have been investigating the mineral resources of Alaska, have incidentally noted and visited hot springs and other mineral springs in the Territory. About 20 hot springs and several cool carbonated, sulphur, and iron springs had been thus observed prior to 1915, when it seemed desirable to make a more detailed examination of these springs, not only because of their medicinal value or because their waters may be marketable, but because of their relation to the other features of the geology. The writer was accordingly detailed to examine these springs during the field season of 1915, and the present report is an account of field work done in that year between June 15 and September 4. The writer spent the first five days in examining springs between Ketchikan and Wrangell, in the southeastern part of the Territory, in company with Theodore Chapin, of the Survey, who was carrying on geologic studies in the same region. He next visited Warm Springs Bay, on Baranof Island, making the trip from Wrangell in company with G. L. Drake, forest expert, in a launch of the Forest Service, through the courtesy of that bureau. He spent the succeeding 10 days in examining the hot springs on Baranof and Chichagof Islands, and thence went to Whitehorse and down Yukon River to Circle. Four days was spent in visiting Circle Hot Springs and four days in waiting for the next downstream steamer. The Fairbanks and Hot Springs districts were then visited, and about two weeks were spent there, notes being obtained from others on several springs in addition to those that were examined. Three hot-spring localities on the north side of the Yukon below Tanana were then examined. The next stop was at Anvik, on the lower Yukon, where arrangements were made with Rev. John W. Chapman for the collection of daily samples of water from Yukon River throughout a year, for chemical study. During the journey on the Yukon and its tributaries samples of the stream waters were collected for analysis. From

Anvik passage was taken to St. Michaels and thence to Seward Peninsula, where five days were spent in visiting a group of carbonated springs and a group of hot springs.

Of the 81 days spent in the Territory, only 50 days were devoted directly to the work, five days at the end of the season being spent in Nome waiting for a southbound steamer, and the remainder of the time being spent in travel from one region to another. Between Ketchikan, where the work was started, and Nome, where it ended, the distance covered was 4,800 miles, half of this being on the Yukon and its tributary, the Tanana.

During the season 23 springs were visited and notes were obtained on 37 others whose existence was not before known to the Survey. Information concerning two spring groups in southeastern Alaska was obtained from Mr. Chapin, and notes concerning 25 others have been furnished by H. M. Eakin, G. L. Harrington, A. G. Maddren, G. C. Martin, F. H. Moffit, and P. S. Smith, of the Survey. Information concerning 22 springs in the Aleutian Islands and Alaska Peninsula has been compiled from the published works of Grewingk,[1] Dall,[2] and Petrof.[3]

Of the 109 springs listed (see Pl. I), 75 are hot or warm springs, 17 are cool carbonated or "soda" springs, 13 are cool sulphur springs, 3 are iron springs, and 1 is a salt spring. The thermal (hot and warm) springs constitute nearly three-fourths of those listed, their large number being due to the facts that such springs occur in well-known places along the Alaska Peninsula and in the Aleutian Islands, and that those in the other regions have no doubt received greater local attention than cool mineral springs. Cool carbonated springs probably issue at many places of which no record was obtained, and cool sulphur springs doubtless occur at many places in the coal-bearing formations of the Territory.

DISTRIBUTION OF SPRINGS.

The territory of Alaska may be divided into five geographic provinces[4]—(1) The Pacific Mountain system, which embraces the coastal ranges and islands of the southeastern "panhandle," the Alaska Range and subsidiary ranges in the southern portion of the Territory, and the southwestern extension, consisting of the Alaska Peninsula and the Aleutian Islands; (2) the Central Plateau region,

[1] Grewingk, C., Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der nordweste-Küste Amerikas mit den anliegenden Inseln: Russ. K. mineral Gesell. Verh., 1848–49, p. 76, 1850.

[2] Dall, W. H., Alaska and its resources, Boston, 1870.

[3] Petrof, Ivan, Alaska, its population, industries, and resources: Tenth Census U. S., vol. 8, 1884.

[4] Brooks, A. H., The physiographic provinces of Alaska (unpublished). The first three provinces and the fifth are recognized and described in The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 15–17 and pl. 2, 1906.

which includes the basins of the great rivers, the Yukon and the Kuskokwim; (3) the Rocky Mountain system, embracing subsidiary mountains in the northern part of Alaska; (4) the Arctic Mountain system, which includes the Endicott Range and subsidiary mountains parallel to the Arctic coast; (5) the Arctic slope region, lying north of the Arctic Mountain system.

So far as present knowledge indicates, the hot and other mineral springs appear to be confined almost wholly to the two southern provinces. This apparent fact may be due, however, to our better knowledge of the southern regions, for detailed surveys in northern Alaska may reveal the presence there of both hot and cool springs.

Four general regions in Alaska are known to contain springs—the southeastern part of the Territory, the southwestern peninsula and islands, the Yukon Basin, and Seward Peninsula.

In southeastern Alaska hot springs are fairly common, and most of them appear to be associated with masses of granitic rocks, probably Mesozoic,[1] which have been intruded into the older sediments that occur in a great part of that region. These granitic masses cover large areas in the region, and the springs apparently issue along minor fault or fracture zones in the rock. Carbonated springs also issue at several places in this region. In at least one place (near New Eddystone Rock) the production of carbon dioxide appears to be connected with relatively recent volcanic activity. In other places the carbonic-acid gas is of more obscure origin, but it may be generated by intrusive rocks or be derived directly from limestone, of which the gas is a constituent.

Nearly all the reported springs of the Alaska Peninsula and the Aleutian Islands are hot and are evidently direct results of volcanic activity, for the region includes many volcanoes, some of them still active.[2] It is worthy of note, however, that although the Wrangell region, in southern Alaska, includes a great lava-covered area[3] and Mount Wrangell is still mildly active, no hot springs are known to have been reported in this region. Small areas of lavas of Quaternary age are widely distributed in the Yukon basin,[4] and in the Pribilof, Nunivak, and Nelson islands in Bering Sea,[5] but no hot

[1] Wright, F. E., and Wright, C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 57–58, 1908.

[2] The geology of portions of the peninsula is described by Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, 1911.

[3] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 54–57, 1905.

[4] The following publications contain geologic maps showing areas of late volcanic rocks in portions of the Yukon basin:

Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pls. 8 and 11, 1913; also, A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pl. 2, 1913.

[5] Brooks, A. H., The geography and geology of Alaska, a summary of existing knowledge: U. S. Geol. Survey Prof. Paper 45, pl. 21, 1906.

springs are known to be associated with them. Detailed study in the Alaska Peninsula and the Aleutian Islands may reveal, in addition to the many hot springs, cool carbonated and cool sulphur springs also; for both carbon dioxide and hydrogen sulphide are common accompaniments of volcanic activity and in some places are thrown out long after other evidences of volcanism have ceased.

The known hot springs in the Yukon basin form three more or less well-defined groups, consisting of those in the region between Circle and Fairbanks, those in the Hot Springs-Eureka district, and those in the region north of the Yukon between Tanana and Ruby. The hot springs in these areas, like those in southeastern Alaska, seem to be associated with masses of intrusive granitic rock, most of which, however, are smaller than the similar masses in that region. At several places the occurrence of hot springs at the borders of small granitic masses suggests strongly that they rise along the fractured zone between the intrusive granite and the country rock; at others, however, the relation of the springs to intrusive rocks is more obscure.

There are three well-known groups of hot springs on Seward Peninsula, and two other groups are also reported, whose positions and characteristics were not definitely learned. Arctic Hot Springs, in the northern part of the peninsula, are at the western edge of a small area of intrusive granite, where the relation of intrusive rock to the hot water appears to be well shown, but at the other springs on the peninsula that have been examined the source of the hot water is not so apparent. A number of cool carbonated springs also issue on Seward Peninsula. Two or three of them seem to be plausibly ascribed to the intrusion of small masses of lavas or dike rocks into the country rocks,[1] but as these consist in large part of limestone they may possibly furnish the carbon dioxide.

MINERAL WATERS.

All spring, river, and other natural waters might, strictly speaking, be termed mineral waters, for to a greater or lesser degree water dissolves nearly every substance with which it comes in contact. All natural waters therefore contain more or less mineral matter in solution. Generally speaking, however, only waters that carry sufficient amounts of material in solution to give them a perceptible taste are popularly known as mineral waters.

The use of mineral waters at health resorts, under the care of competent physicians, is often attended with very beneficial results.

[1] The general geology of the peninsula is shown in a report by Collier, A. J., and others. The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, pls. 10 and 11, 1908.

One of the chief sources of benefit is doubtless the change of habits and the relaxation at such places, but the proper use of the water itself, aside from its mineral constituents, both for drinking and for bathing, is capable of producing great improvement in health. The mineral springs of Alaska have been used most beneficially for bathing. The several springs that are thus used locally have been of great benefit to prospectors and miners, who, after weeks or months of work in the cold waters of the creeks, find great relief from rheumatism in hot-spring baths.

Few highly mineralized waters have been found in Alaska, but as the substances in solution in even moderately mineralized springs have some effect on the human system, the more common substances found in them and their chief effects are briefly stated below.

Silica (oxide of silicon, SiO_2) is the chief constituent of most kinds of rock, mainly in the form of quartz. It is only slightly soluble in ordinary water and hence is present in most waters in only small amounts, 50 parts per million being an unusually high proportion. It is believed to be usually present in water in suspension, as a colloid, or in solution as a silicate or a hydrated silicic acid. Silica in the amounts found in most waters is believed to have very little effect on the human system.

Iron and aluminum are very common in rocks, but, like silica, neither is taken into solution in large quantities by most natural waters. Most waters contain more iron than aluminum, which in many waters occurs in an amount so small that it in analyses is not determined separately from the iron. The total amount of both is rarely more than 25 parts per million. The medicinal value of aluminum in most waters is insignificant. Water containing iron is considered to be of some benefit for drinking, in remedying a deficiency of iron in the blood. Iron-bearing waters are likely to form rusty spots on clothes washed in them and may stain bathtubs and washbasins.

Calcium and magnesium are very common in feldspar and certain other rock minerals. They are fairly soluble and are present in many waters in considerable amounts. The proportion of calcium is usually two to five times that of magnesium. Both substances render water "hard" and are the main basic constituents of the hard scale that is deposited in teakettles and steam boilers. Waters containing considerable amounts of calcium carbonate or magnesium carbonate are of value in neutralizing acidity of the stomach and thus in relieving certain forms of indigestion. Calcium and magnesium waters that contain predominant amounts of chloride and sulphate instead of carbonate are believed to tend to form calculi (gallstones).

Sodium and potassium occur in rocks as the soda and potash feldspars. Although the two elements are found in most rocks in about equal quantities, sodium is usually found in water in much greater amount. The foaming of steam boilers is often caused by soda compounds in solution. Waters that contain sodium and potassium, like those that contain calcium and magnesium, when these occur with carbonates, are of value in treating digestive troubles.

The carbonate radicle (CO_3), which is composed of carbon and oxygen, is a prominent constituent of limestone. Carbon dioxide or carbonic acid gas (CO_2), the gas of "soda" waters, is probably also in many springs derived from carbonate rocks. Like solid carbonates, this gas is soluble in water in considerable amounts, and when present it aids in dissolving and keeping in solution other less readily soluble substances, such as calcium and iron. The carbonate radicle, which is usually found with calcium and sodium, aids in correcting digestive troubles. Carbon dioxide gives water an agreeable taste, aids the flow of saliva, and allays gastric irritation.

The sulphate radicle (SO_4), which is common in waters, is derived chiefly from minerals such as gypsum (calcium sulphate) or is produced by chemical changes in sulphide minerals, chiefly iron pyrite (iron sulphide). Sulphate waters have a cathartic effect, and strong natural sulphate waters may be used as purgatives in the same way as Epsom salts (magnesium sulphate) or Glauber's salt (sodium sulphate).

Sulphide radicles, of which there are several forms more complex than the simple sulphide, are fairly common. They may be derived either from the partial oxidation of sulphur or from the reduction of sulphates. Sulphureted hydrogen or hydrogen sulphide (H_2S), a gas that gives rotten eggs their characteristic odor, is believed to be formed largely by the action of organic (animal or vegetable) matter on gypsum in the presence of carbon dioxide. This fact probably accounts for the presence of both carbon dioxide and hydrogen sulphide gases in many spring waters. Sulphide waters are of value in the treatment of skin diseases, affections of the liver, and chronic malaria.

Chlorine (Cl) is present as chloride in nearly all natural waters, though in only small amounts in many stream and well waters. Its principal salts, such as common table salt (sodium chloride, $NaCl$) and magnesium chloride ($MgCl_2$), are very soluble, however, and hence chloride is present in large amounts in some waters. Chloride waters, or "saline" waters, tend to stimulate the appetite and have a stimulating effect on the organs of digestion.

Slimy or fungus-like vegetable growths of the forms known as algae are common in certain classes of springs, especially sulphur springs. They are usually present in the waters of hot sulphur springs, and the color and texture of the growths appear to vary with the temperature of the water and the swiftness of the current, as well, possibly, as with differences in the varieties of the growths. In the hotter waters their colors are generally brighter—reddish purple and bright green, but their predominant color in the cooler waters is a darker green. In still waters the growth may form a sheet or layer; in swifter currents it is stringy or feathery.

Sulphuraria is a slender green plant that secretes silica and grows in waters having a temperature of less than 122° F. *Crenothrix* and allied growths are small filamentous plants that have a gelatinous layer colored by iron. They develop in cold waters that contain both iron and organic matter.

Hot-water baths accelerate the circulation and induce a flow of blood to the surface. This increase of the quantity of blood in the superficial blood vessels produces congestion and profuse sweating. Hot baths are of benefit in the treatment of partial paralysis and of rheumatism. The high temperature is probably the factor of main value in hot-spring baths and in hot-mud baths. The weight of the mud in the mud baths and the fact that it retains heat may, however, have some effect.

The temperatures of many spring waters remain practically constant throughout the year and are nearly the same as the mean annual temperatures of the localities. Observations of temperature in deep mines and borings in regions of comparatively uniform and undisturbed rock indicate that the temperature below the first 50 feet (in which underground temperature is affected by seasonal variations) increases at the rate of about 1° F. for each 50 feet of increase in depth. In some places this increment may be safely assumed in estimating the depth from which the water of a hot spring rises, but it is questionable whether this rule is applicable to any part of Alaska, both because the rock formations are in most places complex, and because the ground in many parts of the Yukon basin and Seward Peninsula is frozen to a considerable depth. The high temperature of the water of hot springs can usually be assigned more probably either to faults or displacements in the rock formations, to volcanic activity, or to chemical action. The rocks along fault zones and the borders of intrusive masses are probably heated considerably above normal temperatures by the pressure and friction. Warm waters from deep sources pass upward along these fault zones and zones of crushing and are further heated during their ascent to the surface by contact with the heated rocks. In some areas of volcanic rocks there are probably masses below the surface that have not yet cooled to a normal temperature, and water near them becomes heated. Chemical reactions, such as the oxidation of pyrite (iron sulphide) to iron sulphate, liberate heat and may also thus increase the temperatures of underground waters.

The results of analyses of water are reported in several ways, but of late years the statement of the radicles present in parts per million by weight is most common and is used in this report. The amounts of the constituents stated in the analyses therefore indicate the proportion, by weight, of the several constituents to the weight of the mineralized water. For instance, the statement that the amount of calcium radicle in a water is 200 parts per million means that in each million pounds of the water there is 200 pounds of calcium. To indicate this in quantities that can be better appreciated, it may be stated that a heaping teaspoonful of an ordinary salt dissolved in 1 gallon of water represents approximately 4,000 parts per million; a rounding teaspoonful about 2,500 parts; a thimbleful about 600 parts; and the amount that can be held on the point of a penknife 10 to 20 parts.

The minimum amount of solid material in solution that is perceptible to the taste varies greatly with the substance, and to less, though marked, degree with the individual. As small an amount as two or three parts per million of iron is distinctly perceptible to some people, but several times as much aluminum is only barely so. The alkalies (sodium and potassium) and the alkaline earths (calcium and magnesium) are much less easily detected by the taste. About 200 parts per million of calcium or magnesium render a water noticeably "hard." It is probable that chloride and the carbonate and sulphate radicles are the ones that give the distinctive tastes to most mineral waters. About 250 parts per million of chloride renders a water distinctly salty. Of dissolved gases that are present in some waters, 4 or 5 parts per million of hydrogen sulphide gives a perceptible egg-like flavor.

Most of the analyses of the spring waters were made under contract by S. C. Dinsmore at Reno, Nev. Analyses of several were made in the laboratory of the United States Geological Survey by R. B. Dole and Alfred A. Chambers. Analyses of two waters (from Baranof Hot Springs and Chena Hot Springs), made by the Bureau of Chemistry, United States Department of Agriculture, are also reproduced through the courtesy of that department.

The analyses of the Alaskan spring waters have been examined by Mr. Chambers, and remarks on the character of each are included in the descriptions of the individual springs.

An unusual feature of nearly all the waters is their high content of silica. The available analyses indicate that in the springs of sodium carbonate and calcium carbonate type the ratio of silica to sodium plus potassium is considerably higher than it is in the sul-

MAP OF SOUTHEASTERN ALASKA, SHOWING LOCATION OF MINERAL SPRINGS phate and chloride waters. This characteristic seems to be reasonably explained by the fact that in solution the carbonates of the alkalies and alkaline earths hydrolize, producing alkaline solutions that tend to dissolve silica; whereas the sulphates and chlorides in hydrolizing produce solutions that tend to precipitate rather than to dissolve silica.

HOT SPRINGS.

SOUTHEASTERN ALASKA.

DISTRIBUTION.

Hot springs are fairly common on the islands that compose a large part of southeastern Alaska and on the adjacent mainland. Those reported (see Pl. II) may be divided into three geographic groups—those of Revillagigedo Island and the adjacent mainland, those along Stikine River, and those of Baranof and Chichagof islands.

Because of the lack of definite knowledge that hot springs are absent in the areas between these general groups, and because of the lack of detailed information as to the structural conditions in the region, an attempt to draw broad conclusions from the distribution of the springs is probably unwarranted. The springs seem, however, to be definitely related to intrusive masses of rock, principally of granitic material, in the schists, graywackes, and other more or less altered rocks of the region, and appear to issue along zones of fracturing or faulting in the intrusive rocks.

BELL ISLAND HOT SPRINGS.

Bell Island Hot Springs (102[1]) are on the western end of Bell Island, about 50 miles by water north of Ketchikan. (See Pl. III, *A*.) The property was taken up as a homestead in 1902 by George Roe, who erected a bathhouse and a number of cabins along a board walk extending to a landing place opposite the boat anchorage and developed the springs as a resort for the medicinal use of the water. On his death in 1914 the management of the place was continued by his two brothers.

The principal springs issue at the north edge of a small creek, about 400 yards from and 15 feet above high-tide limit in the narrow cove into which the creek empties. The water rises from a narrow fissure about 15 yards long in biotite granite cut by small veins of pegmatite. The rock surface at the springs has been concreted into five basins, each about 4 feet deep, the largest being about 3 by 10 feet in width and length. The observed temperatures of the water in the several basins range from 125° to 162° F. From the western-

[1] Numbers in parentheses correspond to locations indicated on Pl. I (in pocket).

most and hottest basin a part of the water is conducted to an adjacent bathhouse having two wooden tubs in separate rooms. Cool water for the bath is also obtained from the springs by conducting it first through a gratelike arrangement of pipe in the bottom of the cold-water creek.

The waters of all five basins are probably very similar in chemical character, though the coolest basin is locally considered to be less mineralized than the others. In taste and smell they are only mildly sulphureted. The analysis (tabulated on p. 25) of water from the hottest basin shows it to be high in mineral content and of the sodium chloride type, though sulphate is also present in amount secondary only to the chloride.

The total flow of the five basins, as nearly as could be estimated, is 8 or 10 gallons a minute.

About 125 yards downstream from the main group a sixth spring, having a temperature of 109° F. and a flow of about half a gallon a minute, issues in a small board-curbed pool at the base of a large granite boulder. This spring is seldom used, however, and only for drinking. Unlike the hotter springs, whose basins are clear, this cooler spring is lined with a white, jelly-like algal material, whose growth is probably favored by the lower temperature. No other hot or mineral springs were reported on the island.

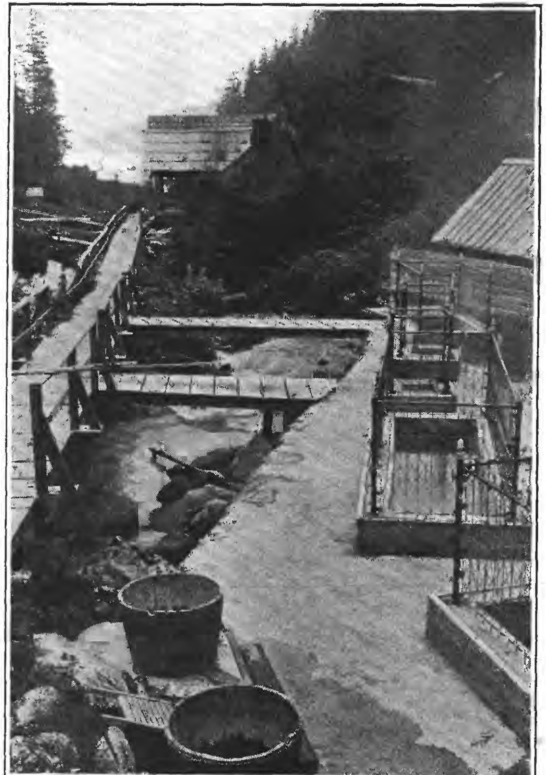
Evidences of slickensiding in the rock near the springs give indication of some faulting in the vicinity; and this may allow the escape of deep-seated hot water along the well-marked fissure—presumably of fault origin—from which the springs rise. The island and neighboring mainland appear to be composed entirely of granitic material,[1] and no evidence of volcanic activity or of other plausible cause for the presence of the hot springs was noted.

The location of the springs in a sheltered cove near a good anchorage for small boats and within a fairly short run from Ketchikan makes them well situated for a pleasure and health resort in this southeastern part of Alaska, which is rapidly becoming recognized as ideal for summer cruising.

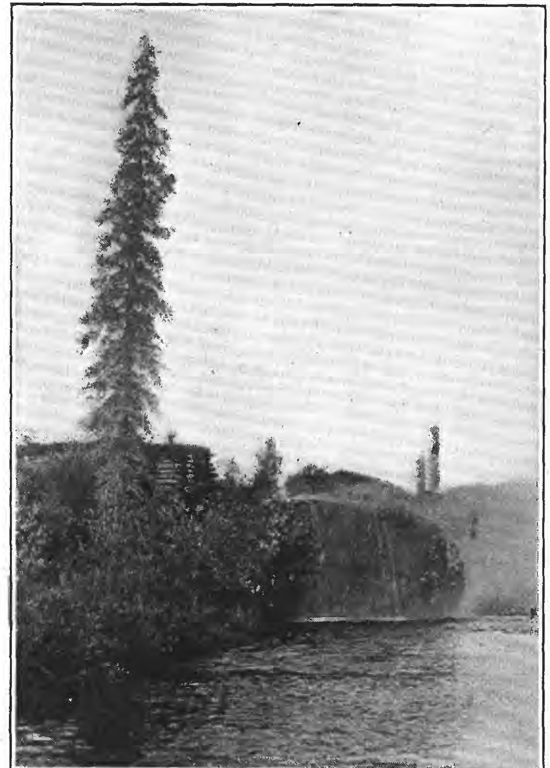
BAILEY BAY HOT SPRINGS.

Bailey Bay Hot Springs (100 on Pl. I) are best reached by launch to the head of Bailey Bay, from which they lie about 3 miles to the northwest, on a creek that empties into Lake Shelockum (Mirror Lake), whose surface stands about 330 feet above the bay. The Forest Service has built a trail from the shore of the bay up the steep

[1] Wright, F. E., and Wright, C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pl. 2, 1908.



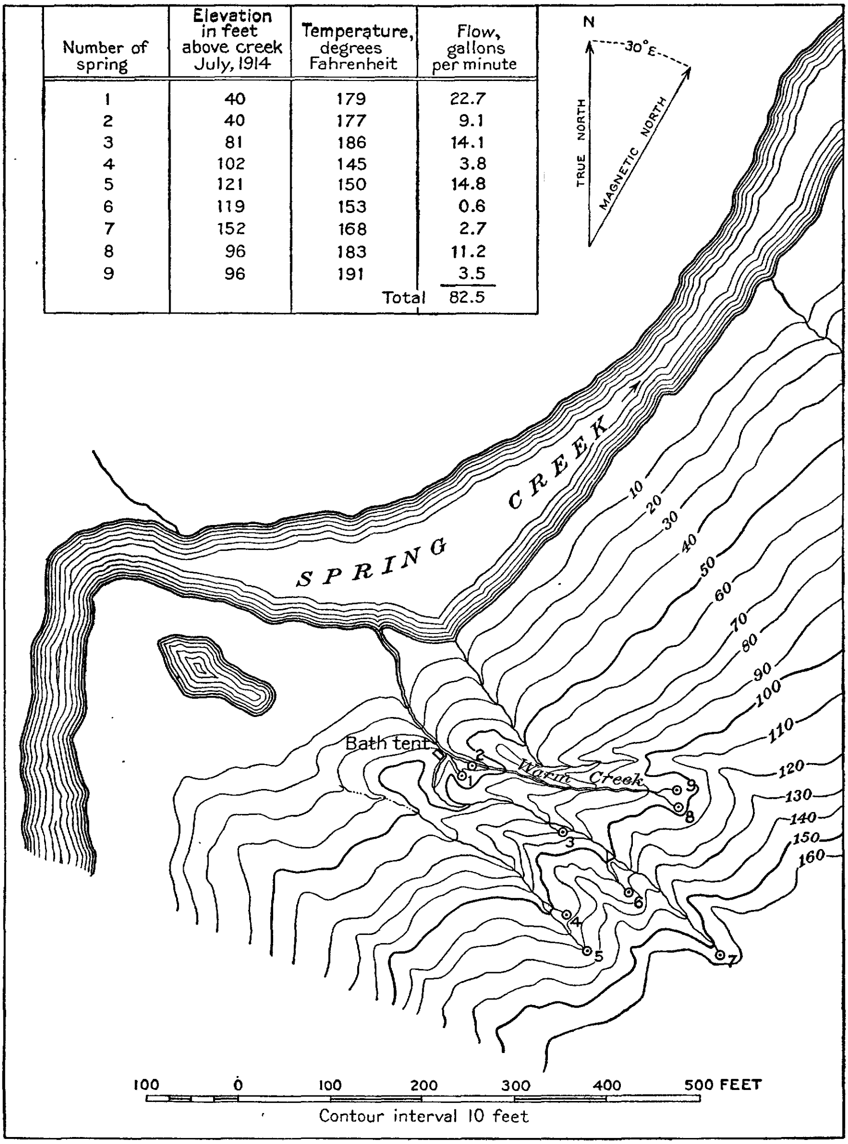
A. BELL ISLAND HOT SPRINGS, SOUTHEASTERN ALASKA.



B. MELOZITNA HOT SPRINGS, RUBY REGION.

slope to the south end of the lake. Thence the springs may be reached by rowboat to the west side of the lake and a quarter of a mile up the creek.

The hot water issues from at least nine springs on the steep slopes on the south side of the creek, the vents lying 40 to 150 feet above the stream. Their positions are shown in figure 1, which was prepared from the survey of the property made by the Forest Service.



Number of spring	Elevation in feet above creek July, 1914	Temperature, degrees Fahrenheit	Flow, gallons per minute
1	40	179	22.7
2	40	177	9.1
3	81	186	14.1
4	102	145	3.8
5	121	150	14.8
6	119	153	0.6
7	152	168	2.7
8	96	183	11.2
9	96	191	3.5
		Total	82.5

FIGURE 1.—Sketch map of Bailey Bay Hot Springs and vicinity, southeastern Alaska.

When visited in 1915 water from the lowest two springs was conducted to a wooden bathtub in a tent near by. The other springs were unused, though a quantity of wood-stave pipe had been brought as far as the lake, the intention having been to pipe the hot water down to a hotel to be built near the bay.

The individual flow of the springs is from about half a gallon to more than 20 gallons a minute, and the total yield, as measured by the Forest Service, is 82½ gallons a minute. The observed temperatures ranged from 145° to 191° F. The hottest spring had the relatively small flow of only 3½ gallons a minute, and the spring of largest flow, which is the lowest and the one used for bathing, had a medium temperature for the group of 179° F. Water for cooling the bath was obtained from an adjacent small cool-water stream. One of the central springs of the group (No. 3 in fig. 1), is the most interesting, as its water issues from a small fissure in a jet 12 inches high, under a pressure that is probably due to hydrostatic head from the slopes above. In 1905 F. E. Wright[1] noted that this jet spurted up 15 inches, and that the water had a temperature of 203° F. The lower temperature and less pressure of the jet in 1915 may represent positive though perhaps temporary decreases that were probably due, in part at least, to rain and the consequent saturation of the surface soil with cold water at the time of the writer's visit.

The rocks of the region are granitic,[2] with some marble-white phases in which mica is scarce, and with pegmatite veins carrying large flakes of black mica. As viewed from the north the springs appear to issue on a steep talus slope at the base of steeper slopes and cliffs of granite. When examined closely, however, each spring appears to issue from bedrock and, like the jet spring, from a crevice in the granite.

The water in each spring basin is clear and shows considerable bubbling of gas that is probably mainly carbon dioxide but that includes enough hydrogen sulphide to give a faint but characteristic odor of bad eggs. Reddish to green algal growths in the pools and overflow channels vary in color and texture apparently with the temperature of the water and the swiftness of its flow. They are probably Cyanophyceae, of which there are several varieties, which grow in natural hot waters up to a temperature of fully 180° F.—a temperature that will soft boil an egg in about 5 minutes.

Small amounts of carbonate, probably of calcium and magnesium, are deposited on stones along the run-off channels of the springs, presumably at the points where the escape of carbon dioxide from the water is sufficient to cause the precipitation of a portion of the material held in solution.

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[1] Op. cit. [2] Idem, pl. 2.

The analysis of water from the jet spring (tabulated on p. 25) shows that it is a moderately concentrated water of the sodium carbonate type. The silica content is unusually high, constituting nearly one-third of the total mineral matter in solution. When present in such a large amount it seems probable that a portion of the silica is present as soluble silicate.

The issuance of the springs at such notably different elevations on a steep slope is unusual and indicates that the several fissures are not closely connected, because all the hot water would tend to flow from the lowest spring. No topographic or other suggestive evidence of faulting in the vicinity of the springs was noted; but the fractured character of the rock in the region suggests that, though actual faulting of considerable extent may not have taken place, deep fractures may be present, which permit the upward escape of the hot water.

HOT SPRINGS NEAR UNUK RIVER.

Hot springs are reported on the north bank of Unuk River (104) about 6 miles above its mouth,[1] but at the time the region was visited by the writer no guide was found who knew their location. They are believed, however, to be of rather small flow and neither very hot nor notably mineralized. The water probably issues from fissures in the granitic material that constitutes the country rock over large areas in the region.

HOT SPRINGS NEAR SAKS COVE.

A group of hot springs (103 on Pl. I) on the eastern side of Behm Canal, about 10 miles southeastward of the mouth of Unuk River (Burroughs Bay) and 5 miles southeast of Saks Cove, was reported to the writer by Mr. W. H. Babbitt, of the Forest Service.

The springs are said to be similar in general character to Bell Island Hot Springs, yielding approximately an equal amount of scalding water that is slightly sulphureted. The water issues in part at the rocky shore and in part directly from a fissure in granite 200 feet back from the shore. The springs are probably similar in mode of occurrence and chemical character to those on Bell Island, near Bailey Bay, and near Unuk River, and, like these, are probably best ascribed to the escape of deep-seated water along fissures in the faulted and fractured granitic rocks that cover an extensive area in the region.[2]

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[1] Wright, F. E., and Wright, C. W., op. cit., p. 201 and pl. 2.
[2] Idem, pl. 2.

SHAKES HOT SPRINGS.

Hot springs that have long been claimed by the Indian Chief Shake, who lives at Wrangell, issue on the north edge of the valley of Stikine River, about 20 miles northeast of Wrangell (100 on Pl. I). During the summer the springs are easily accessible by boat up the river and a slough and tributary creek, from which last they are distant only 200 yards.

They issue at the base of a granite cliff that abruptly limits the valley. Their exact point of issuance is obscured by boulders and undergrowth, but the water seems to come forth in a single stream only a few feet above the valley alluvium. Very probably it rises through a fissure in the intrusive granitic material that forms the greater part of the coastal ranges.[1]

The water has a temperature of 125° F. and a flow of about 100 gallons a minute. It has no appreciable taste nor odor, and no evidence of escaping gas was seen. An abundant growth of green algae lines the run-off channel and pools. The analysis included in the following table (analysis 3) shows that it is a moderately concentrated sodium sulphate water. The content of chloride is notably low. Silica is an important constituent, forming about one-quarter of the total mineral matter in solution.

A part of the flow is conducted in a small trough to a wooden tub in a bathhouse a few yards away, and a cabin and woodshed have been built near by.

The springs are used to some extent by Chief Shake and his tribesmen for bathing and also occasionally by whites. They are easily reached only during the summer months, however, and at least one tragedy is connected with their use. In 1915 the hull of a small boat, half sunken in the slough near the springs, marked the place where two whites had perished while attempting to return to Wrangell after the winter freeze-up had started.

From the river a few miles below the springs an excellent view is obtained of Popof Glacier, clinging to the steep mountain side on the north.

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[1] Wright, F. E., and Wright, C. W., op. cit., pl. 3.

Mineral analyses of waters from hot springs in southeastern Alaska.

[Parts per million except as otherwise designated.]

Constituents.	1	2 [a]	3
Silica (SiO_2)	105	142	108
Iron (Fe)	[b] 1.2	1.5	[b] 1.2
Aluminum (Al)		2.2	
Calcium (Ca)	4.6	13	13
Magnesium (Mg)	1.0	2.1	.4
Sodium (Na)	[c] 201	[c] 54	87
Potassium (K)			9.2
Carbonate radicle (CO_3)	13	53	18
Bicarbonate radicle (HCO_3)	37	27	43
Sulphate radicle (SO_4)	129	32	142
Chloride radicle (Cl)	188	11	6.5
Nitrate radicle (NO_3)	....	Tr.	....
Total dissolved solids at 180° C.	674	413	409
Temperature (° F)	162	186	125
Chemical character	Na-Cl	Na-CO_3	Na-SO_4

[a] Borax present. [b] $Fe_2O_3+Al_2O_3$. [c] Calculated.

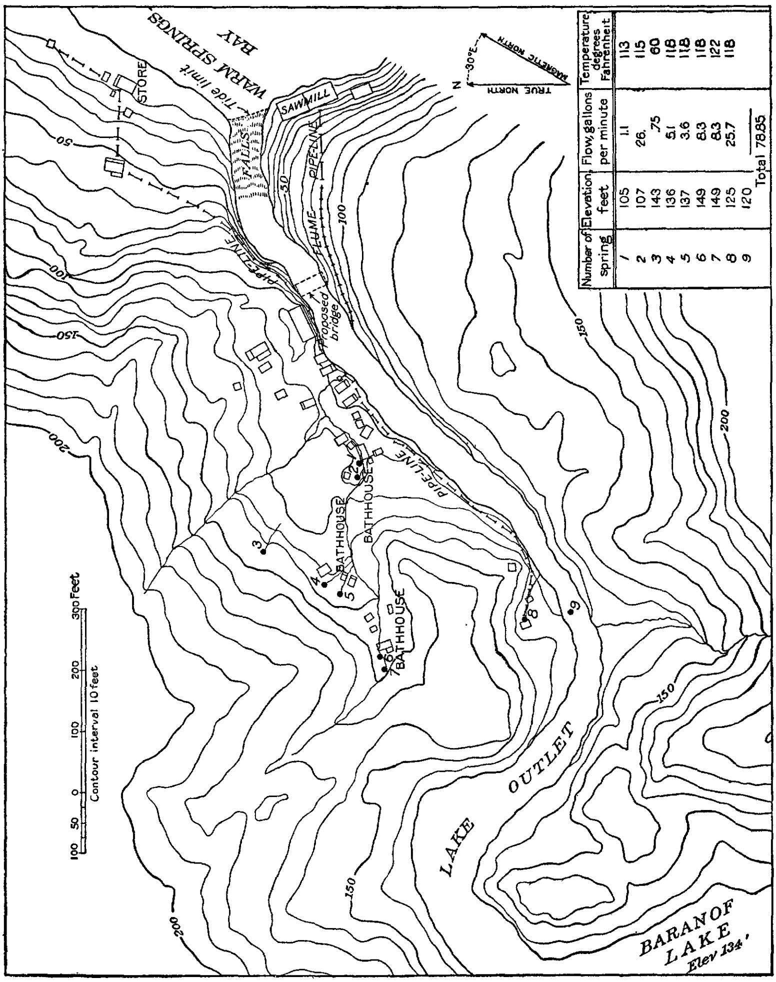
1. Bell Island Hot Springs; lowest and hottest basin. Has slight odor of hydrogen sulphide. Sample collected June 6, 1915, by G. A. Waring; analyzed by R. B. Dole and Alfred A. Chambers.
2. Bailey Bay Hot Springs; "jet" spring. Has slight taste and odor of hydrogen sulphide. Sample collected June 17, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
3. Shakes Hot Springs; principal spring. No perceptible odor or taste. Sample collected June 19, 1915, by G. A. Waring; analyzed by R. B. Dole and Alfred A. Chambers.

MINOR HOT SPRINGS IN THE WRANGELL REGION.

Minor hot springs in the general region of Shakes Hot Springs are reported from three localities: F. Matheson, of Wrangell, reported small flows of hot water (99) in the valley alluvium a few miles westward from Shakes Springs, and K. J. Johansen, also of Wrangell, reported, on authority of the Indians, small hot springs (98) on the south side of Stikine River, 6 or 8 miles upstream from Wrangell. As the lowlands are covered with dense undergrowth and a guide who knew the locations of the springs was not readily found, no attempt was made to examine these minor springs. The third locality in the Wrangell region was reported by George Peterson, of the Forest Service, who had heard that hot water (97) issues at low-tide level near the light on the south end of Vank Island, about 8 miles west of Wrangell. A description of these springs was not obtained by the writer.

A fourth group, which probably contains the most notable hot springs in the neighborhood of Wrangell, is several miles within Canadian territory, on the eastern side of Stikine River, nearly opposite Great Glacier. These springs are remarkable both for their position, nearly opposite the glacier front, and for their large flow. F. E. Wright, who visited the region in 1905 for the United States Geological Survey, reports that a stream of hot water 10 feet wide is formed by about eighteen springs that issue within a space of 200 yards at the base of a granite mountain. A float measurement of the stream indicated a flow of about 150,000 cubic feet in

24 hours (nearly 800 gallons a minute). A green algal growth that forms along the stream indicates by its abundance and color that the water probably has a temperature of about 120° to 150° F. The water is believed by Mr. Wright to issue near or along a fractured zone between the schistose country rock and an intruded granite mass.



Number of spring	Elevation, feet	Flow, gallons per minute	Temperature, degrees Fahrenheit
1	105	1.1	113
2	107	26.	115
3	143	.75	60
4	136	5.1	118
5	137	3.6	118
6	149	8.3	118
7	149	8.3	122
8	125	25.7	118
9	120		
		Total 78.85	

FIGURE 2.—Sketch map of Baranof Hot Springs and vicinity, Baranof Island, southeastern Alaska.

BARANOF HOT SPRINGS.

Baranof Hot Springs (91) issue on the slopes between Warm Springs Bay (a small bay on the eastern side of Baranof Island) and Lake Baranof, a small lake that lies near but more than 100 feet above the salt water. The sketch map (fig. 2), based on a survey by the Forest Service, shows the positions and elevations of the several springs, and the accompanying legend gives their respective temperatures and flows.

At each spring the water issues from among granite boulders or coarse granite gravel that overlie bedrock of the same material. The waters of all the springs appear to be similar in character, being distinctly sulphureted but not otherwise very noticeably mineral in taste. The two analyses (tabulated on p. 32) of water from these springs, although not collected from the same spring, are very similar in character. Each water is of the sodium carbonate type, of moderate total mineral content, with silica as an unusually large proportion of the total.

Considerable gas, that is probably carbon dioxide, is given off at several of the springs, and the usual green algae, in places coated nearly white with sulphur, grow along the run-off channels.

The springs have been locally used as a health resort for several years, and a number of cabins have been erected by local dwellers for rental to others who come to the springs. When visited in the summer of 1915 there were three bathhouses, the principal one, containing six wooden bathtubs, being erected near and supplied by spring No. 2. Springs Nos. 6 and 7 also supplied separate tubs in a cabin adjacent to them and spring No. 5 supplied a large wooden tub in a near-by cabin. Water from spring No. 8 was piped down to two or more cabins near the bay. Spring No. 9 issues from a crevice at the low-water edge of the stream that cascades from Lake Baranof to the bay and was not accessible.

The main country rock of the locality consists of intrusive granitic materials,[1] but in the vicinity of the springs dioritic and possibly more basic rocks appear. Prominent, straight, narrow, parallel gorges on the southern side of the bay indicate possible faulting. As was pointed out by Joseph McCoombs, who lives at the springs, the boulders on the north side of the stream in the immediate vicinity of the springs are rounded as if waterworn, whereas those in the present stream channel are angular. It would therefore appear that the stream has comparatively recently shifted its course, possibly owing to faulting. Although the evidence presented by the gorges and the boulders is by no means conclusive, the springs appear to be in a locality of some crustal movement, and may possibly be ascribed to fault fissures that allow the upward escape of deep-seated water.

The bay and lake are surrounded by snow-covered mountains, and the locality is reported to receive a considerably greater snowfall than the remainder of the island. The winter climate is fairly mild, however, and parties occasionally spend the winter at the springs.

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

SITKA HOT SPRINGS.

Sitka Hot Springs (92 on Pl. I), which lie 16 miles down the coast from Sitka, were perhaps the earliest of Alaska's mineral springs known to white men. (See Pl. IV, *A*.) They were visited in 1841 by Sir George Simpson, governor in chief of the Hudson Bay Co.'s territories in North America, who wrote of them as follows:[1]

> The establishment in the neighborhood consisted of three snug cottages, being kept in order by an old fellow of a Russian and his daughter. * * * This establishment is employed as a hospital for invalids from Sitka. * * * In the neighborhood there are four distinct springs. * * * At its source the principal spring possesses a temperature of 54° R., or 153½° F., being hot enough, as we found by experiment, to cook an egg in eight minutes. From this spring the two baths, one for the natives and the other for the whites, are fed, while by flowing about 50 yards through several channels the waters are reduced to an average temperature of 130° F., or 43½° R.
>
> As this natural "medicine" is held in high estimation by the surrounding tribes, the native bath enjoys no sinecure of it. When the country is sufficiently peaceable for moving about it safely, the savages think nothing of coming two or three hundred miles to benefit by the healing waters, while they do their best to take their traveling expenses out of them by lying in soak for hours at a time, with nothing but their heads visible, eating, drinking, and, I may add, sleeping in the bath.

Besides showing the early development of the springs by the Russians, the account of Sir George is of interest in stating that the natives used the springs extensively. So far as the writer could learn, no other hot springs visited by him had in early days received much attention from the natives. Of late years, however, springs that have been developed and used by the prospectors have come to be used to some extent by the natives.

The higher maximum temperature of 153½° F. recorded by Sir George in 1841, as compared with the maximum of 149° F. noted by the writer in 1915, possibly indicates a slight cooling of the water; but the point of observation, the depth of immersion of the thermometer and its accuracy, and the amount of cold water infiltrating from the rain-soaked ground may easily account for the small difference.

Dall,[2] writing of the history of the country, says that in 1861

> a hospital for skin diseases was opened at Sitka, near the sulphur springs. The water contained sulphur, iron, chlorine, and manganese, and had a temperature of 122° F. * * * Whitby records the existence of hot saline springs below high-water mark near Sitka.

The "sulphur springs" mentioned are very probably the Sitka Hot Springs, as no springs in the immediate vicinity of Sitka are

[1] Simpson, Sir George, Narrative of a journey round the world during the years 1841 and 1842, vol. 2, pp. 194–196, London, 1847.

[2] Dall, W. H., Alaska and its resources, pp. 353, 472, Boston, 1870.

A. SITKA HOT SPRINGS, BARANOF ISLAND, SOUTHEASTERN ALASKA.

B. TENAKEE HOT SPRINGS, CHICHAGOF ISLAND, SOUTHEASTERN ALASKA.

C. CIRCLE HOT SPRINGS, CIRCLE DISTRICT.

known to the writer. The locality of the "hot saline springs" is not given by Dall; hot water may issue alongshore at Sitka Hot Springs, but of late years such springs have not been recognized.

For several years the Sitka Hot Springs have been conducted as a health and rest resort, a hotel and several cottages furnishing accommodations for about 30 guests. The principal buildings are about 100 yards from and 50 feet above the beach, and the springs issue from slopes somewhat higher. The observed elevation, temperature, and flow of each of the four springs are as follows:

	Elevation above highest high tide.	Temperature.	Flow.
	Feet.	*°F.*	*Gals. per min.*
Main Spring	60	149	9½
Magnesia Spring	55	142	2¼
Sulphur Spring	55	124	1¼
Old Russian Spring	80	95	(a)

a No appreciable flow.

The flows of the several springs increase from the coolest to the hottest, the hottest spring yielding much more water than the total flow of the others. This is unusual; in most groups of hot springs the highest temperature is apt to be found in a spring of minor flow.

The Old Russian Spring was unused in 1915, and formed a pool that was still curbed with logs said to have been put in place many years ago. The Sulphur Spring, about 40 yards to the northwest, supplied a small bathhouse reserved for the natives. Water from the other two springs was piped down to the hotel, 30 yards away, and in addition to supplying several bathrooms was also used in a hot-water heating system for the building.

Analyses of waters from the two larger springs tabulated on page 32 show that they are almost identical in composition. Each is a highly mineralized sodium chloride water and is essentially a weak brine. Chloride constitutes more than one-half of the total solids. Relatively small amounts of carbonate and bicarbonate are present and magnesium is very low. Although the waters are saline they evidently are not derived from the near-by sea, for the relative proportions of the constituents are not the same as in sea water. For example, in the spring waters the ratio of calcium to sodium is about 1:3.6, and of sulphate to chloride the ratio is about 1:30; whereas in sea water these ratios are respectively about 1:30 and 1:7.

In the vicinity of the springs the granite from which the hot waters issue is cut by narrow dikes of darker rock, resembling diabase, that is classed as a spessartite (garnet) lamprophyre.[1] In the numerous rocks and islets dotting the water northward between the springs and Sitka hard metamorphosed sandstones and other sediments of Mesozoic age[2] are penetrated by dikes and massive bodies of intrusive granite. Although the hot waters issue at the surface from granite they may owe their escape from considerable depths to

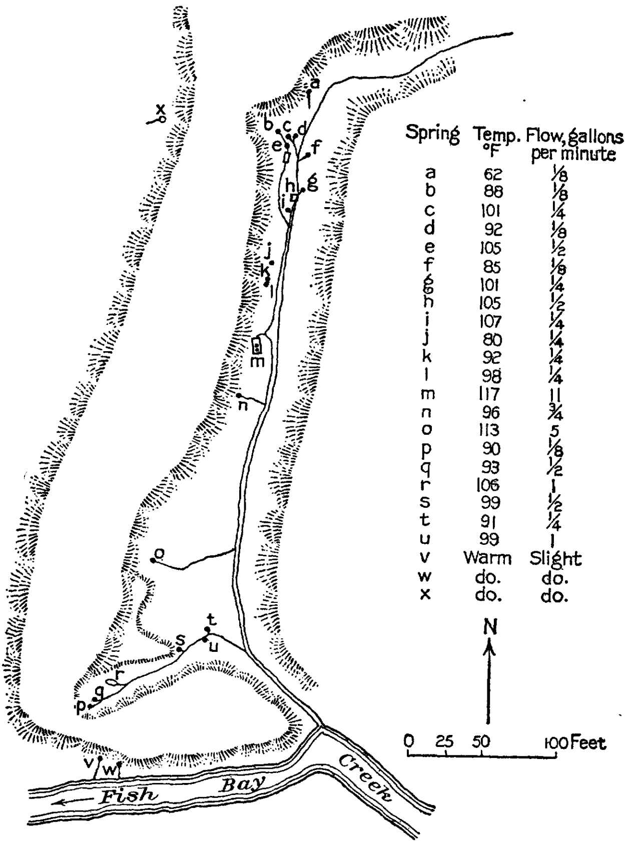


FIGURE 3.—Sketch map of hot springs near Fish Bay, Baranof Island, southeastern Alaska.

crevices or fissures along contact zones between the intrusive granite and the altered sedimentary rocks.

HOT SPRINGS NEAR GUT BAY.

E. W. Merrill, of Sitka, told the writer that a few years ago he found the water of the first creek on the northern side of Gut Bay, on the eastern coast of Baranof Island (93), to be warm and to taste

[1] Alaska, vol. 4, p. 18, Harriman Alaska Expedition, 1904.
[2] Knopf, Adolph, op. cit., pl. 1.

disagreeably, probably of hydrogen sulphide. Search was not made for the source of the warm water, but it very probably comes from springs near the creek channel and not far upstream.

The rocks in the vicinity of Gut Bay are of Paleozoic age, comprising limestone and schists as well as greenstones and other varieties of ancient lavas.[1] The hot water possibly rises along a fractured and fissured zone in the country rock.

HOT SPRINGS NEAR FISH BAY.

A number of hot springs (89 on Pl. I, in pocket) issue along a small stream about 3 miles east of the head of Fish Bay, 40 miles north of Sitka. These are possibly the springs that have been referred to as being in Cook Bay.[2] Evidence that Fish Bay has been known as Cook Bay is not at hand, however, nor is there any other bay on Baranof Island that is generally known as Cook Bay.

The positions of the several springs and their temperatures and approximate discharges are shown in figure 3. The waters of the several springs appear to be very similar; all are mildly sulphureted but not otherwise notably mineral in taste. More or less active bubbling is caused at the several vents by a gas which, when collected in a bottle, extinguishes a flame and is probably carbon dioxide.

The analysis of water from spring m (see fig. 3), included in the following table (analysis 5), shows that it is a sodium carbonate water of moderate concentration. Unlike most of the hot-spring waters the chloride content is very low. Silica is high, as it is in other of the Alaskan waters. The presence of 34 parts per million of the borate radicle (B_4O_7) is noteworthy and seems to indicate the presence of volcanic emanations of intrusive volcanic rocks carrying appreciable amounts of boron.

[1] Knopf, Adolph, op. cit., pl. 1.
[2] Wright, C. W., Nonmetallic deposits of southeastern Alaska: U. S. Geol. Survey Bull. 284, p. 60, 1906.

Mineral analyses of waters from hot springs in the Yukon River basin, Alaska.

[Parts per million except as otherwise designated.]

Constituents.	1	2 [a]	3	4	5
Silica (SiO_2)	96	71	96	122	110
Iron (Fe)	[b] 1.8	[b] .60	.75	.5	.75
Aluminum (Al)			1.6	2.1	1.6
Calcium (Ca)	4.6	2.4	378	378	13
Magnesium (Mg)	1.1	.2	7.2	2.6	2.4
Sodium (Na)	[c] 58	55	1,440	1,365	[c] 69
Potassium (K)		2.3	60	57	
Carbonate radicle (CO_3)	.0	35	.0	.0	63
Bicarbonate radicle (HCO_3)	93	30	29	31	43
Sulphate radicle (SO_4)	49	43	88	97	24
Chloride radicle (Cl)	9.8	2.8	2,745	2,740	4.5
Nitrate radicle (NO_3)	....	Trace.	.0	.0	Trace.
Borate radicle (B_4O_7)	....	.0	Trace.	Trace.	34
Total dissolved solids at 180° C.	268	[d] 228	4,877	5,046	393
Temperature (°F.)	122	....	149	142	117
Chemical character	Na-CO_3	Na-CO_3	Na-Cl	Na-Cl	Na-CO_3

[a] Contains 0.1 part per million of lithium; negative tests obtained for phosphate, arsenate, manganese, and strontium.
[b] $Fe_2O_3+Al_2O_3$.
[c] Calculated.
[d] By summation, with bicarbonate computed as carbonate.

1. Baranof Hot Springs; uppermost spring (No. 7 of fig. 2). Sample collected June 22, 1915, by G. A. Waring; analyzed by R. B. Role and Alfred A. Chambers.
2. Baranof Hot Springs; probably from spring No. 8 of fig. 2. Sample collected Aug. 13, 1913, by W. G. Weigle; analyzed by F. B. Furber, Bureau of Chemistry, U. S. Dept. Agriculture.
3. Sitka Hot Springs; principal spring. Tastes salty and distinctly of hydrogen sulphide. Sample collected June 25, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
4. Sitka Hot Springs, "Magnesia Spring." Tastes distinctly salty and has faint odor and taste of hydrogen sulphide. Sample collected June 25, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
5. Hot Springs near Fish Bay; principal spring. Has slight odor and taste of hydrogen sulphide. Sample collected June 26, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.

Algal growths, the usual accompaniment of thermal sulphureted water, form greenish leathery coatings along the run-off channels. At two or more places along the small creek there are deposits of black muck, similar to that at Kruzgamepa Hot Springs (13), which A. F. Rogers, of Stanford University, examined microscopically and found to consist of opaque, black colloidal ferrous sulphide, diatoms, and earthy matter.

Fish Bay Hot Springs were first made accessible to white men by William Hanlan, of Sitka, who was told of their approximate location by Indians. After two unsuccessful trips, he found them about 1905, cut a trail to them through the dense forest, and constructed the log bathing pool at spring m (fig. 3). Within recent years they have been frequently visited by the men from the logging camp of W. R. Eubanks, at the head of the bay. Several of the springs have been excavated and used either as clear-water or as mud baths.

A considerable area east of Fish Bay and also the higher slopes to the south and west are occupied by Paleozoic schists and associated rocks, but the bedrock in the vicinity of the bay is composed of later granitic materials, intruded into the older formation. The eastern border of the intrusive belt is in the neighborhood of the springs.[1]

[1] Knopf, Adolph, op. cit., pl. 1.

Rock is not well exposed at the springs, being covered by soil and loose material, but the fragments examined are of schist, with quartz veins. On the northern shore at the head of the bay a coarsely crystalline hornblende-feldspar rock is exposed. The steep, forested slopes along the northern shore are scarred by numerous landslides, which suggest a broken or crushed condition of the underlying rock. The small creek, along whose western side almost all of the hot springs issue, may also follow either a crushed zone in the bedrock or possibly even the contact zone between the schist and the hornblende rock.

The shore at the head of Fish Bay is flat and covered with subangular stones, the largest about 6 inches in longest dimension. The normal tides here have a range of about 10 feet and alternately cover and expose the beach for about a quarter of a mile. While the tide is coming in bubbles issue at many places in the water near the shore, suggesting that carbon dioxide or other gas may be escaping from the ground. A test with a flame indicated, however, that it is air, which has probably been trapped in the porous gravelly beach by the rapidly rising tide.

HOT SPRINGS ON NORTH ARM OF PERIL STRAIT.

On the north shore, about three-quarters of a mile eastward from the head of North Arm of Peril Strait (Hooniah Sound), heated water (87) issues at about half-tide level from the mussel and kelp covered rocks. As the warm water rises beneath or flows into the cold sea water, its presence is betrayed by convection currents, which give an oily appearance to the surface; but when examined at low tide the warm water has no noticeable taste nor odor. There is only a little bubbling, as of gas, and a small amount of dark-green vegetable growth, either algae or a seaweed.

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

The analysis of the water of the largest of the three springs (analysis 1, p. 40) shows that it has a high total mineral content and is of the sodium sulphate type. Although the sample collected contained considerable chloride it seems not to have been greatly contaminated with sea water left in the moss and gravel by the receding tide, for if it had been so contaminated it would have contained more chloride than sulphate.

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

Cliffs of massive granitic material rise from the narrow bouldery talus slope along the shore. In the main the rock seems to be comparatively unaltered, but near the springs there is a zone, possibly a dike, of fractured and altered dioritic rock. In the hand specimen this material shows considerable epidote and chlorite, products of the alteration of the original hornblende, and F. L. Hess, of the United States Geological Survey, noted that it contains much sphene. The escape of the spring water, probably heated either by the depth from which it rises or by chemical reactions in the altered rock, is apparently facilitated by the presence of this fractured mass of rock in the larger mass of intrusive crystalline material of the region.[1]

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

HOONIAH WARM SPRINGS.

Hooniah Warm Springs (86) are on the oceanward coast of Chichagof Island, about 70 miles northwest of Sitka. They may be reached by launch in calm weather, but as the coast is rocky and there is usually a heavy surf they have not been often visited. A log bathhouse or sweat chamber has been built over the principal spring, however, and the locality is the occasional camping place of hunters and trappers. The springs are in a small rock cove, in which much driftwood is cast up, on a beach of large rounded stones.

The principal spring issues at the edge of the forest, a few feet above the limit of drift logs and about 25 yards from and 15 feet above normal high-tide level. The water issues at a temperature of 111° F. from a vertical opening the size of one's hand, in dark hard schistose rock. After flowing through a natural rock pool, over

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

which the bath chamber has been built, the discharge—30 gallons a minute—cascades down to tidewater.

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

The analysis of water from this spring, tabulated on page 40, shows that it is a moderately concentrated sodium chloride water containing considerable sulphate. Silica forms more than a third of the total content, possibly in part as a soluble silicate.

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

Conditions at the main spring, where the water appears to issue directly from a fissure in the schist, indicate that the thermal water rises along such seams in the rock, which dips 80° S. 20° W. The abnormal temperature of the water may be due solely to the depth from which it rises, but it seems probable that it is due, in part at least, to the presence of intrusive rocks, which form a wide zone east of the springs.[1] The schist from which the warm water issues is a common alteration phase of the Paleozoic or Mesozoic sediments near their contact with intrusive rocks throughout southeastern Alaska.

TENAKEE HOT SPRINGS.

Tenakee Hot Springs (88 on Pl. I), formerly known as Hooniah Hot Springs, form one of the best-known of the Alaskan spring resorts. In 1891 there was a small native village near the springs,[2] which were probably locally used to some extent much earlier.

For 20 years or more the place has been used as a bathing resort by whites, and within the last 10 years a considerable settlement has been built up here, with post office (established in 1903) and supply stores. (See Pl. IV, *B*.)

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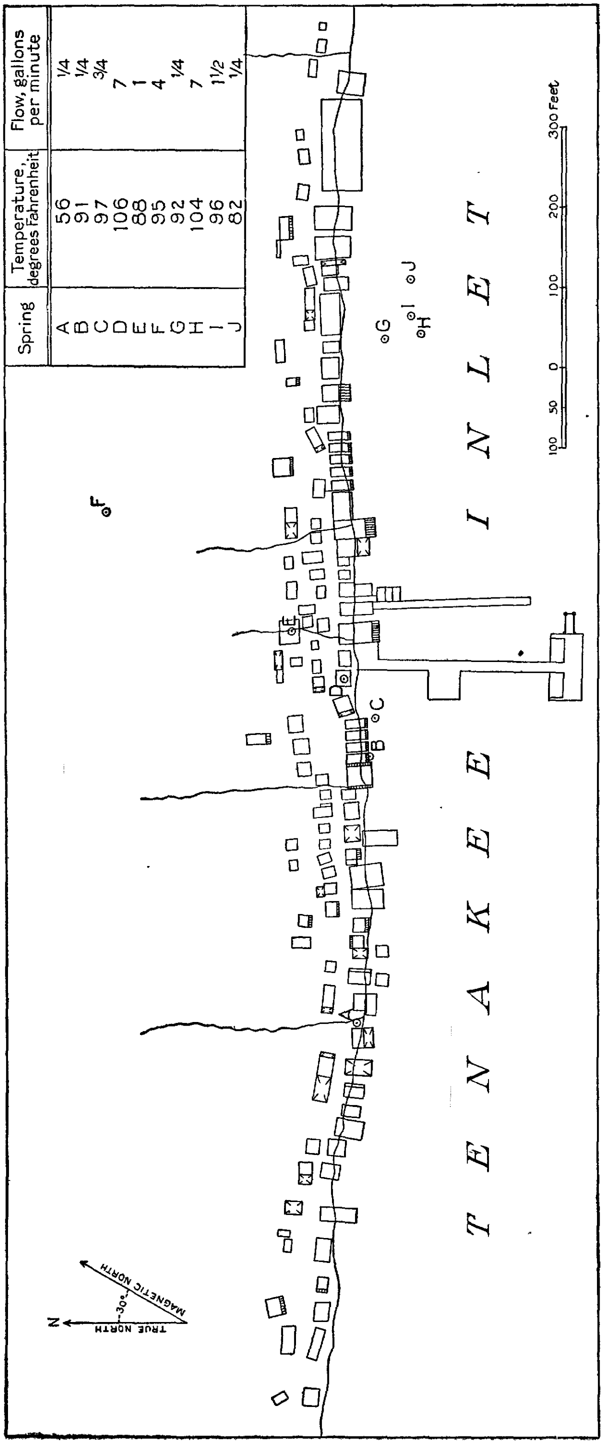
[1] Knopf, Adolph, op. cit., pl. 1.

[2] Pacific Coast Pilot, Alaska, pt. 1, p. 163, Washington, 1891.



Spring	Temperature, degrees Fahrenheit	Flow, gallons per minute
A	56	1/4
B	91	1/4
C	97	3/4
D	106	7
E	88	1
F	95	4
G	92	1/4
H	104	7
I	96	1½
J	82	1/4

FIGURE 4.—Sketch map of Tenakee Hot Springs and vicinity, Chichagof Island, southeastern Alaska.

The springs are on the north shore of Tenakee Inlet, approximately halfway by steamer route between Juneau and Sitka—about 100 miles from either place by the rather tortuous course necessitated by the several islands. The weekly steamer between Juneau and Sitka stops there regularly, going and returning.

In 1915 the Forest Service improved the property, which is within the Tongass National Forest, constructing a plank walk and moving the various cabins into alignment along it. These cabins have been erected by individuals, who pay a nominal lease to the Forest Service for the land and rent the cabins to visitors. The several springs and the improvements in 1915 are shown on the sketch map (fig. 4), prepared from a survey of the property by the Forest Service.

The principal spring (D, fig. 4) issues a few feet above high-tide level in a cemented bathing pool in a long building. The water rises through a fissure in the rock bottom of the pool, which continually overflows. This pool has been the only bathing place, certain hours being specified for its use by men and by women, but in 1915 it was the intention to provide better accommodations. The observed discharge was 7 gallons a minute and the temperature was 106° F. The temperature is said to vary with the stage of the tide from about 104° to 109° F., being warmest at high tide.

A noticeable increase both in temperature and discharge may be possible at high tide, owing to greater hydrostatic pressure and consequent shutting off of the escape of warm water through lower fissures in the rock; but the presence or absence of such a phenomenon was not satisfactorily determined by the writer.

Other springs issue in the vicinity of the principal spring. Spring F (fig. 4) was formerly piped down to the bathhouse for drinking, but it has been allowed to become choked with vegetation since a nearer spring, E, has been opened and the water conducted to the board walk as a drinking supply. Its warm temperature and distinctly sulphureted taste render it unpalatable to many persons, however. A cool sulphur spring, A, which has been surrounded by a cylindrical concrete wall 6 feet high and thus forced to overflow above the reach of the tide, is to some people a less unpleasant drinking water, though it tastes more strongly of hydrogen sulphide. Spring H issues only a short distance above low-tide limit and hence is covered by salt water most of the time. Its flow and temperature are, however, nearly the same as those of the principal spring. In 1915 a wooden spout a foot high had been securely placed over the vent, which gave off considerable gas as well as water. This gas repeatedly extinguished a flame and was probably carbon dioxide. Smaller springs, G, I, and J, in the vicinity, also actively bubbled, presumably with the same gas. Several other minor springs are said to be exposed at extreme low tide.

Analyses of water from the principal spring and from the cool sulphur spring are tabulated on page 40. The two waters are of the sodium sulphate type and the proportions of the several substances are nearly the same in each, though the cool water is only about one-half as concentrated as the hot water. The presence of borax in each water is worthy of note, especially as no source of borate is evident in the vicinity.

The rock formation in the vicinity of the springs appears to consist of dark gneiss, intruded by light-gray granite, both of which are phases of an intrusive crystalline area in Paleozoic sediments. Small amounts of schist are also present near the springs, apparently in the contact zone between the old sediments and the crystalline rocks.[1] The principal spring rises from a fissure in the gneiss. The other springs possibly also rise along fissures, either in the gneiss or in the granite, but the bedrock surface near them is covered by a layer of gravel, cemented by the deposition of lime from the spring water.

As was pointed out to the writer by Ed. Snyder, merchant and postmaster at Tenakee, springs C, D, E, and F lie nearly in a line that trends northeastward, and possibly they issue along the same fissure. The crevice in the bathing pool at D also trends northeastward.

The abnormal temperatures of the springs may be due to local crushing, caused by the intrusion of lighter-colored granitic material into the more gneissic rock, or it may, perhaps, be due merely to the rise of the water from a considerable depth along the zone of fracturing, though not necessarily of appreciable faulting, at the contact of the crystalline and sedimentary rocks.

HOT SPRINGS NEAR HEAD OF TENAKEE INLET.

About 4 miles above the mouth of a large creek that enters the head of Tenakee Inlet (84), scalding water issues at several points at the right-hand edge of the stream canyon. The hottest water rises with a temperature of 179° F. in a shallow algae-lined pool about 50 feet long and 3 to 8 feet wide, on the border of a gravel flat at the base of a steep forested slope. When visited in July, 1915, the discharge from this pool, together with that from an adjacent minor pool, was only about 4 gallons a minute, and it sank into the gravel after flowing only a few yards northeastward parallel with the base of the canyon side. Near the edge of the creek, however, 75 yards distant along a well-defined channel from the main pool, hot water of a considerably lower temperature issued at several

[1] Knopf, Adolph, op. cit., pl. 1.

small vents. Minor warm pools without surface discharge were also noted along the high-water margin of the gravelly stream channel. The positions of the several springs and pools with respect to each other and the canyon sides are shown in figure 5.

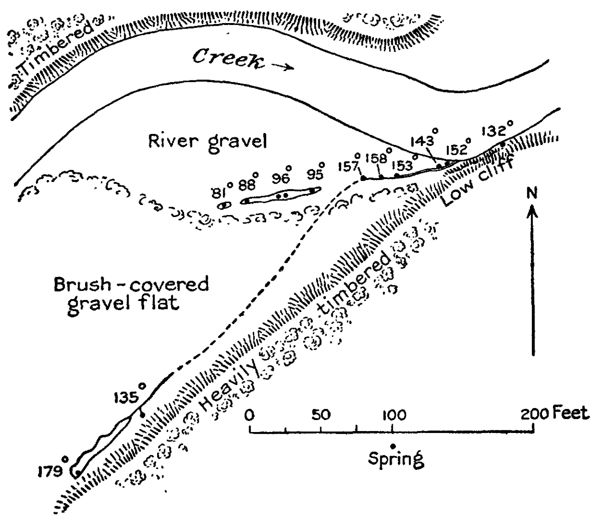


FIGURE 5.—Sketch map of hot springs and vicinity, near head of Tenakee Inlet, Chichagof Island, southeastern Alaska.

Although the positions of the minor hot springs suggest that their water may come from the principal spring, the three northernmost springs issue directly from seams in a low cliff at the creek edge. The conditions indicated that all six northern springs issue from a small fissure that extends about S. 70° W. The water of these cooler springs is without noticeable odor and taste, but that of the hottest pool, which is apparently supplied from another fissure, is distinctly sulphureted and also tastes noticeably mineralized. A thin white coating that probably consists chiefly of lime carbonate is deposited on pebbles in its overflow channel. An analysis of the water of the hottest spring, given in the following table (analysis 5), shows that it is a sodium sulphate water of fairly high mineral content, similar to the water of Tenakee Hot Springs. Like the water of other hot springs of Alaska it has an abnormally high content of silica.

Mineral analyses of waters from hot springs in southeastern Alaska.

[Parts per million except as otherwise designated.]

Constituents.	1	2	3	4	5
Silica (SiO_2)	40	96	94	57	119
Iron (Fe)	1.4	3.1	1.0	.5	2.1
Aluminum (Al)	5.3	....	2.4	Trace.	4.6
Calcium (Ca)	37	8.5	35	11	21
Magnesium (Mg)	11	Trace.	2.8	.6	2.3
Sodium (Na)	206	59	201	111	137
Potassium (K)	3.8		4.0	2.8	4.1
Carbonate radicle (CO_3)	.0	25	24	28	7.2
Bicarbonate radicle (HCO_3)	35	18	26	2.4	48
Sulphate radicle (SO_4)	329	35	302	166	226
Chloride radicle (Cl)	133	42	99	31	33
Nitrate radicle (NO_3)	1.0	.3	.0	1.0	.0
Borate radicle (B_4O_7)	Present.	....	Present.	Present.	Present.
Total dissolved solids at 180° C.	786	276	787	431	592
Temperature (°F.)	101	111	106	56	179
Chemical character	Na-SO_4	Na-Cl	Na-SO_4	Na-SO_4	Na-SO_4

1. Hot springs on North Arm of Peril Strait; northernmost spring of main group. Has no noticeable taste or odor. Sample collected June 29, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
2. Hooniah Warm Springs; principal spring. Has faint taste and odor of hydrogen sulphide. Sample collected June 28, 1915, by G. A. Waring; analyzed by R. B. Dole and Alfred A. Chambers.
3. Tenakee Hot Springs; principal spring. Sample collected June 23, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
4. Cool mineral spring at Tenakee Hot Springs. Has distinct odor and taste of hydrogen sulphide. Sample collected June 23, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
5. Hot springs near head of Tenakee Inlet; spring at pool. Has noticeable odor and taste of hydrogen sulphide, and deposits small amounts of calcium carbonate. Sample collected July 1, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.

The rock exposed in low cliffs on each side of the creek, near the springs, is dioritic, much altered on the surface, and is traversed by white veinlets of material that has been examined chemically by W. T. Schaller, of the United States Geological Survey, and found to consist chiefly of a zeolite whose optical properties indicate that it is probably heulandite. This mineral may have been derived from the decomposition of plagioclase feldspars in the dioritic rock. The rock appears to form a ledge trending N. 60° E. through the more prevalent granitic material. Its presence in the larger area of granite suggests that its intrusion is the main cause for the issuance of the hot water. The relation of the springs to the two varieties of rock is not clearly evident, however, and the geologic structure to which the issuance of hot water is due may be the larger one of a contact zone between the intrusive crystalline rocks and Paleozoic sediments.[1] Along the creek channel, near the springs, there are fragments of white crystalline limestone, which become more common and more angular toward the head of the creek, indicating that the limestone (a member of the Paleozoic sedimentary series) crops out not far upstream.

At the time of the writer's visit no trail had been cut to the springs through the dense forest and undergrowth, and their loca-

[1] Knopf, Adolph, op. cit., pl. 1.

tion was known to only a few whites and Indians. It would, however, be comparatively easy to clear a road to them along the creek from the head of the inlet and to pipe the water a few hundred yards downstream to a suitable place for a bathhouse and other buildings.

OTHER HOT SPRINGS NEAR TENAKEE INLET.

Several hot springs in addition to those at Tenakee and near the head of Tenakee Inlet were reported to the writer, but no attempt to visit them was made, as a guide could not be found and search for such small springs in the dense undergrowth was not practicable.

Hot springs (85) near Nika Bay, a small bay on the west side of Port Frederick, southwest of the village of Hooniah, and hot springs (82) on a creek near the head of Mud Bay, northwest of the same village, were reported by George Peterson, of the Forest Service.

Hot springs (83) on the north shore of Lisianski Inlet, west of Hooniah, were reported by W. G. Weigle, of the Forest Service, but only their approximate location was learned.

Tom Starr, of Tenakee, the native guide who conducted the writer to the hot springs near the head of Tenakee Inlet, reported a warm spring (81) near Lituya Bay, on the coast of the mainland, about 80 miles northwest of Hooniah, but he had not personally visited this spring.

A "hot spring near Hooniah" reported to the Geological Survey may be one of the thermal springs already mentioned, but there are possibly several other springs of warm or hot water in the region. The northern part of Chichagof Island consists of a series of Paleozoic sediments, intruded by later crystalline rocks,[1] all more or less fractured; so that conditions favoring the presence of thermal springs probably exist at a number of places. The springs that are now known are all near tidewater, where they have been easily discovered. As the interior of the island is penetrated more and more other springs, now hidden in the dense undergrowth, will probably become known.

HOT SPRING ON TWELVEMILE CREEK.

A hot spring on Twelvemile Creek (51, Pl. I) near the head of Kiagna River, a tributary of upper Chitina River, was reported to F. H. Moffit, of the United States Geological Survey, by James Barkley, who has prospected extensively in the region. In 1906 or 1907 Mr. Barkley found a small stream of heated water beside the creek, but on revisiting the place about 1913 could find only a small

[1] Knopf, Adolph, op. cit., pl. 1.

area of warm mud at its site. During the intervening years the spring had apparently been either partly buried by slide material or had been destroyed by other changes in surface or underground conditions. The spring is in a region of altered sediments that are believed to be chiefly of Paleozoic age.[1]

SOUTHWESTERN ALASKA.

DISTRIBUTION.

Hot water doubtless issues in many localities on the Alaska Peninsula and its extension in the Aleutian Islands, especially in the vicinity of the numerous volcanoes, active or quiescent.

Russell[2] says of the region:

> The conspicuous and in fact the only well-characterized volcanic belt in Alaska begins in the east, at the head of Cooks Inlet, and extends westward throughout the Alaska Peninsula and Aleutian Islands. This belt of igneous activity is nearly 1,600 miles long, with a width in general of less than 40 miles. It is so narrow and well defined that two parallel lines drawn on a map of Alaska, 25 miles apart, may be made to include nearly every volcano in the belt that is known to have been active in historic times. This may, for convenience, be termed the Aleutian volcanic belt.
>
> The numerous volcanic vents that mark the course of this long narrow belt, the many earthquakes that have been felt at intervals since the discovery of Alaska in its vicinity, and many changes of level recorded by terraces, as well as by the observations of white men, all indicate that a fracture or perhaps a series of intersecting breaks in the earth's crust there exists, along which marked changes have taken place in recent times and are probably still in progress. The sea to the south of the Aleutian Islands is deep. The deepest soundings obtained previous to 1896 were in that region in what is known as the Tuscarora deep. North of the Aleutian Islands lies Bering Sea, for the most part shallow, which corresponds with the submerged continental border along the Atlantic coast of North America. The conditions are such as to favor the view that the Aleutian volcanic belt is not only a belt of fracture, but that differential movements of the rocks of a pronounced character on the two sides of the belt have occurred—that is, it is a belt of faulting.

The statement of Grewingk[3] that there is definite information of volcanic activity on 25 of the Aleutian Islands, on which 48 craters have been enumerated, with at least 4 more on the Alaska Peninsula and 2 on the shore of Cook Inlet, has been quoted by Russell[4] and others. Later observers have found a few volcanoes that were not known to Grewingk, and several of the localities indicated by him have been found to be of lavas but not volcanic within historic times.

[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pl. 21, 1906.

[2] Russell, I. C., Volcanoes of North America, pp. 268–269, New York, 1897.

[3] Grewingk, C., Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der nordwest-Küste Amerikas mit den anliegenden Inseln: Russ. k. mineral. Gesell. Verh., 1848–49, p. 195, 1850.

[4] Op. cit., p. 270.

Mount Calder, at the north end of Prince of Wales Island, mentioned by him as being a volcano, is composed of limestone. There are, however, at present 33 volcanoes of actual or relatively recent activity recognized in Alaska, all being in its southern portion. These volcanoes have been indicated on Plate I (p. 12), by G. C. Martin, of the United States Geological Survey.

During recent years the most notable eruption has been that of Mount Katmai, June 6 to 8, 1912.[1]

Grewingk[2] specifically mentions hot springs in the following places, concerning only a few of which additional information is at hand: Hot springs (92) on Baranof Island (Sitka Hot Springs, see p. 28); hot springs (75) near Balboa (Portage or Parenosa) Bay; hot springs (74) on a little island at the entrance of Morzhovoi Bay, probably Amagat Island; hot springs (73), called by the Russians "Goratschuch Kljutschei," on the inlet of the same name;[3] hot springs (76) at Port Moller (see p. 45); hot springs (72) and hot marshes near Pogromni Volcano, on Unimak Island; hot springs (70) on a little island on the northwest side of Akun Island; hot springs (69) near the crater on Agutan Island; hot springs (68) near Makushin Volcano, on Unalaska Island;[4] hot springs on Umnak Island, both at the base of Vsevidof Volcano (64) and northeast from it (65);[5] hot springs (67) on Bogoslof Island (see p. 47); hot springs (63) and exhalations of gases on Kagamil Island; hot springs (62) at the base of the volcano on Chuginadak (Tanach-Angunach) Island; hot springs (61) and mud craters on Seguam Island; hot springs (58) and mud craters on Conical Volcano[6] on

[1] For detailed descriptions of this eruption see Dailey, I. M., Report of the eruption of Katmai Volcano: Am. Geog. Soc. Bull., vol. 44, No. 9, pp. 641–644, 1912. Clark, G. A., The Katmai eruption: Seismol. Soc. America Bull., vol. 2, No. 4, pp. 226–229, 1912. Martin, G. C., The recent eruption of Katmai Volcano in Alaska, an account of one of the most tremendous volcanic explosions known in history: Nat. Geog. Mag., vol. 24, No. 2, pp. 131–181, 1913.

[2] Op. cit., pp. 204–208.

[3] These are probably the springs which Petrof (Tenth Census, vol. 8, p. 19, 1884) says are less than half a mile from the village of Protassof or Morshevoi [Morzhovoi]. Of these springs he says: "There is a series of warm sulphur springs and ponds, which would afford the sickly natives partial or permanent relief could they only be induced to bathe therein; but, while there is not one man, woman, or child in the village free from cutaneous disease of some kind, not one of them can be induced to make the exertion necessary to try the efficacy of the waters."

[4] These are possibly the springs which Dall (Alaska and its resources, p. 472, 1870) mentions as being near Port Levashef or Captains Harbor and having a temperature of 94° F., though hot springs may formerly have issued nearer to the crater of Makushin. N. O. Lawton (Makushin sulphur deposits: Min. and Sci. Press, vol. 98, pp. 259–260, 1909) says there are only solfataras, exhaling hydrogen sulphide and sulphurous acid, within the crater of Makushin.

[5] Dall (Alaska and its resources, p. 472, 1870) states that the water in one of these springs rises 2 feet and falls again four times an hour. This water is boiling. It does not issue from a well-defined vent.

[6] Dall (Op. cit., p. 473) says that these craters are funnel-shaped, about 2 feet in diameter at the top, and frequently full of mud in a state of ebullition, and that sulphurous odors and subterranean noises, like the escape of steam, are always noticeable.

Atka Island;[1] hot springs (59) near Kliuchef Volcano on Atka Island; hot springs (56) near White Volcano on Adak Island; hot springs (55) at the base of Kanaga Volcano on Kanaga Island. Grewingk also says (p. 160) that, according to Bragin, 20 versts westward from Amchitka Island there lies Sitignak, a small rocky island with fire-spitting peak and several hot springs.[2] This islet is not shown on more recent maps, however, and the report of its existence may have been erroneous.

Dall[3] mentions the following hot springs in addition to those listed by Grewingk: Hot springs (71) that issue between tide marks on a small island southeast of Akun Island; hot springs (66) near Inanudak Bay or Deep Bay, on Umnak Island, ranging in temperature from boiling to lukewarm, in some of which he says the Aleuts are accustomed to bathe; and hot springs (60) 5 miles from Korovin Bay, Atka Island. He also speaks of hot springs in a verdant valley between Korovin and Kliuchef volcanoes, on the same island, which are possibly the same as those mentioned by Grewingk near Kliuchef Volcano (59).

In addition to springs mentioned by Grewingk and by Dall, Petrof[4] reports that hot springs (57) emerge from the rocks in many places on Great Sitkin Island. He also states that there are hot springs on nearly every island of the Rat Island group, though smoking craters (very probably accompanied by hot springs) exist only on Semisopochnoi (54) and on Little Sitkin (53). He adds that the Little Sitkin crater is probably the westernmost active volcano in the Aleutian chain. Little Sitkin has not more recently been referred to as a volcano, however, and it is probable that its activity, if notable, is solfataric rather than truly volcanic.

Near the head of Stepovak Bay there is said to be an area known as "Kupreanof Volcano," where steam and other vapors rise through many fissures.[5] The true character of this area appears, however, not to be definitely known.

In the fall of 1916 Charles H. McNeil wrote to the United States Geological Survey stating that natives report a large hot spring on West Fork of Douglas River. This stream enters Cook Inlet between Cape Douglas and Kamishak Bay. The spring is probably about 25 miles west of Cape Douglas.

Analysis of water from only one of these springs on the Alaska Peninsula—the group on Akutan Island (69 on Pl. I)—is available.

[1] Petrof (Tenth Census, vol. 8, p. 93, 1884) says that at two or three places on Atka Island "the natives report mud craters throwing up liquid masses varying in color from red to green, blue, and a brilliant yellow."

[2] Dall (Alaska and its resources, p. 473, 1870) also mentions these hot springs.

[3] Idem, pp. 472–473.

[4] Petrof, Ivan, Alaska, its population, industries, and resources: Tenth Census U. S., vol. 8, p. 93, 1884.

[5] Underwood, J. J., Alaska, an empire in the making, p. 330, New York, 1913.

The following analysis of this spring, presented through the courtesy of the Bureau of Chemistry, shows that the water is of the sodium chloride type, rather high in concentration and content of silica and bicarbonate.

Mineral analysis of water from springs on Akutan Island, southwestern Alaska.[1]

[Parts per million except as otherwise designated.]

Silica (SiO_2)	84	Sulphate radicle (SO_4)	24
Iron (Fe)	.6	Chloride radicle (Cl)	157
Calcium (Ca)	9.1	Nitrate radicle (NO_3)	.4
Magnesium (Mg)	1.6	Lithium[2]	.25
Sodium (Na)	136		
Potassium (K)	12	Total solids[3]	535
Carbonate radicle (CO_3)	.0	Chemical character	Na–Cl
Bicarbonate radicle (HCO_3)	110		

PORT MOLLER HOT SPRINGS.

Port Moller Hot Springs (76 on Pl. I) were visited in 1908 by H. M. Eakin, of the Geological Survey, who has furnished the following notes concerning them.

The springs issue on the southwest side of the bay, near the shore and only a few feet above high-tide level, in one principal and several minor pools. The water is scalding, being probably at a temperature between 150° and 180° F. It has a "slick" alkaline taste but no noticeable odor, though there is much bubbling of carbon dioxide or other odorless gas. No algal growths are formed in the pools or run-off channels, and the water can be plainly seen rising from the gravelly or muck-covered bottoms of the pools. The absence of algal growths is an additional indication that the gas is carbon dioxide and not hydrogen sulphide. No mineral deposits were noticed, however, a fact that indicates the absence of notable amounts of carbonates in solution.

The hot water issues at the northern base of hills of recent volcanic rock, practically at the contact of this material with limestone that underlies it and forms the lowland thence to the beach.[4] The issuance of the hot water is probably connected with the recent lava, though it may issue along a minor fault. A number of such breaks have been observed in a small coal field a few miles to the southwest. Knowledge of the materials in solution might furnish suggestive evidence as to whether the water rises through the limestone or is confined to the volcanic rocks in its underground course, but so far

[1] Sample received by Bureau of Chemistry, U. S. Department of Agriculture, Aug. 13, 1914. Analyzed by W. F. Baughman.
[2] Spectroscopic determination.
[3] By summation, with bicarbonate computed as carbonate.
[4] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pl. 8, 1911.

as is known to the writer, no analysis of the hot-spring water has been made.

There seems to have been a large native village near the springs at one time, for ruins of huts still remain, half buried by heaps of clam shells 6 to 8 feet thick. A wide tidal flat near the springs furnishes an abundant supply of these shellfish, and they probably afforded an easy means of livelihood until the settlement was perhaps attacked by disease or by more aggressive natives and was abandoned. When visited by Mr. Eakin the place was the site of a temporary camp of Eskimo hunters.

It is doubtful whether the bay has ever been much visited for the sake of the hot springs, for the Alaskan natives, especially those of the northern part of the country, seem to have made little use of hot springs until they were shown their possibilities for bathing by the whites.

HOT SPRINGS NEAR PORT HEIDEN.

Hot springs (77 on Pl. I) have been reported near the shore on or near the bay of Port Heiden, but no definite statement of their temperature or other characteristics is at hand. The settlements along the peninsula are chiefly native villages, seldom visited by steamer or launch, and little information of any kind concerning the neighborhood of Port Heiden is at hand.

The lower lands in the vicinity of Port Heiden are covered largely with Quaternary gravels and sands that overlie rocks, reported to be coal bearing, which may be of Cretaceous age.[1] The hot water possibly issues in the lower (Quaternary) lands from the underlying older deposits.

HOT SPRINGS ON SHORE OF BECHAROF LAKE.

On the southwest shore of Becharof Lake, near the base of Mount Peulik (Smoking Mountain), hot springs (78) have been reported to members of the Geological Survey, but no description of them is at hand. The issuance of hot water here is possibly connected directly with volcanic activity in the region, for, as is indicated by its name, Mount Peulik is a volcano in which activity has not entirely ceased. The rock formation near the springs, however, consists of sandstone, probably of Jurassic age, through which the lava of Mount Peulik has been erupted.[2]

[1] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pl. 6, 1911.

[2] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pl. 6, 1905. Also, Atwood, W. W., op. cit., pl. 6.

HOT SPRINGS NEAR KATMAI PASS.

The following brief description of hot springs near Katmai Pass (79) has been published:[1]

The pass lies between two volcanoes, the one on the right having a cone scarcely modified by erosion, while that on the left is somewhat furrowed but carries no glaciers. Below the pass, on the Katmai side, streams of very hot water burst out of the ground in many places and, joining together, form a considerable rapid stream. This water contains much sulphureted hydrogen and makes copious precipitates of iron and sulphur, so that the earth through which it oozes is colored a brilliant yellowish red.

It is reported that during the eruption of Mount Katmai, in June, 1912, a crater was opened near these springs, and they were buried by volcanic material. It is probable, however, that hot water still issues at some point in the vicinity.

HOT SPRINGS ON BOGOSLOF ISLAND.

A. G. Cameron, who spent several months among the Aleutian Islands with the Fisheries Commission about 1914, told the writer that at that time hot water issued at several places (67 on Pl. I) on Bogoslof Island, a volcanic rock mass in the Aleutian group, 30 miles north of Umnak Island. No large vents were noted by Mr. Cameron, the water appearing to issue from numerous crevices in the rock around the lower part of the island.

Bogoslof Island is very interesting to the geologist. Its history up to 1899 is described in detail, so far as the available records give it, by Merriam,[2] who characterizes it as having been in recent years the seat of more violent volcanic activity and as having undergone greater changes in form than any other part of North America. According to the accounts and reports that Merriam has brought together the first land recorded was a great rock, seen in 1768 or 1769, which later became known as Ship Rock or Sail Rock. Early in May, 1796, amid earthquake shocks and the ejection of volcanic material (both noted by natives on Umnak Island) Old Bogoslof Island, about a quarter of a mile in diameter, arose near Ship Rock. The forces that produced the island also ejected great quantities of steam and sulphurous vapor, but volcanic action gradually subsided until in 1820 vapor issued only from the highest peak. A waterfall then issued from a fissure near the base of the island—a "bow-shaped spring," presumably of hot water, though its temperature appears not to have been observed. By 1832 the notable issuance of vapor seems to have ceased. The island then appears to

[1] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 146, 1907.

[2] Merriam, C. H., Bogoslof, our newest volcano: Alaska, vol. 2, pp. 291–336, Harriman Alaska Expedition, New York, 1902.

have undergone rapid disintegration, until in 1873, when the next definite observations were made, it had been reduced considerably in height and shortened to about three-quarters of its original length.

In 1883, probably rather late in the year, New Bogoslof Island arose about two-thirds of a mile northwest of the older islet, though its advent was not accompanied by disturbances that were noticed on Umnak or the other neighboring inhabited islands. In May, 1884, members of the Revenue Service landed at the islet group and made some observations. According to measurements made by them New Bogoslof Island was about 500 feet high (100 feet higher than the older islet) and about twice as long, its greatest diameter at the base being about half a mile. A large fissure and many smaller crevices in New Bogoslof gave off great quantities of steam and sulphurous vapors. The sea water near the base of the island bubbled as if boiling, but the thermometer showed little difference between the surface and bottom temperatures. The water in the anchorage southwest of the island was also bubbling up vigorously, probably because of the escape of carbonic acid gas, which is a common accompaniment of volcanic disturbances.

During the next few years New Bogoslof Island rapidly disintegrated, until in 1891 it had decreased notably in height and Ship Rock, which had been a prominent crag beside it, had fallen. Old Bogoslof was cold, but on New Bogoslof great quantities of steam and other vapors still issued from thousands of crevices, around which needle-like crystals of sulphur were deposited. Most of the rock of this islet was hot, and pools of hot water were found along the beach. Four years later the activity of the vapor vents had greatly diminished, though they still steamed vigorously, and the islet had become flat-topped.

In 1896 there was no longer evidence of volcanic activity on New Bogoslof, but warm water is reported to have issued from crevices in its sides.

The Harriman Expedition (1899) did not land on the islands, but photographs that were taken by members of the expedition indicate that the steaming had almost if not entirely subsided.

In 1906, about the time of the San Francisco earthquake, there was renewed activity at Bogoslof, though this activity is believed to have been only coincident with and not related to the earthquake. Two new peaks, McCulloch and Metcalf, were uplifted between the older islets, but on September 1, 1907, McCulloch Peak was destroyed by an explosion, ashes from it falling at Unalaska, 60 miles away. In 1908 the position of this peak was marked by a lagoon and the remaining rock masses were united into a single island by strips of gravel. Old and New Bogoslof had long been cold, but Metcalf

Peak was hot, and steam and sulphur vapors issued from many crevices in its sides.[1]

During March and April, 1909, the island showed renewed activity, observers at sea having noted great clouds of vapor.[2]

On September 19, 1910, a new islet was shoved up from beneath the ocean. Several weeks later this islet was visited by officers of the Revenue Service, who found that it was an area of hot volcanic ash and baked mud, from which spouted up a column of scalding water.[3] Definite records of this or later periods of activity have not been found by the writer. During 1914, at the time of Mr. Cameron's trip in the region, the island appears to have been quiescent, and the hot water reported by him is probably a phase of the less active stages of the volcanic mass.

The rock of the several peaks is practically all volcanic, consisting of hornblende andesite, basalt, basaltic agglomerate, and pumice. Some of the rock contains much disseminated pyrite,[4] which is probably the source of at least a part of the sulphur and the sulphurous gases.

WARM SPRINGS ON ATTU ISLAND.

Attu Island (51), the westernmost of the Aleutian chain, is about 20 by 40 miles in extreme width and length. Upon it there are several small lakes, which Mr. Cameron reports to be warm enough in summer for comfortable bathing. Although he did not observe direct evidence of warm springs it seems probable that thermal water does issue, for there is said to be a small, mildly active volcano, or more probably an area of solfataras, on the island.[5]

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[1] The following articles relate to the condition of Bogoslof Island about this time:

Jordan, D. S., and Clark, G. A., The Bogoslofs: Pop. Sci. Monthly, vol. 69, pp. 481–489, 1906.

Eakle, A. S., Recent volcanic eruptions in Bering Sea: Min. and Sci. Press, vol. 96, p. 353, 1908.

Smith, P. S., Notes on recent changes in the Bogoslof Islands: Science, vol. 27, p. 695, 1908.

Jaggar, T. A., jr., The evolution of Bogoslof Islands in Bering Sea: Science, vol. 28, p. 575, 1908.

Jaggar, T. A., jr., The evolution of Bogoslof Volcano: Am. Geog. Soc. Bull., vol. 40, pp. 385–400, 1908.

[2] Greeley, A. W., Handbook of Alaska, p. 171, New York, 1909.

[3] Underwood, J. J., Alaska, an empire in the making, pp. 334–335, New York, 1913.

[4] Jaggar, T. A., jr., The evolution of Bogoslof Islands in Bering Sea: Science, vol. 28, p. 575, 1908.

[5] Underwood, J. J., op. cit., p. 340.

YUKON BASIN.

DISTRIBUTION.

Hot springs are known at a number of places in Yukon basin. The principal springs occur in three fairly well defined areas, comprising, respectively, the region between Circle and Fairbanks, the Hot Springs-Eureka district, and the Tanana-Ruby region. Several scattered springs lie outside of these principal groups, however, to the north in the slopes of the Endicott Range, to the south toward Mount McKinley, and in the region of lower Yukon and Kuskokwim rivers.

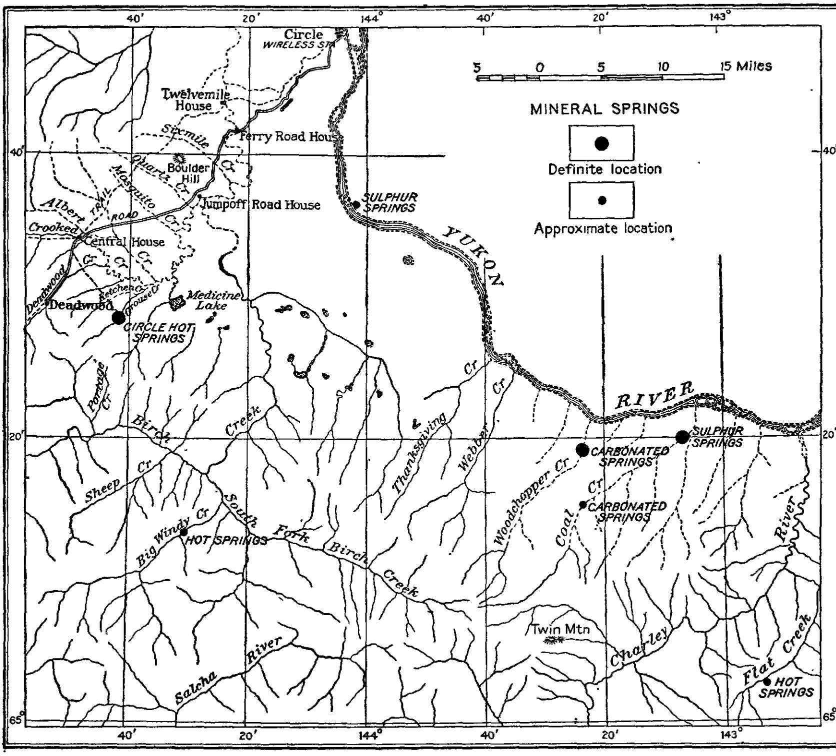
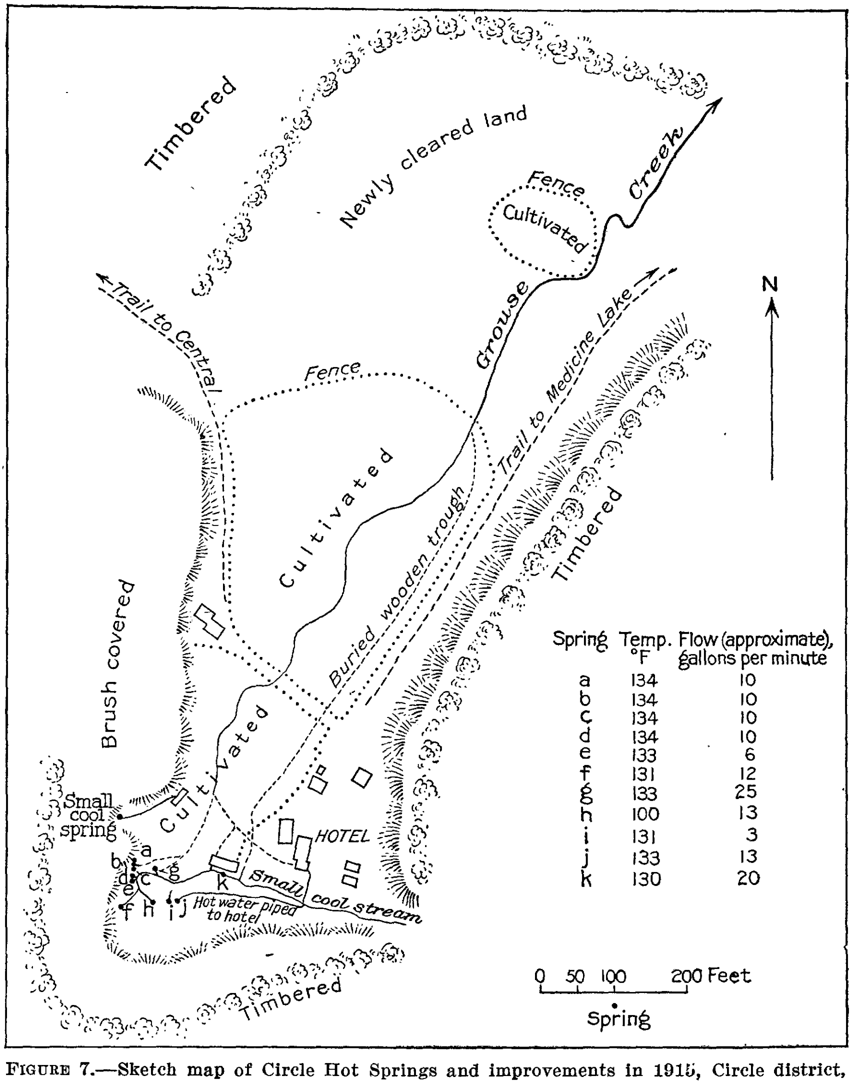


FIGURE 6.—Map showing location of mineral springs, Circle district, Alaska.

The springs do not seem to be related to great structural features, but most of them appear to be associated with intrusive rocks. The geologic conditions in the vicinity of each spring, in so far as they were observed or have been reported, will be mentioned in the description of each locality.

CIRCLE HOT SPRINGS.

Circle Hot Springs (30) have been developed and used for a number of years both as a bathing resort and for vegetable growing. (See fig. 6.) They are southwest of the town of Circle, at the base



Spring	Temp. °F	Flow (approximate), gallons per minute
a	134	10
b	134	10
c	134	10
d	134	10
e	133	6
f	131	12
g	133	25
h	100	13
i	131	3
j	133	13
k	130	20

FIGURE 7.—Sketch map of Circle Hot Springs and improvements in 1915, Circle district, Alaska.

of mountains that form the southern border of the wide flat valley of Yukon River. In 1915 they were best reached by wagon road to Central House, 34 miles from Circle, and thence southward by trail 8½ miles. In summer the roads are soft, owing to the thawing of the marshy lowland, but at the time of the writer's visit an attempt was being made to establish a light automobile service over the road between Circle and the Miller House, 15 miles west of Central. In winter the springs are easily accessible by sleigh or by dog sled.

In 1909 the land, including the springs, was homesteaded by F. M. Leach, who has expended much labor in clearing and leveling ground near the springs and in developing the hot-spring water for the irrigation of vegetables, especially of potatoes. The springs have also been developed to some extent as a bathing resort; but as they must depend on Circle and a few small mining camps for patronage they have no great value for this purpose.

The position of the several springs and the improvements in 1915 are shown in Plate IV, *C*, and in the sketch map (fig. 7). About a dozen individual hot springs have been developed, their observed temperatures and flows being listed in the figure. The nearly uniform temperature of the principal springs is notable, for most groups of hot springs show considerable differences in the temperatures of individual vents. Seepage water issues from the slopes above the higher springs, so a somewhat greater flow of hot water can probably be developed. Warm seepage water from the ground below the greenhouse also enters the run-off creek, whose total flow at the lower end of the cultivated land was about 340 gallons a minute, or 38 miner's inches. The water is conducted through the garden in flumes placed underground to keep the soil warmed, and is piped to the hotel building for domestic uses. It was the intention of Mr. Leach to use the hot water for heating chicken houses and thus simplify the problem of keeping poultry through the winter.

The bathing facilities of 1915 consisted of a log bathhouse, containing a dressing room and a pool in an adjoining room. This pool and a similar one at the end of the building (for the use of the natives) have been excavated in the decomposed bedrock. In them the water registered 110° F., a comfortable bathing temperature. The vapors constantly rising from the pools cause the logs to decay rapidly every three or four years and compel the renewal of the bark roof.

A considerable part of the garden land near the springs has been prepared by terracing the steep hillside, and the cultivable area of permanently thawed ground has thus been increased. The action of the hot water in keeping the ground thawed and warmed is claimed to lengthen the growing season by several weeks. Care is necessary to keep the land well drained, however, as the water is noticeably mineralized and is apt to deposit salts harmful to vegetation. At the springs themselves small amounts of native sulphur are deposited on the green algal growths that are present. The characteristic rotten-egg odor of hydrogen-sulphide gas was not noted by the writer, but considerable gas, which is probably carbon dioxide, as it extinguishes a flame, is given off at the principal vents. In a few places thin coatings of lime carbonate are formed on the pebbles along the run-off streams, and a small amount of a yellow acid alum was noted at one spot.

The analysis (tabulated on p. 62) of water from the northernmost hot spring of the group (spring a, fig. 7) shows that it is rather highly mineralized, of the sodium chloride type, though carbonate and sulphate are also present in relatively large amounts.

The slopes in the immediate vicinity of the springs are of disintegrated granite consisting principally of quartz, feldspar, and black mica. No float pieces of other kinds of rock were found along the course of the stream, but the mountains on the west and south are known from previous geologic studies to be composed of schist,[1] and schist is also exposed in a wagon-road cut 13 miles east of Central. The granite found in the schist area is believed to occur in intrusive masses. In the absence of other observed evidence as to the cause of the hot springs it may be assumed with a fair degree of probability that they are directly related to the intrusion of the granite, an action that probably opened fissures along which heated water may rise from a considerable depth to the surface. A possible source of the chemicals in the water is not so easily found. The granite does not appear to contain minerals that would furnish the chloride, sulphate, and carbonate, which are the principal constituents, but these and other constituents may be derived from the schist of the region.

HOT SPRINGS ON BIG WINDY CREEK.

A group of hot springs (31 on Pl. I) on Big Windy Creek, about 18 miles in a direct line east of south from Circle Hot Springs, was not visited by the writer, but the following notes concerning the springs were kindly furnished by C. H. Rogers, of Eagle Creek.

The springs are on Big Windy Creek about 4½ miles above its junction with South Fork of Birch Creek. They issue in a rather inaccessible steep, narrow canyon, which is in part blocked by great boulders, and the springs are therefore best reached by going up Birch Creek to the mouth of South Fork and thence over the hills southwestward. Well-defined game trails are found, which lead down to the springs.

[1] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pl. 2, 1913. The granitic rock shown on this map south and southeast of the springs extends northward over them.

One of the two principal springs is on the north bank, about 10 feet above the creek; the other is on the south bank, about 20 feet above the creek. Several smaller springs issue on the north bank and others possibly in the creek itself. The water appears to be not so hot as that of the Circle Hot Springs, though it is said that by digging in the springs hotter water is found. The water gives off considerable gas, having the characteristic odor of hydrogen sulphide, and tastes more strongly mineralized than that of the Circle Hot Springs.

The flow of the several springs is difficult to estimate, but the total flow is not large. It is sufficient, however, to keep open throughout the winter a large pool 10 feet deep, which is visited by moose, bears, and other animals.

The rock of the vicinity consists of massive intrusive granitic material.[1] These springs, therefore, like the Circle Springs, may be due to the intrusion of granite into the schistose country rock.

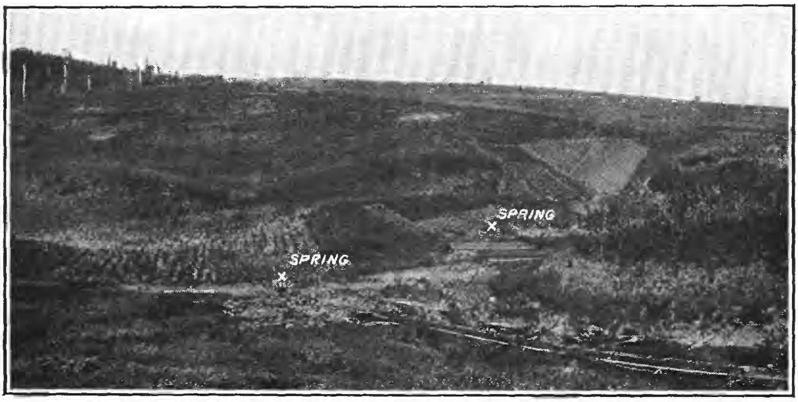
HOT SPRINGS NEAR FLAT CREEK.

C. H. McCartney, who has prospected in the region southeast of Circle, stated to the writer that there are probably springs of hot water (36 on Pl. I) on the slopes above Flat Creek, a tributary of Charley River, for during the winter Flat Creek remains open along part of its upper course, about which considerable vapor rises. No definite vents were observed by Mr. McCartney, however, nor did he note odors of hydrogen sulphide—a common accompaniment of hot springs.

The rock near the springs is probably an ancient schist, which occupies a considerable area near the headwaters of Flat Creek, though other ancient sediments, as well as granitic and other igneous rocks, are found in the neighborhood.[1] The heated water possibly rises along the contact zone between one of the intrusive igneous rock masses and the older sediments.

[1] Prindle, L. M., op. cit., pl. 2.

A. CHENA HOT SPRINGS, FAIRBANKS DISTRICT.



B. BAKER HOT SPRINGS, HOT SPRINGS DISTRICT.

C. LITTLE MELOZITNA HOT SPRINGS, TANANA REGION.

CHENA HOT SPRINGS.

Chena (locally pronounced shenâw) Hot Springs (29), near a tributary of Chena River, have for several years been improved as a resort, with cabins and bathhouse, and during the winter have been the objective of sleighing parties from Fairbanks. (See fig. 8.)

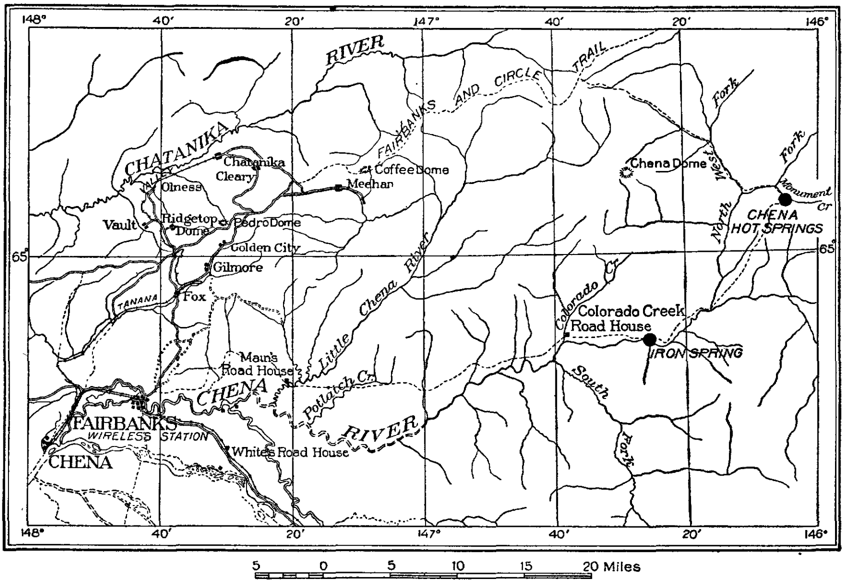


FIGURE 8.—Map showing location of mineral springs in Fairbanks district, Alaska.

The distance up the river valley and canyon is about 62 miles and is easily traversed, when the ground is snow covered, in runs of a few hours each between the two roadhouses on the way. In summer, however, the lowland trail becomes so miry as to be almost impassable, and the trip may be made by saddle horse as quickly and more easily by way of Fairbanks Creek and Olympia Creek, though the Olympia Creek trail is 20 miles longer.

The springs rise in a small flat (see Pl. V, *A*) on the south side of Monument Creek beside a small cold-water stream that empties into the creek half a mile below. The hot water formerly issued mainly in the stream channel, but the stream has been diverted by a ditch so as to make the hot springs more accessible. In the summer of 1915 the principal springs and the improvements were as indicated in figure 9. The log bathhouse contained a dressing room, a sweat room, and a bathroom containing five wooden clear-water tubs and a mud-bath tub. Hot water was supplied by springs b and c (fig. 9), and cold water was also piped in from the stream, for the spring water is too warm (126° F. at the tubs) to be endurable by many people. The vapor constantly rising from the water causes the logs to decay rapidly and necessitates their renewal every three or four years.

Slight differences in the taste and odor of the water from the several springs may be noted but appear to indicate no difference in character, all being sulphureted in varying degrees but not otherwise notably mineralized to the taste.

Analyses of water from two springs of the group (see table on p. 62) indicate that there is very little difference in the character of the water from the different vents. Both are moderately mineral-

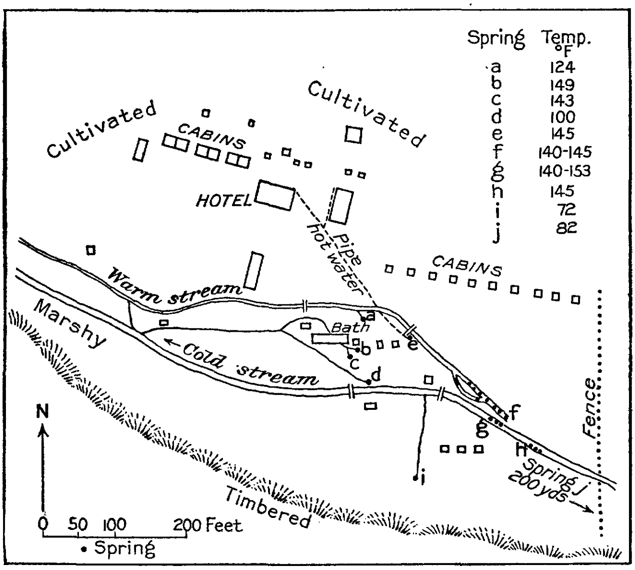


FIGURE 9.—Sketch map of Chena Hot Springs and improvements in 1915, Fairbanks district, Alaska.

ized waters of the sodium carbonate type. They contain very little calcium and magnesium but considerable sulphate and silica.

Some of the vents give off much gas, which a test with a flame indicates to be carbon dioxide. Algal growths, ranging in color from bright green and copper-colored in the hotter water to a dark green in the cooler portions, lined the run-off channels to their junctions with the cold-water stream. Patches of algae also persisted in the cold-water stream, the temperature of which was from 70° to 66° F. down to its junction with Monument Creek, whose water was 55° F. The creek water contained no noticeable algal growths. During the early part of the summer extensive deposits of native sulphur were reported to have been formed near several of the hot springs. A freshet a couple of weeks prior to the writer's visit had removed these, but deposits were again forming at several places. The deposition of sulphur at these springs appears not to be dependent directly on the temperature, as it was noted at spring b (fig. 9) at a temperature of 149° F. and near spring e, where the water registered only 120° F. The sulphur is probably produced by the oxidation of hydrogen sulphide and other sulphides present in the water. The chemical reactions are not simple, however, and the change is not due to simple oxidation and release of the sulphur from combination.

The total flow of the hot springs, as determined by careful float measurements in the run-off channels, is about 220 gallons a minute. A nearly equal amount of warm water may seep into the cold-water stream along its channel and banks, however, for measurements of discharge just above the uppermost springs and a short distance below the junctions of the hot-water channels with the cold-water stream showed an accession of about 500 gallons a minute within this distance. A part of this increase doubtless comes from marshy lands south of the creek, but the greater portion is believed to rise as thermal water.

The springs are locally believed to have formerly issued farther south, at the edge of the valley. A warm seepage still issues 200 yards southeast of the present uppermost spring (h, fig. 9) in the rocks a few feet above the creek flat, and the valley border is peculiarly pitted by depressions a few feet in diameter and depth that are lined with angular stones as if the earth and softer rock had been removed from below and the talus stones had settled down. These pits have possibly been formed by the thawing action of the hot water, which has shifted its points of issuance from time to time.

The rock in the vicinity of the springs is all granitic so far as seen.[1] On the higher slopes to the southeast the granite is replaced by schist, into which the granite appears to be intrusive, as it is believed to be at Circle Hot Springs. Probably Chena Hot Springs, like Circle Hot Springs, are due to the rise of deep-seated thermal water along fissures in the intruded schist.

HOT SPRINGS NEAR TOLOVANA RIVER.

Near the summit of hills on the western side of the valley of Tolovana River (see fig. 10) issue hot springs (27), which are reported to taste slightly alkaline and to have a mildy sulphureted odor. There is considerable bubbling from the several small vents a few yards apart on the hillside, but the gas is probably in the

[1] The intrusive area of granite shown on the east side of West or North Fork of Chena River (see A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pl. 8, 1913) extends farther east than mapped, and includes the locality of the hot springs.

main carbon dioxide, not hydrogen sulphide, or a stronger odor of the latter gas would be evident. It is said that the hand can hardly be held in the water, indicating a temperature of 120° or 130° F.

According to studies of the United States Geological Survey,[1] the springs are in an area of intrusive granitic rock, close to its contact with old slates and other altered materials.

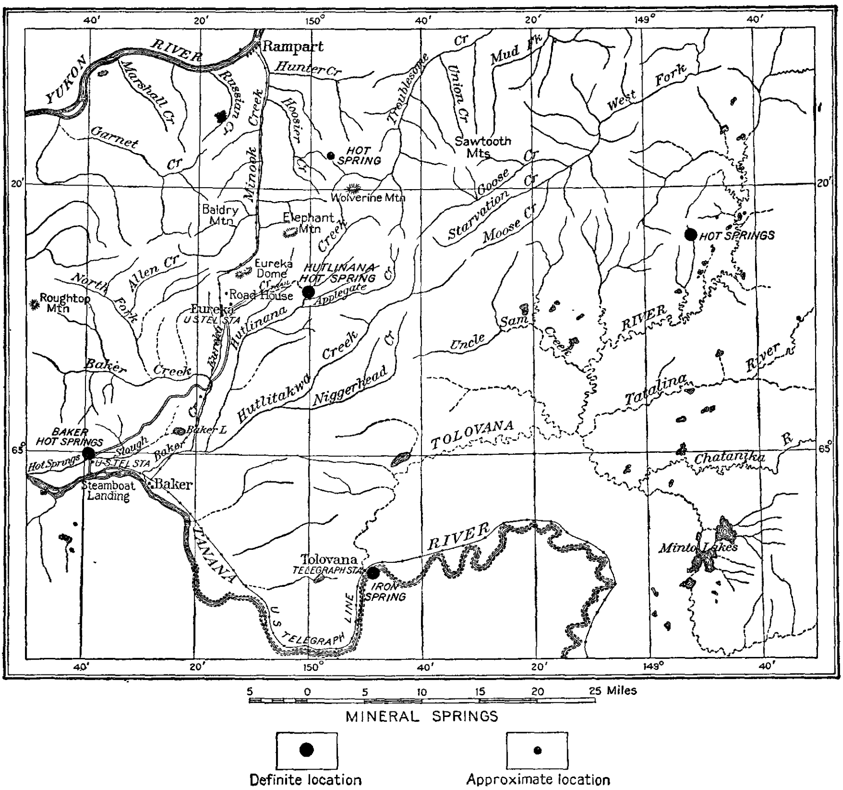


FIGURE 10.—Map showing location of mineral springs in Hot Springs district, Alaska.

Although the springs are only 4 or 5 miles directly west of the head of steamer navigation at a log jam in Tolovana River, they are said to be best reached in summer by a prospectors' trail from a point 30 miles farther upstream along the very crooked river; for the lowland is marshy and dotted with lakes. The springs are not well marked and are not easily found except by following the trail.

An unconfirmed report was received of other hot springs which are said to lie about 20 miles in a direct line northeast of those just described, in the lowland along Tolovana River where it flows for a number of miles in a general westward course. This report may, however, relate to the springs west of the river.

[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pl. 8, 1913.

HOT SPRING NEAR LITTLE MINOOK CREEK.

Frank Conway, a prospector in the Tolovana district, told the writer that while crossing the divide between Little Minook Creek and a tributary of Hess Creek he came upon a spring (25) that was fairly hot and yielded a stream of water several inches wide. Special attention was not paid to it at the time, and its precise location can not be stated, but it is probably one of a number of small thermal springs that will become known and receive local attention when the more inaccessible parts of the region have been better explored.

The spring is in a region where the rocks are mainly ancient conglomerate, sandstone, and other sediments, but in the neighborhood of the divide between Little Minook and Hess creeks there are small areas of intrusive granitic rock.[1] As other hot springs in the region are near the borders of similar areas of intrusive rocks it seems reasonable to suppose that the hot spring near Little Minook Creek also issues in the contact zone near one of the intrusive masses.

HUTLINANA HOT SPRING.

Hutlinana Hot Spring (24) issues at the edge of the creek of the same name, 8½ miles by trail east of Eureka post office, which is 23 miles by wagon road northeast of Hot Springs.

There appears to be only one spring, which issues from a fissure at the base of a cliff that terminates the steep canyon side down to the west edge of the creek. When visited, a bathing place was formed by a pool, rudely square, about 6 feet across and 1 foot deep, excavated in the partly disintegrated rock and covered by a tent. The water is clear, with no noticeable taste and only a faint odor of hydrogen sulphide, though there is a constant bubbling, probably of carbonic acid gas. A temperature of 114° F. was recorded—about as hot as is comfortable for bathing—and the discharge was measured as approximately 50 gallons a minute.

The analysis of the water (analysis 4 in table on p. 62) shows that it is a rather highly concentrated sodium carbonate water containing minor amounts of sulphate and chloride.

At the time of the writer's visit, in August, 1915, a cabin stood 75 yards below the spring on a small alluvial flat, where potatoes and other vegetables were maturing well. Two older, unoccupied cabins stood on the opposite side of the creek.

The spring has been used to some extent by the placer miners of the Eureka Creek district for bathing, but it is almost too far from the placers for this use, especially as the trip involves a descent of 1,000 feet from the divide between the two streams and the return climb up the steep trail.

[1] Prindle, L. M., op. cit.

The rock at the spring is quartzitic and has nearly vertical bedding or shearing planes that strike N. 25° E. It is a phase of the altered sediments, probably mainly of lower Cretaceous age, that cover a considerable area in the region.[1] Faulting has not been noted in the vicinity, but the presence of the spring indicates at least deep fracturing and fissuring that permit the escape of water of abnormally high temperature.

BAKER HOT SPRINGS.

Baker Hot Springs (23 on Pl. I) are near Tanana River, 103 miles by trail or 200 miles by the river below Fairbanks. They have long been known to the whites, as they are only 5 or 6 miles from Baker Creek, an early placer-gold district. In 1902 the place was homesteaded by J. M. Karshner, and for several years the springs were known by his name. In 1906 they were leased by F. G. Manley, who built here a large and well-appointed hotel, constructed cement bathing tanks, and developed the place as a resort, and for a time they were known as the Manley Hot Springs. Mr. Manley also established a dairy and started to raise vegetables and poultry on an extensive scale, using the hot water to heat a greenhouse and the poultry houses. The enterprise was not entirely successful, however, and the improvements were not kept in repair, and in April, 1913, the hotel was destroyed by fire. Since that date the springs have received little attention as a resort, though one cement pool, 10 by 12 feet, 4 feet deep, has been kept in repair. The water reaches this pool at a temperature of 114° F. and forms a much-appreciated bathing place.

Since the property was first occupied by Mr. Karshner the land has been cultivated and the hot water has been successfully used in growing potatoes, cabbages, and other vegetables. In 1910 about 150 tons of potatoes were shipped from the ranch to the Iditarod mining district, 700 or 800 miles downstream. In 1915 about 60 acres of land was under cultivation. About half of this area is kept permanently thawed by warm seepage water that does not issue as springs. The erosion of the slopes in this thawed area, as noted by A. H. Brooks, is like that of the land in a more temperate climate, probably because the ground is permanently thawed, and possibly also in late years because it is cleared and cultivated.

The positions of the springs and the improvements are shown in figure 11, prepared mainly from the Land Office survey of the Karshner homestead. Two principal springs (see Pl. V, *B*), each issuing in a small rock-walled basin, rise 50 yards apart, near a small creek. The observed temperatures were 136° F. for the eastern

[1] Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pl. 4, 1913.

and 125° F. for the western spring, and the respective discharges were approximately 35 and 110 gallons a minute. The water has been used for irrigating a garden on adjacent land, and part of the

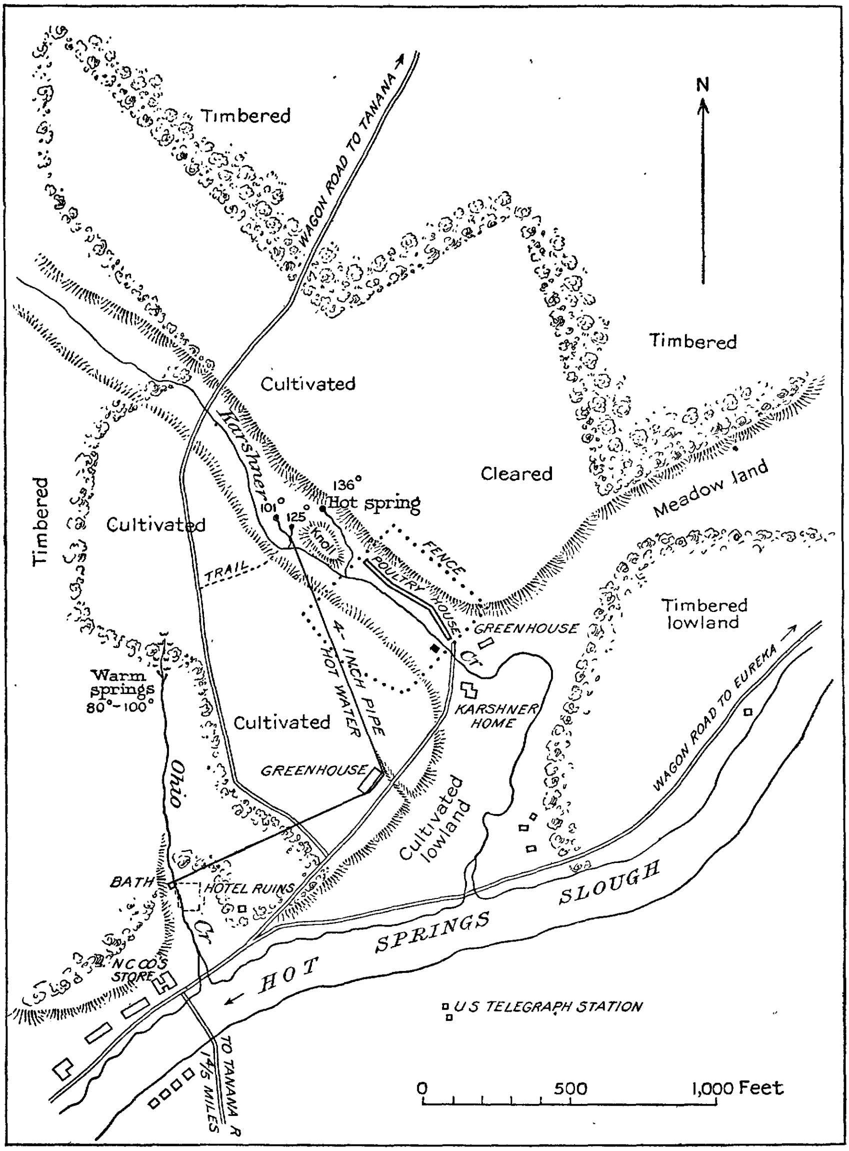


FIGURE 11.—Sketch map of Baker Hot Springs and improvements in 1915, Hot Springs district, Alaska. Based on Land Office survey of Karshner homestead.

flow from the eastern spring was formerly used in heating the poultry houses. Water from the western (larger) spring is piped to a hothouse and to the bathing pool at the hotel site. Warm water also issues in a small spring near the largest one and in a marshy area at the head of a small creek between the main springs and the hotel site.

The water has no noticeable odor or taste. There is a small amount of bubbling, probably of carbon dioxide, and thin coatings of a white brittle substance, probably lime carbonate, are deposited on stones along the run-off channels. The water is said to eat up iron vessels rapidly. The original iron pipe from the springs was so much corroded that it was taken out and replaced by galvanized pipe. This corrosion is probably due to the rather high proportion of chloride in the water, which is shown in the analysis of water from the largest spring (analysis 5 in table below). The analysis shows, however, that the water carries only a moderate amount of mineral matter in solution, other constituents being present in minor amounts relative to sodium and chloride.

Hard rock is not well exposed near the springs, the material being a variety of granitic rock containing quartz, feldspar, and mica, technically classed as monzonite.[1]

The cause for the hot water can not be definitely stated, but presumably the rock is faulted or fractured and deep-seated thermal water reaches the surface along the resultant fissures.

Mineral analyses of waters from hot springs in the Yukon River basin, Alaska.

[Parts per million except as otherwise designated.]

Constituents.	1	2	3 a	4	5
Silica (SiO_2)	82	77	72	44	59
Iron (Fe)	1.3	b 1.2	....	.09	b .80
Aluminum (Al)	3.7		....	....	
Calcium (Ca)	29	2.3	2.9	22	9.1
Magnesium (Mg)	2.1	1.2	.2	6.0	.9
Sodium (Na)	248	c 94	107	208	121
Potassium (K)	8.6		Trace.		8.2
Carbonate radicle (CO_3)	.0	.0	....	.0	.0
Bicarbonate radicle (HCO_3)	173	118	116	494	86
Sulphate radicle (SO_4)	98	78	89	67	48
Chloride radicle (Cl)	252	26	35	38	120
Nitrate radicle (NO_3)	.0	....	Trace.	....	....
Total dissolved solids at 180° C	816	388	d 363	634	417
Temperature (°F.)	134	149	124	114	125
Chemical character	Na-Cl	Na-CO_3	Na-CO_3	Na-CO_3	Na-Cl

a Trace of lithium.
b $Fe_2O_3+Al_2O_3$.
c Calculated.
d By summation with bicarbonate computed as carbonate.

1. Circle Hot Springs; northernmost spring. Gives off carbon dioxide; deposits small amounts of sulphur, calcium carbonate, and alum. Rapidly corrodes iron vessels. Sample collected July 12, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
2. Chena Hot Springs; spring that supplies bathhouse. Sample collected Aug. 5, 1915, by Robert Chamberlain; analyzed by R. B. Dole and Alfred A. Chambers.
3. Chena Hot Springs; probably spring a of figure 9. Sample collected in 1912, by P. J. B. LeBlanc; analyzed by J. B. Reed, Bureau of Chemistry, U. S. Department of Agriculture.
4. Hutlinana Hot Spring. Gives off considerable gas, probably carbon dioxide; has no noticeable odor or taste. Sample collected Aug. 6, 1915, by G. A. Waring; analyzed by R. B. Dole and Alfred A. Chambers.
5. Baker Hot Springs; western of the two principal springs. Has no noticeable odor or taste. Rapidly corrodes iron vessels. Sample collected Aug. 5, 1915, by G. A. Waring; analyzed by R. B. Dole and Alfred A. Chambers.

[1] Eakin, H. M., op. cit., p. 23.

WARM SPRINGS WEST OF GLACIER.

J. D. Courtney, who for several years resided at Glacier, in the upper Kantishna River basin, southwest of Fairbanks, reports that warm springs (40) probably rise 6 or 8 miles west of Glacier. At this place there are many areas of a few acres, sunken 50 feet or more below the general level, which contain dead trees standing in water that remains unfrozen throughout the winter. These areas of open water are resorted to by ducks and other waterfowl during the autumn and by larger game during the winter.

The region has not been examined in detail by a geologist, but the surface materials consist chiefly of Quaternary deposits, and ancient gneiss is exposed in the higher lands to the south.[1] The sunken areas described by Mr. Courtney are probably depressions in the uneven surface of the glacial gravels and clays that cover parts of the region. Distinctly thermal water may issue from springs in some of these depressions, though it is possible that the water is cold but is prevented from freezing by local protection.

WARM SPRINGS NORTH OF GLACIER.

Mr. Courtney, who reported unfrozen ponds in the country west of Glacier, also told the writer that similar open ponds (39) are found about 20 miles to the north, between the site of Diamond camp and Toklat River. In this region the waters of both Toklat River and Moose River sink for stretches of a mile or two and reappear apparently warmed, for the streams remain unfrozen throughout the winter for short distances below these sunken stretches.

Ponds and streams that remain open throughout the year are reported at several other places in Alaska. Thermal waters may cause this phenomenon, or local conditions may be such as to protect the ordinary surface waters from freezing.

The surface in the region of these open waters is largely covered by porous glacial gravels,[1] which may prevent freezing in the same way that very porous gravels in some of the placer workings are kept unfrozen by circulating underground water.[2]

According to Dall [3] many springs along the coast near St. Michaels and some to the northeast, near the village of Ulukuk remain unfrozen all winter. He says that many of those near St. Michaels

[1] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pl. 9, 1911.
[2] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 17, 1914.
[3] Dall, W. H., Alaska and its resources, 1870, pp. 33 and 36, Boston, 1870.

have a temperature of 28° to 30° F. [sic], even when the air is several degrees below zero. He also notes that the water of those near Ulukuk, though not very warm, retained a temperature of 32° to 34° F. in extremely cold weather.

HOT SPRINGS ON RAY RIVER.

According to the statements of several men who have visited them, hot springs issue from gravel at the edge of Ray River, about 35 miles above its mouth (22 on Pl. I). They are reached by a difficult trail that leads through a narrow gorge to a more open canyon above.

In cold weather the position of the springs is indicated by much vapor, but the points of discharge are masked by the river gravel. The water is too warm for bathing, but it is cooled by running it into basins dug in the gravel and adding to it some river water. It has no strong taste but has a noticeable odor of hydrogen sulphide.

The warm water has been used by prospectors in the vicinity for raising lettuce, radishes, and other quick-growing vegetables, and it was reported, though not very credibly, that one prospector had hatched eggs by burying them in the warm, dry gravel close to the springs.

A description of the rock formation of the locality is not at hand, but reconnaissance studies in the region [1] and knowledge of the rocks observed at other hot springs in the interior indicate that the rock at the springs is probably part of a granitic mass that is intrusive in the older volcanic and sedimentary materials composing the country rock.

LITTLE MELOZITNA HOT SPRINGS.

Little Melozitna Hot Springs (Pl. V, *C*) are so known locally because they are on a tributary of Little Melozitna River, though they are about 2½ miles from that stream. The springs (21) are best reached by trail that leads northward from Hub roadhouse, which is on the north bank of Yukon River 30 miles below Tanana. The distance from Hub to the springs is about 27 miles, according to pacing traverse. (See fig. 12.)

The springs are on a small flat on the east side of Hot Springs Creek, a stream about 30 feet wide. Their location is indicated from

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[1] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pl. 8, 1913.
Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pl. 4, 1913.

a distance by a group of trees that are notably taller than those of the surrounding slopes.

The hot water issues chiefly from one spring on the left bank of the creek, in a log-curbed bathing pool that measures 3 by 7 feet and is 2 feet deep. This spring is on the gravelly flat only 5 or 6 yards from the edge of the creek and is about 18 inches above its level when it is at medium stage.

Although they are called hot springs, the recorded temperature of the largest and warmest spring was only $99\frac{1}{2}$° F. Its flow is about 60 gallons a minute. A small seep just north of the main spring registered 90° F., and three other small springs 30 to 55 yards upstream, at the edge of the creek, registered temperatures of 96°, 82°, and 82° F. The water tastes mildly of hydrogen sulphide and the odor of this gas is noticeable for 100 yards or more down the wind from the springs. Gases bubble up actively in the springs, possibly both hydrogen sulphide and carbon dioxide, and the usual green algal growth that accompanies thermal sulphur waters lines the run-off channels. An incomplete analysis of water from the principal spring indicates that it is moderately high in mineral content, containing about 350 parts per million of solids in solution. It is of the sodium carbonate type, though its content of chloride is relatively high. Silica forms nearly a quarter of the total solids. In such a water, which is of rather high temperature and contains considerable sodium, part of the silica may be present as soluble silicate (SiO_3).

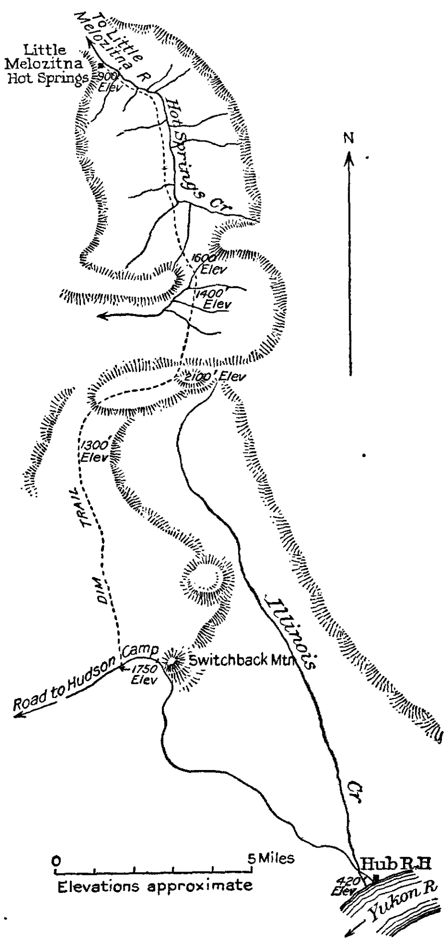


FIGURE 12.—Sketch map showing location of Little Melozitna Hot Springs, Tanana region, Alaska.

A small cabin was built near the principal spring in 1913 by two French trappers, but it has been occupied for only short times, as there has not been much game in the region in recent years.

The rock exposed in the steep slopes at the edge of the valley 50 yards west of the springs and also in a small cliff at the edge of the creek 300 yards to the south (upstream) is granitic. The granitic area, however, seems to be small and to be confined to the slopes southward to Hub roadhouse is mainly quartz schist, with which are associated ancient metamorphic rocks.[1] Along the crest of the ridges forming the limits of the basin of Hot Springs Creek there are prominent crags that probably are also of schist. One bare rocky patch several hundred feet in diameter, on top of a wide tundra-covered ridge on the trail 10 miles from the springs toward Hub, is dioritic, however, and is probably a small intrusive area in the country rock.

The presence of the small area of granitic rock at the springs strongly suggests that the rise of the warm water is due to the intrusion of this rock in the schist, and the consequent development of fissures or a zone of fracturing along which the thermal water rises from a considerable depth.

MELOZITNA HOT SPRINGS.

Melozitna Hot Springs (20 on Pl. I) are so known locally because they are on a tributary of Melozitna (or Big Melozi) River, though they are fully 10 miles from the main stream. The springs are best reached by trail that leads northward from Kokrines, a small trading point and post office on the north bank of Yukon River 100 miles below Tanana. The distance from Kokrines to the springs is about 16 miles (see fig. 13). The trail is easily traversed by dog team in winter, but in summer the thawed tundra makes heavy traveling for horse or man.

The hot water rises, practically all in one spring, in a shallow pool 6 feet in diameter on top of a cemented gravel mass that has been cut by Hot Springs Creek—a fair-sized river—into a remarkable bank (Pl. III, *B*, p. 20). The overflow from the pool cascades 17 feet over this bank to the creek at normal stage. Hot water also breaks out, apparently from the same spring, at points about 3 and 14 feet below the edge of the bluff.

The temperature of the water as it rises in the pool is 131° F. The overflow, as nearly as could be measured, is about 100 gallons a

[1] Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pl. 3, 1913.

minute, and the discharges of the two streams from the face of the cliff, as measured with a bucket, are about 25 and 5 gallons a minute for the upper and lower, respectively, making a total visible discharge of about 130 gallons a minute, or 14½ miner's inches. The gas that rises in the pool extinguishes a flame, indicating that it is principally carbon dioxide. The water tastes mildly but distinctly of hydrogen sulphide, and a distinct odor of this gas is perceptible at a distance of several yards from the pool. Small amounts of native sulphur are deposited along the borders of the pool, probably by the oxidation of the sulphide gas and other sulphides present. The reactions that take place can not be expressed by simple chemical equations, however. A thin white coating, probably of lime carbonate, is also formed on some of the pebbles along the run-off channels and gives good indication of the source of the lime carbonate that has cemented the gravel bluff.

An analysis of the water (analysis 1 on p. 74) shows that it is moderately mineralized and of the sodium chloride type, though sulphate is also an important constituent.

In August, 1915, the water in the pool had a clear dark hue similar to that of "black sulphur" waters. This appears, however, to have been due to a thin, slimy, dark-brown layer, presumably an algal growth, on the stones in the bottom of the pool and not to the presence of notable amounts of sulphides in the water. The margins of the pool and of the discharge channels were lined with pale salmon-pink algae, which in only a few spots showed the more usual greenish hues.

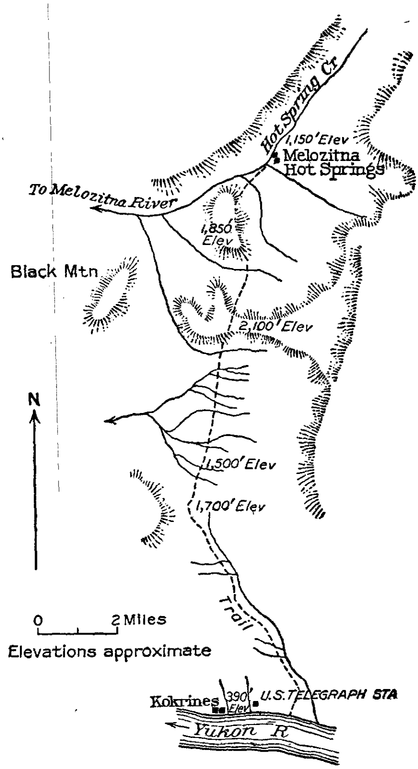


FIGURE 13.—Sketch map showing location of Melozitna Hot Springs, Ruby region, Alaska.

In December, 1911, a two-room cabin and a dog house were built on the gravel bank near the springs. Two small log bathhouses, apparently of somewhat earlier construction, on either side of the spring, have furnished bathing facilities by means of wooden tubs and sweat chambers. The springs are visited for several days at a time during the winter, both by parties of whites and of natives, but in summer the difficult trail causes them to be used only rarely.

The country rock in the vicinity of the springs, so far as observed, is of granite or similar crystalline rocks. In the beds of two creeks one-quarter and three-quarters of a mile south of the springs water-worn pebbles of white crystalline limestone were noted. This material probably comes from the steep mountains 2 or 3 miles eastward, which appear to consist of bedded sedimentary rocks, probably of Paleozoic age.[1] Somewhere in its underground course the hot-spring water probably traverses limestone and absorbs from it calcium, carbonates, and carbon dioxide gas. The cause for the abnormal temperature of the water is not evident; it may be due either to faulting or to the intrusion of granite into the sedimentary rocks, either of which would produce a high temperature gradient and furnish fissures for the upward escape of deep-seated water.

The springs evidently issued at their present location and formed the cemented gravel knoll or bank at a time when the creek channel was somewhat farther away. The stream has, however, apparently within comparatively recent years, attacked the cemented bank, and at present is undercutting it. Within a few decades the present pool may therefore be destroyed and the hot water allowed to issue at the river level.

HORNER HOT SPRINGS.

Horner Hot Springs (19 on Pl. I), although only three-quarters of a mile from Yukon River, appear to have been unknown to the whites until about 1913, when they were shown by an Indian to F. G. Horner, who has built a cabin and planted a small garden near them.

The springs issue at several points along a small creek that enters Yukon River 5 miles below Kokrines, all but one of the springs noted being on the right (west) side of the creek.

The principal spring issues from a granitic cliff 100 feet from and 40 feet above the creek. Part of the discharge, which is about 25 gallons a minute, at a temperature of 117° F., is piped to a wooden bath tub in the cabin immediately below. (See Pl. VII, *C*.) In 1915 the remainder of the discharge had not yet been utilized, but a narrow alluvial strip along the creek was available for use as an irrigated garden. The water has a faint taste and odor of hydrogen sulphide but is not otherwise noticeably mineralized. Pale salmon-colored to green algal growths, common in thermal sulphur waters, line the run-off channel.

[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pl. 21, 1906.

An analysis (tabulated on p. 74) shows that the water is of moderate mineralization and of the sodium chloride type, though carbonate and sulphate constitute large portions of the total of acid radicles.

The other springs, of which seven were noted, issue at intervals from about 175 to 350 yards upstream from the principal spring and at heights of 2 to 20 feet above the creek. Like the principal spring they come from a fractured and partly disintegrated granitic rock, and the water is aparently under some pressure, as it issues with an upward current from each vent. These minor springs seem to be very similar to the main one. Their temperatures range from 86° to 120° F., and their discharges are from about one-quarter of a gallon to 8 gallons a minute, the total flow of the seven springs being about 20 gallons a minute, or less than the flow of the principal spring alone. The usual algal growth is seen at each spring, and it varies in color with the temperature of the water.

The geology of the region has not been studied in detail and the rock structure has not been worked out. The granitic rock from which the springs issue is fractured, however, so the heated water may rise along a fissure in a zone of faulting that is possibly followed in part by the stream channel. This fissure would provide a means of escape upward for deep-seated hot water. The area covered by the granitic material is believed to be only a few square miles at most, and it probably represents a mass intruded into the old sedimentary rocks that cover the greater part of the region.[1]

WARM SPRINGS ON ALATNA RIVER.

C. E. Giffin, of the Geological Survey, reports that the stream water along a considerable stretch of the upper Alatna River (4 on Pl. I) is too warm to be pleasant for drinking, a fact which indicates that a large quantity of warm water enters the river in that part of its course, but no definite springs were observed during the reconnaissance of the region.

The rocks along Alatna River are mainly of Paleozoic age and are chiefly limestones and metamorphic schists.[2] The warm water possibly issues at a number of places from fractured zones in these rocks, but geologic studies in the vicinity have shown neither extensive faulting nor the intrusion of granitic materials into the old sediments near the river, though there is an intrusive granitic mass, several square miles in area, on the higher slopes west of the river.

[1] Brooks, A. H., op. cit.

[2] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pl. 2, 1913.

WARM SPRING NEAR REED RIVER.

In 1886 the Kobuk River basin was penetrated by an exploring expedition under the direction of Lieut. G. M. Stoney, of the United States Navy. Reed River, a small tributary of the upper Kobuk, was examined and a warm spring (3) near its headwaters visited by Ensign M. L. Reed, after whom the stream was named by Stoney. Of this spring Stoney says in his report:[1]

> There was but one hot spring there, a pool 20 feet in circumference and 2 feet deep, full of water of blood-warm temperature that wells up quietly from the bottom without bubbles or disturbances of any kind and fills the pool with a clear, tasteless, odorless water; the overflow runs into and fills smaller pools lying lower down the mountain side. The bottoms of all the pools are covered with green moss, on which is a limelike deposit, and the ground and rocks about the pools are similarly coated. About the edges of the main spring were thousands of small snails. The atmosphere is not affected in temperature, nor are the rocks and ground about. The natives say the temperature of the spring varies; that sometimes it is so hot they can cook meat in it.

The mention of snails is a feature that was not observed at any hot spring by the writer. The statement of the natives that the spring varies in temperature is another unusual feature of this spring, if it is true. Such springs are almost universally very constant in both temperature and flow, however, and the statement of the natives should be verified instrumentally before being accepted.

The spring probably issues from the ancient metamorphic schists that form the country rock of the region.[2] Intrusive granitic material is present 20 or 30 miles to the east, however, and other intrusive masses may exist in the vicinity of the spring.

HOT SPRINGS NEAR SELAWIK RIVER.

There is said to be a group of hot springs (2 on Pl. I) near the headwaters of Selawik River, but no definite information concerning them is at hand. They probably issue from Mesozoic or older sedimentary rocks, as these ancient sediments (overlain by Quaternary gravels) cover large areas in the region.[2] Whether the rise of the heated water is due more probably to faulting or to the intrusion of granitic or other crystalline rocks into these sediments can not be stated.

HOT SPRINGS ON A TRIBUTARY OF INNOKO RIVER.

In the summer of 1915 a prospector told C. E. Giffin, of the United States Geological Survey, that he had found hot springs (18 on Pl. I) on a tributary of the upper Innoko River. He stated that the flow of water was considerable and that it was decidedly hot, but gave no details concerning other features of the springs.

[1] Stoney, Lieut. G. M., Naval explorations in Alaska, p. 47, Annapolis, 1900.
[2] Smith, P. S., op. cit., pl. 2.

The rocks of the region consist chiefly of Mesozoic sandstones and other sediments, into which at many places igneous rocks are intruded.[1] From the conditions noted at other springs in Alaska it seems probable that those in the upper Innoko Basin are directly related to an igneous intrusion.

WARM SPRINGS NEAR IDITAROD.

A. G. Maddren, of the Survey, reports that springs (38 on Pl. I) near the north bank of Otter Creek, about a mile above Discovery, or 10 miles southeast of Iditarod, stay open all winter. The temperature of the water was not observed but is presumably several degrees above normal. The water issues near the contact of granite and slate,[1] where fissures or seams extending to considerable depths very probably furnish means of escape for deeper thermal waters. No noticeable deposit is formed by the springs, but the rock is considerably stained as if by iron.

HOT SPRING NEAR WHITEFISH LAKE.

The following information concerning a hot spring (47 on Pl. I) near Whitefish Lake, which lies near Tulusak River, a tributary to the lower Kuskokwim, is furnished by A. G. Maddren, of the United States Geological Survey.

On the headwaters of a tributary of Ophir Creek, which flows into Whitefish Lake, a hot spring is used for bathing by prospectors and by Lapp reindeer herders.

The water bubbles up with considerable force through a heavy mantle of moss among willows 1½ or 2 miles above the limit of timber, forming a stream 2 to 3 feet wide and a foot deep. The spring is about 750 feet above Whitefish Lake, which is believed to be about 250 feet above sea level. Its water is clear and of nearly scalding temperature. There is possibly a slight odor of hydrogen sulphide, but no algal growth was apparent when the place was visited by Mr. Maddren. A couple of tents erected over the run-off stream 200 to 300 yards below the spring have formed bathing places at points where the water is of an endurable temperature.

The water issues in a small area of granite that is intrusive in a region of volcanic tuffs of Carboniferous age.

Mr. Maddren also reports that about 13½ miles in a direct line east of south from the spring there is a siliceous sinter cone 150 feet high, at the east edge of Myrtle Creek, at the contact of an area of shales on the east with granite on the west. The cone is evidently an old hot-spring formation, but the creek has cut into its base so that any warm water that still issues probably seeps directly into the stream.

[1] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pl. 3, 1914.

HOT SPRINGS NEAR TULUKSAK RIVER.

Mr. Chase, storekeeper at Anvik, told the writer that his partner, F. H. Kruger, visited hot springs near Tuluksak River (46 on Pl. I), in the vicinity of Whitefish Lake, and found there much "green slime," doubtless algal growth, and noted a distinct sulphurous odor but did not especially observe the temperature and flow of the water. From the specific mention of algal growths and of hydrogen sulphide the locality is believed to be different from that near Whitefish Lake which was visited by Mr. Maddren, but here, as at the spring examined by Mr. Maddren, the rock is probably granitic, consisting of an intrusive mass in the sedimentary rocks, probably of Cretaceous age.[1]

SEWARD PENINSULA.

DISTRIBUTION.

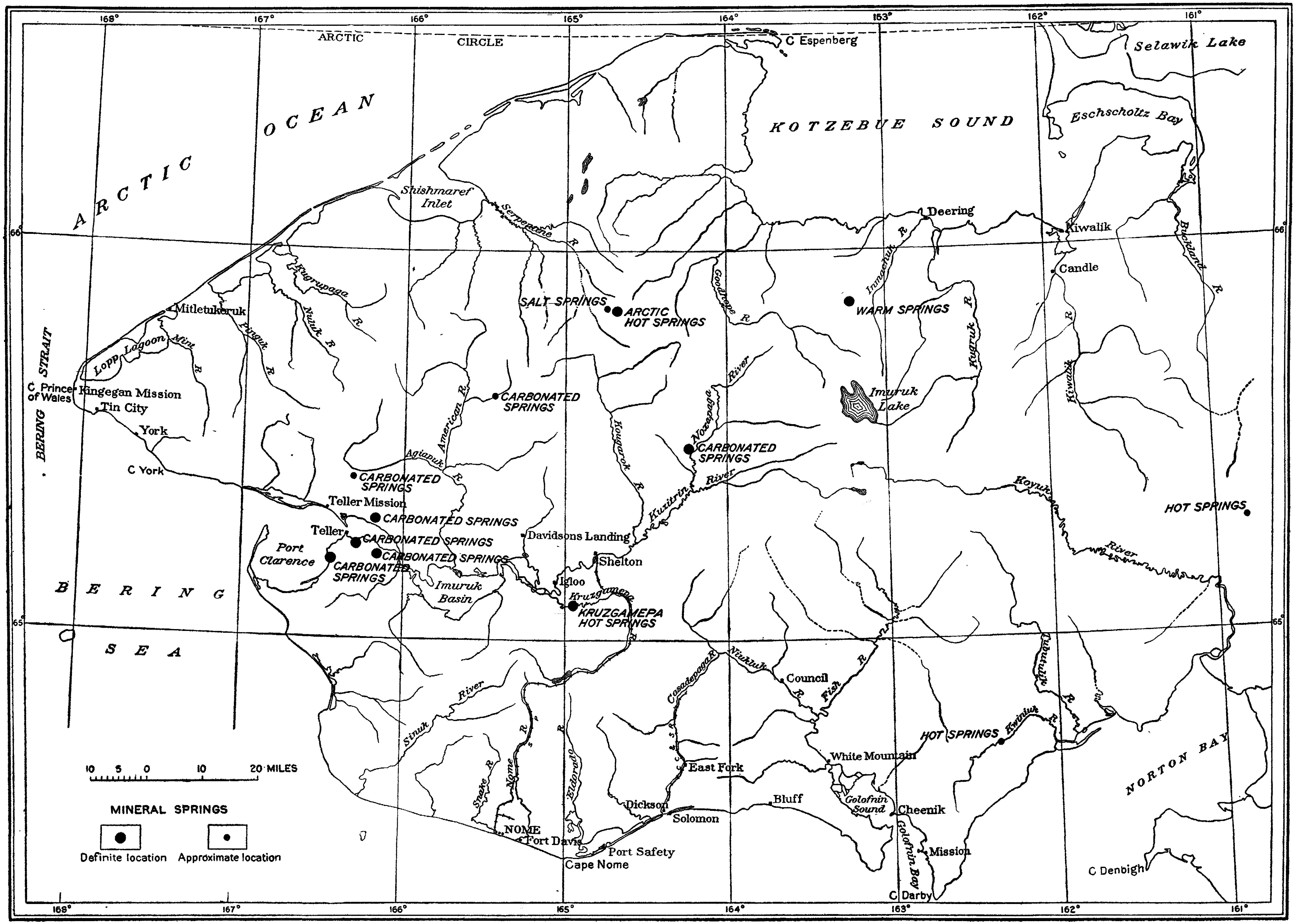
Hot springs are reported to occur at several points on Seward Peninsula. (See Pl. VI.) The geologic conditions at all of them are not known in detail; but examinations made of those whose rock structure has been determined indicate that all are directly related to areas of granitic rocks, intruded into older sedimentary or metamorphic materials. The springs do not seem to be connected either with extensive faulting or with volcanic activity.

KRUZGAMEPA HOT SPRINGS.

Kruzgamepa Hot Springs (Pl. VII, *A*) are 70 miles north of Nome, in the wide flat valley of Kruzgamepa River, one-third of a mile south of the stream. The property (13 on Pl. I) was homesteaded a number of years ago and has produced considerable amounts of potatoes, cabbages, turnips, and other vegetables, which have found ready sale in Nome, where they have been sent by the trains of the Seward Peninsula Railway, which passes within 8 miles of the springs, and, since the discontinuation of train service, by light cars pulled by dogs. In the summer of 1915 these dog cars furnished the easiest and quickest means of reaching the springs. In winter a shorter route by dog team is found through Goldengate Pass, about 10 miles west of the railroad.

Several years ago the property was kept up as a resort, and was often visited by parties from Nome and other mining centers of the region; but the roadhouse and saloon building was burned in 1908 and since that date the bathhouse has not been kept in repair. The locations of the several springs and the improvements on the property are shown in figure 14.

[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pl. 21, 1906.



MAP OF SEWARD PENINSULA, ALASKA, SHOWING LOCATION OF MINERAL SPRINGS.

An area perhaps 100 yards wide and half a mile long, bordering a small creek that is at times a flood-water channel of Kruzgamepa River, appears to be permanently thawed by the hot water, and as this ground is loose and sandy, not dense and peaty, as are the moss-covered hillsides of the region, it has been especially adapted to growing vegetables.

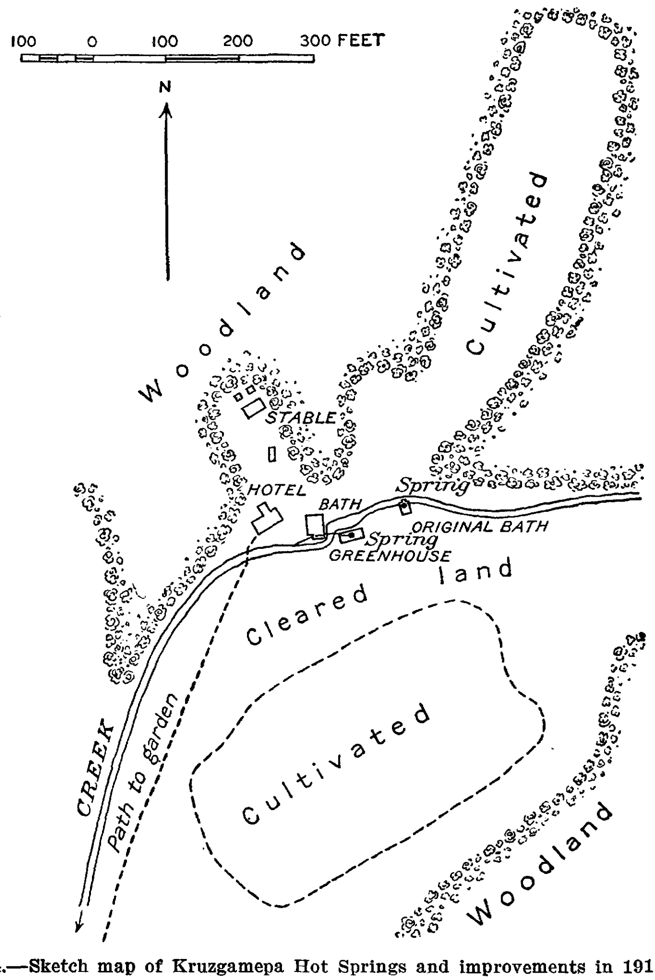


FIGURE 14.—Sketch map of Kruzgamepa Hot Springs and improvements in 1915, Seward Peninsula, Alaska.

Hot water is visible only in small quantities, as it tends to seep off below the surface through the loose alluvial valley materials. In the fall of 1915 the total visible discharge of hot water at the springs was only about 8 gallons a minute. The hottest spring, which has a temperature of 156° F., issues in a small curbed pit in a greenhouse near the bathhouse. The water was carried in a box flume through a sweat chamber to two bathing pools in a bathhouse, one pool for men and the other for women. A stand box in the flume afforded a place to dip out water for drinking and was known as the "medicine chest."

The water is clear, has only a slight odor of hydrogen sulphide, and tastes distinctly salty. It deposits small amounts of rust-colored iron oxide. A slight deposit of alum was seen at the principal spring. An analysis of the water (analysis 3, below) shows that its content of solids is high. It is a sodium chloride water that is practically a weak brine. Although the springs are not very far above tide limit, the ratio of sulphate to chloride in the spring water is so low that the high salinity seems not to be due to an admixture with sea water. In the spring water the ratio of sulphate to chloride is about 1:138, whereas in sea water it is about 1:7. The calcium-sodium ratios also are markedly different, being 1:2.9 in the spring water and about 1:30 in sea water.

Mineral analyses of waters from hot springs in the Yukon River basin and Seward Peninsula, Alaska.

[Parts per million except as otherwise designated.]

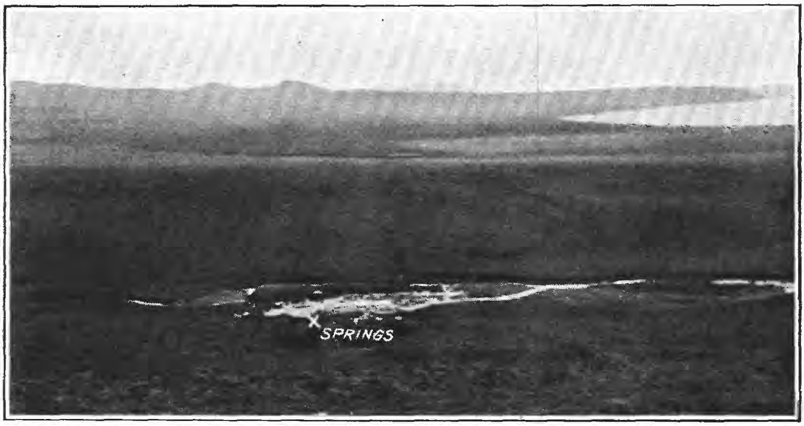
Constituents.	1	2	3
Silica (SiO_2)	78	29	87
Iron (Fe)	.75	2.7	.7
Aluminum (Al)	....	.2	4.1
Calcium (Ca)	11	10	545
Magnesium (Mg)	2.8	3.0	7.4
Sodium (Na)	} a 107	a 58	1,587
Potassium (K)			61
Carbonate radicle (CO_3)	31	32	.0
Bicarbonate radicle (HCO_3)	32	22	21
Sulphate radicle (SO_4)	61	45	25
Chloride radicle (Cl)	92	39	3,450
Nitrate radicle (NO_3)	Trace.	Trace.	.0
Borate radicle (B_4O_7)	Present.	.0	Present.
Total dissolved solids at 180° C.	442	292	5,955
Temperature (° F.)	131	117	156
Chemical character	Na-Cl	Na-Cl	Na-Cl

a Calculated.

1. Melozitna Hot Springs; principal spring. Has distinct odor and taste of hydrogen sulphide. Deposits small amounts of sulphur and calcium carbonate. Sample collected Aug. 12, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
2. Horner Hot Springs; principal spring. Has slight taste and odor of hydrogen sulphide. Sample collected Aug. 10, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
3. Kruzgamepa Hot Springs; spring in hot house. Has distinct salty taste, and slight taste and odor of hydrogen sulphide. Deposits small amounts of sodium chloride, calcium carbonate, and alum. Sample collected Sept. 2, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.

The two bathing pools have been excavated in the alluvium beside the small creek, and some hot water probably rises in them. The temperature in these pools was only 110° F., however, a comfortable temperature for bathing. A bathhouse was first constructed 30 or 40 yards east of the present one, and small amounts of water, 100° F. in temperature, still issue at this earlier-used spring.

A. KRUZGAMEPA HOT SPRINGS, SEWARD PENINSULA.



B. CARBONATED SPRINGS NEAR BERING, SEWARD PENINSULA.

C. HORNER HOT SPRINGS, RUBY REGION.

The stream channel eastward, upstream from the original spring, contained in 1915 a long narrow strip of practically dead water, somewhat turbid as if from small amounts of carbonates in suspension, and covered in part by an iridescent film of iron oxide. From a point about 50 yards below the bathhouse to nearly 300 yards downstream the creek was also very sluggish and contained turbid water about 80° F. in temperature. This was partly covered by a film of iron oxide and supported a growth of green algae. At the lower end of the sluggish stretch a stream of about 60 gallons a minute flowed over a gravelly riffle to another sluggish stretch. The increase in flow of the creek is doubtless due to warm water seeping into it from the lowland along its course. A heavy stand of oats, well filled out and shoulder high, covered part of this permanently thawed and warmed lowland on September 2, 1915. Snow may cover this ground during the winter, but turnips and other root vegetables may be left in it without danger of freezing, and pulled only as needed.

Along the creek channel about 30 to 40 yards below the bathhouse there was, in 1915, a deposit of black ooze, which A. F. Rogers, of Stanford University, on microscopic examination, found was an opaque black ferrous sulphide,[1] containing several species of diatoms, as well as fine grains of quartz, biotite mica, muscovite mica, garnet, chlorite, tourmaline, and hornblende.

As the springs are in an alluvial river valley, the underlying rock formation is not visible. The nearest slopes on the south, 2 or 3 miles away, expose schists and gneisses, intruded by small areas of granitic rocks.[2] It would appear plausible, therefore, that beneath the river alluvium at the springs the bedrock may be gneiss, intruded by a granitic mass; and that, as is apparently true at several other Alaskan hot springs, the heated water rises along the fractured contact zone between the two kinds of rock.

ARCTIC HOT SPRINGS.

Arctic Hot Springs (12), on Hot Spring Creek, a tributary of Serpentine River, were not visited by the writer but have been described by Collier.[3]

> Along Spring Creek for a distance of about half a mile there are hot sulphur springs. Two of these, the upper and lower ones, were visited by the writer. The upper spring is on the banks of the creek, probably above any except the

[1] Mr. Rogers stated in a letter to the writer that the ferrous sulphide is probably similar to the mineral hydrotriolite, described by Siderecks (in a Russian article abstracted by Doss in Neues Jahrb., 1902, Band 2, p. 397), from Hadishibey, Limau, Russia.

[2] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, pl. 10, 1908.

[3] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 2, pp. 55–56, 1902.

highest floods. The spring is in the center of a broad mound, 10 feet in diameter and perhaps 2 feet high, built up from material precipitated by the spring water. The temperature of the water is about 212° [probably only approximately]. The lower springs are below the high-water mark of the creek. The amount of water is not over 1 miner's inch. For some distance around the spring the ground is warm, making it an ideal place for wintering in that climate.

H. B. Barnett, of Teller, and Arthur Drewer, of Davidsons Landing, furnished the writer with the following additional information:

A distinct odor of hydrogen sulphide is present, but the water does not taste very noticeably mineralized. In addition to the mound described by Collier, small amounts of a hard, white deposit, probably lime carbonate, are also deposited on stones along the hot-water stream.

A few years ago prospectors built a cabin near the upper spring and a bathhouse over a bathing pool 10 to 12 feet in diameter. Cold water from the creek is admitted to lower the temperature sufficiently for bathing.

The springs issue at the west border of an intrusive granitic area about 5 miles in length and width, in a region of schists, slates, and other altered rocks.[1] As is believed to be true at other hot springs, the heated water of Arctic Hot Springs probably rises from a considerable depth along the fractured contact zone between the instrusive granite and the country rock.

WARM SPRINGS NEAR INMACHUK RIVER.

Warm springs near the upper course of Inmachuk River (15), in the northern portion of Seward Peninsula, have been visited by F. H. Moffit, of the United States Geological Survey. The springs remain unfrozen throughout the winter, but the temperature of the water is probably less than 100° F. It issues from crystalline limestone[2] and forms a shallow stream 3 or 4 feet wide. (See Pl. VIII, *B*.) No odor of hydrogen sulphide was noted, and the water did not appear to Mr. Moffit to be perceptibly mineralized.

The relation of these springs to the rock structure is not evident, but the water possibly is heated by contact with rocks that have been warmed by friction in a zone of minor faulting. The heat may be due in part to chemical reactions, but in the absence of an analysis of the water, the probability of such a source of heat can not be stated.

[1] Collier, A. J., op. cit., pl. 3. See also more detailed map in Moffit, Fred. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, pl. 3, 1905.

[2] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, pl. 3, 1905.

A. CARBONATED SPRINGS, REVILLAGIGEDO ISLAND, NEAR NEW EDDYSTONE ROCK, SOUTHEASTERN ALASKA.

B. WARM SPRINGS NEAR INMACHUK RIVER, SEWARD PENINSULA.

HOT SPRINGS NEAR KWINIUK RIVER.

Hot springs whose waters are distinctly sulphureted are reported at two neighboring localities near Kwiniuk River (16 on Pl. I), which enters Norton Bay a few miles west of the larger and better-known Tubutulik River. So far as learned these springs are rather inaccessible, have seldom been visited by whites, and have not been developed or improved for bathing.

The rocks of the region have not been examined in detail but are believed to consist of Paleozoic sediments, including metamorphic schists and other altered materials.[1] As their character and structure are so little known, their probable relation to the springs can not be stated.

HOT SPRINGS NEAR SWEEPSTAKE CREEK.

Sweepstake Creek, a tributary of Koyuk River, enters the latter 30 or 40 miles by trail above the river's mouth. On a small tributary to the creek there are said to be hot springs (17 on Pl. I), which in winter make picturesque carvings in the ice of the creek. Like a number of other Alaskan springs, they have not yet become well known, and in 1915 no detailed description of them was obtainable.

The rocks of the locality are probably the same Paleozoic sediments and metamorphic schists[2] that are believed to be present at the springs to the southwest near Kwiniuk River.

CARBONATED SPRINGS.

SOUTHEASTERN ALASKA.

DISTRIBUTION.

Carbonated or "soda" springs issue at a few scattered points in southeastern Alaska. (See Pl. II.) All of them seem to be assignable to the local geology and not to any general structural features. In some places the production of carbon dioxide seems to be associated with the presence of lava of a fairly recent period of effusion, but sufficient information concerning all the localities is not at hand to warrant a general statement to this effect.

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[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pl. 21, 1906. Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, pl. 10, 1908. Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay–Nulato region: U. S. Geol. Survey Bull. 449, pl. 6, 1911.

[2] Brooks, A. H., op. cit., pl. 21. Smith, P. S., and Eakin, H. M., op. cit., pl. 6.

CARBONATED SPRINGS NEAR NEW EDDYSTONE ROCK.

Strongly carbonated or "soda" springs (109) issue on the eastern side of Revillagigedo Island, opposite New Eddystone Rock, a prominent islet crag in Behm Canal. The springs rise almost wholly between high and low tide limits on a rocky shore near the mouth of a large creek. One of the principal springs issues among the rocks 2 to 3 feet above low tide. In 1915 its discharge issued mainly through a piece of 1-inch pipe with elbow coupling that had been driven into the vent. (See Pl. VIII, *A*.) Owing to the large amount of carbon dioxide given off the water is discharged in spurts one-half to one second apart. The total discharge of this spring, as nearly as could be measured, was 4 gallons a minute, and the temperature was 50° F., while that of the adjacent salt water was 57° F. The water tastes strongly carbonated and also distinctly sulphureted, and the rocks over which it flows are deeply iron stained. An analysis of water from this spring (analysis 1 on p. 87) shows that it is a highly mineralized calcium carbonate water. The small amount of chloride (which forms only one-tenth of the total solid contents) indicates that there is very little, if any, admixture of sea water in the sample collected. The reported absence of sulphate shows that this radicle, if present at all, is in solution in only very small amount.

Water from this spring is said to have been bottled and sold locally for a short time a few years ago, as "Eddystone Water." The iron content would probably stain the bottles and injure its extensive sale.

A few yards offshore from the main spring large numbers of bubbles continually rise. Considerable carbonated water may also escape at this place, but it looked as if only gas was given off. Numerous minor gas vents are indicated just offshore, northward from the main spring, by groups and strings of bubbles, and probably much gas escapes also along the rocky shore above tide limit.

Near the mouth of the creek, 500 yards northward from the main spring, there is another group of bubbling springs, the principal one of which is 4 or 5 feet below high-tide level. The water issues directly from a rock fissure, in a deeply iron-stained basin 10 inches in diameter and 2 or 3 inches deep. The recorded temperature here was 49° F., and the discharge was about a quart a minute. This water is strongly carbonated, like that of the spring analyzed, but instead of a sulphureted taste it has a slightly bitter or puckery taste, probably due to iron. When visited, the location of this spring was pointed out by a signboard, and it probably was the favorite drinking spring for the former residents in a cabin near the southern group of springs. As at the southern group there are minor bubbling vents in the tidewater near shore, and there is at least one other small spring, which rises in an iron-stained rock basin a few yards from the drinking spring.

The rock formation at the springs has been described in an earlier report of the Survey as "a banded schist complex cut by pegmatite dikes."[1] Lava of Quaternary (relatively recent) geologic age has been observed along the shore for about 5 miles southward from the springs. Small areas of lava are also exposed along the canal shore opposite the springs,[2] and other areas may be present on the densely forested slopes behind the springs. New Eddystone Rock is also of lava, possibly a volcanic neck which rises 234 feet high, according to the Coast Survey chart of the region.

It was reported that carbonated springs issue at New Eddystone Rock itself, but careful search around the islet at about half tide failed to disclose any evidence of such springs.

The extrusion of lava upward through the schist of the region may be the cause of the issuance of the carbon dioxide gas and carbonated water, for in other regions of volcanic rocks carbonated springs are fairly common. Much carbonic acid gas is given off from active volcanoes, and apparently the escape of the gas continues long after volcanic activity has ceased.

CARBONATED SPRINGS NEAR UNUK RIVER.

Carbonated springs near Unuk River (105) have been visited and described briefly by F. E. Wright.[1] Several small springs, having a total flow of about 1,000 gallons daily (nearly a gallon a minute), issue on the west side of the river about 2½ miles below the international boundary. The temperature of the water is 44° F. It gives off sufficient carbon dioxide to extinguish a candle, and some hydrogen sulphide is perceptible by its taste and odor. Small amounts of native sulphur are deposited, and much iron as a rusty coating of the oxide forms along the run-off channels. A travertine deposit of lime carbonate is also formed at each of the several small springs.

A small area of crystalline schist[2] is included in the greater mass of intrusive granite of the region near the locality of the springs, and the issuance of the mineralized water is perhaps due to this contact of different rock materials.

CARBONATED SPRINGS NEAR SODA BAY.

Carbonated springs (107) issue near Soda Bay, on the western side of Prince of Wales Island. These springs were visited in 1915 by

[1] Wright, F. E., and Wright, C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 201, 1908.
[2] Idem, pl. 2.

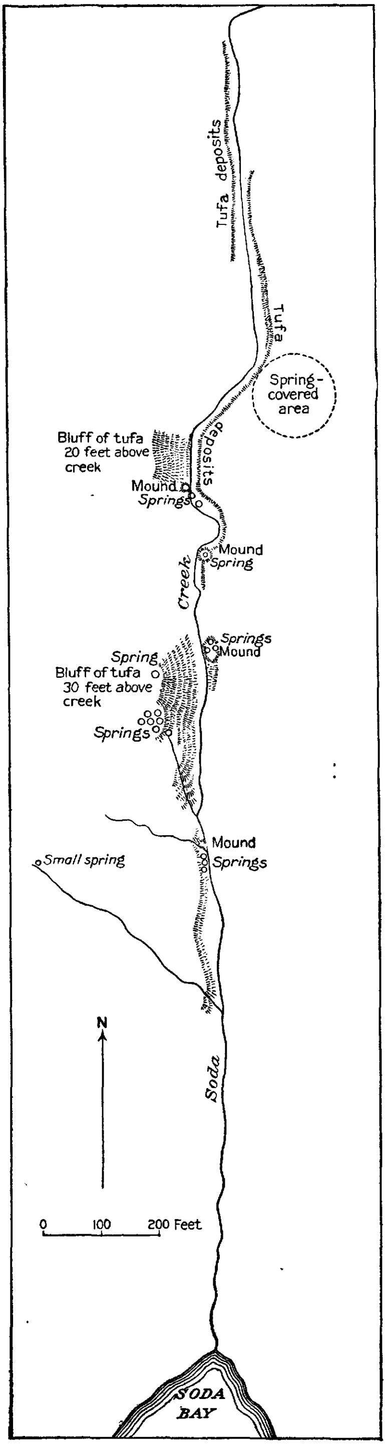

Figure 15.—Sketch map of carbonated springs and vicinity near Soda Bay, Prince of Wales Island, southeastern Alaska.

Theodore Chapin, of the Geological Survey, who furnished the following description of them:

Carbonated springs are present on the west coast of Prince of Wales Island, at Soda Creek, a small stream that enters the head of Soda Bay, 7 miles east of the north end of Dall Island and about the same distance northwest of Hydaberg. A number of springs issue on each side of the creek and have built up deposits of tufa in places 30 feet or more in height. These deposits extend along the creek for one-quarter of a mile and back from the creek for several hundred feet. The tufa is dominantly yellow in color, but in some places it is a conspicuous brilliant red. Three forms of it were examined chemically by A. A. Chambers, of the United States Geological Survey, for gold, mercury, antimony, and arsenic, but no trace of any of these metals was found. The tufa is deposited in several forms. Stratified deposits line the banks of the creek, and mounds from a few inches to 8 feet high have been built up in the stream (see Pl. IX, *B*). As a rule a main vent is found at the top of each mound, and smaller streams of carbonated water issue from the base and sides. At the base of one yellow mound is a spring that deposits bright-red tufa. Springs issuing from below the surface of the creek were evidenced in a number of places by a vigorous bubbling. The springs are not large and generally do not flow as a stream but spread out in all directions, trickling down the sides of the mounds, which are continually building outward and upward. The positions of the main springs are shown on the sketch map (fig. 15), and there are many other minor vents.

A partial analysis of water from one of the largest springs indicates that it is of the calcium carbonate type and rather highly mineralized, having about 2,600 parts per million of solid matter in solution.

The flow of the spring from which the water sample was taken was roughly approximated as about 5 gallons an hour by the length of time it took to fill a quart bottle. The water of the various springs ranges in temperature from 48° to 71° F. It has a pleasant taste and is free from disagreeable odor. It is used locally for drinking but has never been marketed.

The rocks in the immediate vicinity of the springs are chiefly slates, graywackes, and other old, more or less altered materials. Limestone outcrops not far from the springs, however, and may supply the relatively large amounts of calcium and of carbonate and carbon dioxide that the water contains. The rocks are probably all of Carboniferous age and are believed to form large portions of Prince of Wales Island.[1]

CARBONATED SPRINGS NEAR TROCADERO BAY.

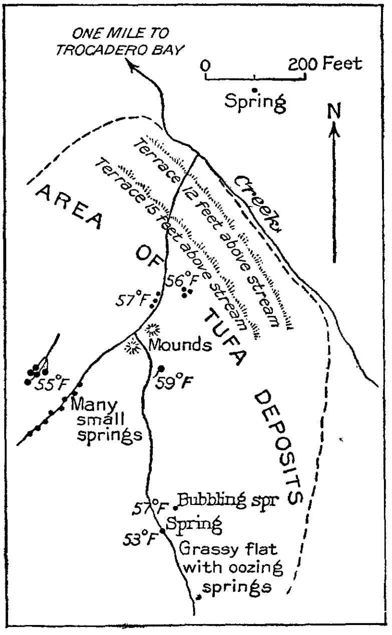

FIGURE 16.—Sketch map of carbonated springs and vicinity near Trocadero Bay, Prince of Wales Island, southeastern Alaska.

Carbonated springs (106) near Trocadero Bay were visited by Theodore Chapin during his geologic studies in the region, and the following description of them has been prepared by him:

Carbonated springs issue about a mile above the mouth of an unnamed creek that flows into an arm of Trocadero Bay, locally known as Big Harbor. They are 4 or 5 miles north of the Soda Bay springs and 10 miles southeast of Craig. A large number of individual springs issue on the west side of the creek, where they have built up tufa deposits over a considerable area. (See fig. 16.) The individual vents are small, but in several places the combined flow of a

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

number of them form streams of appreciable flow. One of the largest springs bubbles up in a pool 2 or 3 feet in diameter, the overflow of which makes a trickling streamlet. Most of the water from the springs is soon lost in the porous tufa over which it flows.

The temperatures of the several springs range from 53° to 59° F. The water effervesces freely, has a sharp, pleasant taste, and is free from disagreeable odor.

An analysis (tabulated on p. 87) of water from one of the principal springs shows that it is of high mineral content and calcium carbonate in type. The various other substances are present in moderate amounts.

The spring deposits are composed of red and yellow tufa and are similar in appearance to those near Soda Bay, but the mounds are less well developed. The tufa deposits form two terraces, 12 and 15 feet in height, from which the springs issue. The general character of these terraces is shown in Plate IX, *C*.

The Trocadero springs are not well known, having been visited only by the local prospectors. They are a mile from the beach, in a region covered by a dense growth of underbrush through which no trail to them has been cut, though one could be easily opened.

The carbonated water issues from a series of graywackes and other altered sedimentary rocks of Carboniferous age[1] that are very probably of the same series as those near the Soda Bay springs. Limestone is, however, present in the vicinity and may be the source of the calcium and carbonate constituents of the water.

ZAREMBO SPRINGS.

Zarembo Springs (95) issue near the shore of St. Johns Harbor, on the northwest side of Zarembo Island, 23 miles west of Wrangell. The carbonated water rises, apparently at only one place, in the tidal flat of the south side of the harbor, about 45 yards from the shore.

Several years ago the water was bottled and marketed for a short time. In order to render it available for this purpose a small building and a concrete box, 5 feet square and 10 feet high, were constructed over the spring, thus keeping out the tide water and forming a pool of the spring water inside. A wharf that connected the spring house with a cabin on shore (Pl. IX, *A*) has been broken in two since the abandonment of the place.

At low tide the water escapes from beneath the concrete box in a stream of about one-half gallon a minute. Its observed temperature was 47° F., while the tide water registered 63° F.

[1] Wright, F. E., and Wright, C. W., op. cit., pl. 1.

A. ZAREMBO SPRINGS, ZAREMBO ISLAND, SOUTHEASTERN ALASKA.

B. CARBONATE MOUND FORMED BY SPRINGS NEAR SODA BAY, PRINCE OF WALES ISLAND, SOUTHEASTERN ALASKA.

C. CARBONATE TERRACES FORMED BY SPRINGS NEAR TROCADERO BAY, PRINCE OF WALES ISLAND, SOUTHEASTERN ALASKA.

Only a moderate amount of gas rises in the spring, but the water is effervescing with carbon dioxide. It deposits small amounts of iron and forms an iron film in the concrete box. The iron is not present in solution in sufficient amount to give the water a perceptible taste but is said to be enough to stain bottles and to injure the sale of the bottled water. Analyses (tabulated on p. 87) show that the water is of high mineral content consisting chiefly of calcium and carbonate. The proportion of sodium is fairly large, but the amount of sulphate is remarkably small for a water of such high concentration.

In the bay, about 700 yards N. 10° W. of the spring, large bubbles were noted continually rising to the surface. On testing with a flame they appeared to be of air, not of carbon dioxide, and probably were due to air trapped by the rising tide in the porous gravel of the harbor, under the same conditions as at the head of Fish Bay (p. 33). Smaller groups of bubbling vents, probably of the same character, were noted at a few places along the shore northwest of Zarembo Springs.

There is reported to be another minor carbonated spring in the forest half a mile south of Zarembo Springs, but its exact location was not learned.

Rock in place is not exposed on shore immediately opposite the springs, but 200 yards to the northwest there is a low point of greenstone, with schistose to coarsely crystalline phases, which continues for several miles to the west. East of the springs the rocks are slates, schists, and other altered materials.[1] The springs apparently issue in the contact zone between the two formations.

The greenstone lava is in places interbedded with slate. The relation of the carbonated springs to the lava is not clearly evident, but it seems plausible that the production of carbon dioxide is connected more or less closely with the lava flows.

CARBONATED SPRINGS ON SOUTH END OF ZAREMBO ISLAND.

George Peterson, of the Forest Service, reports that, in addition to Zarembo Springs, carbonated springs (96) are said to issue at the south end of the island near the shore. This latter group appears not to have been developed, however, nor visited, except by an occasional hunter or prospector. So far as reported their waters are cold and similar in taste to that of Zarembo Springs.

The rock formation in the vicinity of the springs is probably composed of the same series of greenstone lava flows that is present near Zarembo Springs.[1]

[1] Wright, F. E., and Wright, C. W., op. cit., pl. 3.

YUKON BASIN.

DISTRIBUTION.

Only four cool carbonated-spring localities in the Yukon basin were reported. Two of these are near together, near Yukon River in the region of Circle; the third is in the Nenana coal fields; and the fourth is near the lower course of the Yukon. The apparent scarcity of carbonated springs in the region is remarkable, but this scarcity may be partly due to lack of detailed knowledge of the region. The tendency of cool carbonated water to issue chiefly in areas of comparatively recent volcanic activity may in part explain their scarcity in the interior of Alaska, however, as areas of recent lava are not plentiful in the region.

CARBONATED SPRINGS NEAR WOODCHOPPER CREEK.

Fred Brentlinger, of Circle, reports small carbonated springs (33) of very good drinking water, about 45 miles southeastward from Circle, beside the trail up Woodchopper Creek. The principal spring is about half a mile below the mouth of Mineral Creek, or 3 miles from Yukon River. (See fig. 6.) Others issue at two or more points farther up Woodchopper Creek. None of these springs appear, up to 1915, to have been developed in any way, and they have been known only to prospectors in the region.

According to reconnaissance studies of the Survey [1] the springs are in a belt of conglomerates, sandstones, and shales of Eocene age, flanked on the north and the south by older, more-altered sediments. From the description obtained of the positions of the springs they may issue near the contact of the older and newer rocks, but this relation was not definitely learned.

CARBONATED SPRINGS ON COAL CREEK.

Fred Brentlinger, who is personally familiar with the springs on Woodchopper Creek, has also visited carbonated springs (34) on Coal Creek, about 12 miles by trail from the steamer landing at Woodchopper Creek. The trail follows up Woodchopper to Mineral Creek, up Mineral for a couple of miles, then across the divide, and up Coal Creek for about a mile. The water normally issues in considerable flow on the canyon side about 75 feet above the right bank of the stream, but in winter the spring glazes over and the water emerges from beneath the ice lower down, at times being forced by the ice to the left edge of the creek. The water is strongly carbonated and the channel is somewhat stained with iron.

The rock formation, as indicated by reconnaissance studies of the Survey,[1] probably consists of sedimentary rocks of Paleozoic age,

[1] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pl. 2, 1913.

though the springs may issue near the contact of these older rocks with the belt of conglomerates and other sediments of Eocene age on the north, in which the carbonated springs near Woodchopper Creek (p. 84) are believed to be situated. From the reconnaissance geologic work and the reported locations of the springs it seems that the springs on Coal Creek and the upper ones near Woodchopper Creek may issue along the same contact zone, trending northwest-southeast between the belt of Eocene and the wider areas of older rocks.

CARBONATED SPRING ON HOSEANNA CREEK.

In the summer of 1916 G. C. Martin visited a cool carbonated spring (42) in the Nenana coal fields and furnished the following notes concerning it:

The water issues near the south side of Hoseanna or Lignite Creek about 3 miles above its junction with Nenana River. According to surveys by the General Land Office the spring is in the NW. ¼ sec. 3, T. 12 S., R. 7 W., Fairbanks meridian, at an elevation of about 1,400 feet. A pool about 18 inches in diameter had been excavated at the spring and the water apparently was used to some extent for drinking. The overflow was perhaps 2 gallons a minute, and the channel for some distance downstream was iron stained. The temperature of the water was about that of other springs of the region, or about 50° F. There was no noticeable effervescence, but the water tasted distinctly carbonated. The spring issues on a gravel bench about 10 feet above the creek. The bedrock exposed near by consists of schists and altered volcanic materials, but the sedimentary rocks of the coal measures are also present in the vicinity, possibly being exposed by faulting.

There are several other small mineralized springs farther upstream, in the NE. ¼ sec. 3; and A. G. Maddren reports that about 6 miles farther upstream a small mineralized creek enters Hoseanna Creek in the SW. ¼ sec. 34, T. 11 S., R. 6 W.

CARBONATED SPRINGS NEAR MARSHALL.

About 7 miles east of Marshall (Fortuna Ledge post office), an important supply point on the tundra lowland on the north bank of Lower Yukon River and half a mile from the landing at the slough from which the trail to Willow Creek starts, there is a group of carbonated springs (45) in the lowland between Spruce and Wilson creeks. These springs were visited in 1916 by G. L. Harrington, of the United States Geological Survey, who furnishes the following notes:

Several mounds up to 4 or 5 feet in height have been built by the spring deposit, which consists chiefly of lime carbonate and iron oxide. Two or three of the mounds no longer yield an appreciable flow, but the others supply streams of perhaps 1 to 2 gallons a minute of cool carbonated water. Several of the springs have slight flow, but the water issues in pools in which bubbles of gas, probably carbon dioxide, intermittently rise. Along the flat to the south, over which these springs drain, there is an area fully one-quarter of a mile long, having very little vegetation but covered in large part by a thin layer of lime carbonate.

In 1916 a saloon had been built over one of the principal springs and a pool 2 or 3 feet deep excavated, from which water was dipped for serving at the bar. An analysis of a sample from this spring (tabulated on p. 87) shows that the water is calcium carbonate in type with a high content of total solids. It is supersaturated with free carbon dioxide, and 1,340 parts per million of this gas was found on analysis three months after the sample was collected. The other constituents are present in relatively small amounts compared with the total content. Similar springs are also reported to issue at points about 6 and 10 miles farther east, in the lowland bordering Yukon River.

The nearest bedrock exposures are of greenstones on the north and Quaternary lavas on the south. The geology of the region has not been worked out in detail, but the presence of carbonated water is possibly connected with the intrusion of the volcanic rocks upward through Cretaceous sediments, which cover large areas in the region.[1]

SEWARD PENINSULA.

DISTRIBUTION.

Carbonated springs have not been reported from the southern portion of Seward Peninsula but have been from seven places in the northern half. (See Pl. VI.) Five of these spring localities are within a few miles of Teller and form one general group. The other two are about 35 miles northeast and 65 miles north of east of Teller. They seem, from their geographic positions, to be unrelated to the others, though they may be due to similar geologic conditions.

Satisfactory evidence in the matter was not obtained, but it seemed that those near Teller may be related, directly or indirectly, to the issuance of small masses of lava through the old limestones and other altered sediments of the region.

CARBONATED SPRINGS NEAR BERING.

A group of carbonated springs (6) issues about a mile northwest of Bering, on the east shore of Port Clarence. The water issues

[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pl. 21, 1906.

mainly on the north edge of Willow Creek, a small stream, at the base of a steep hillside, about a half mile from the beach.

In a marshy area of about 40 by 75 feet the carbonated water rises at several points, with a total flow of perhaps 30 gallons a minute. Temperatures of 35° to 41° F. in the springs were noted on August 31, 1915, the creek water having a temperature of 49° F. The spring water is strongly but not effervescingly charged with carbon dioxide and is very palatable. Considerable flocculent iron oxide is deposited on sticks and roots in the marshy pools, and small amounts of white brittle material that is probably lime carbonate is deposited in a few places on the muck. The springs have often been visited by people from Teller, 5 miles to the north, who have taken away demijohns of the water for drinking. The springs are also occasionally visited by the natives, and sometimes they attract the reindeer herds of the region as a sort of salt lick.

An analysis (included in the following table) shows the water to be very highly mineralized, of the calcium carbonate type, though chloride is also present in large amount.

Mineral analyses of waters from carbonated springs in Alaska.

[Parts per million except as otherwise designated.]

Constituents.	1	2	3	4 [a]	5	6
Silica (SiO_2)	75	71	69	68	40	19
Iron (Fe)	1.3	5.2	2.5	67	6.2	2.2
Aluminum (Al)	3.7	7.0	4.1	2.3	4.0	14
Calcium (Ca)	273	484	353	375	366	477
Magnesium (Mg)	117	45	70	80	58	118
Sodium (Na)	110	63	208	218	32	186
Potassium (K)	9.6	7.0	10	11	14	7.0
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	1,439	1,854	1,939	2,249	1,456	1,805
Sulphate radicle (SO_4)	.0	4.5	2.8	1.2	18	41
Chloride radicle (Cl)	132	13	31	28	3.1	380
Nitrate radicle (NO_3)	.0	Trace.	Trace.	Trace.	Trace.	.0
Borate radicle (B_4O_7)	.0	.0	Trace.	.0	....	.0
Total dissolved solids at 180° C.	1,362	1,582	1,653	[c]1,958	1,270	2,077
Temperature (° F.)	50	59	47	....	[b] 50	35
Chemical character	Ca-CO_3	Ca-CO_3	Ca-CO_3	Ca-CO_3	Ca-CO_3	Ca-CO_3

[a] Negative tests obtained for phosphate, arsenate, nitrite, bromine, and iodine. A trace of manganese, 0.3 part of lithium, 1.0 part of ammonium, and 2.0 parts of strontium reported.
[b] Approximate.
[c] By summation, with bicarbonate computed as carbonate.

1. Carbonated springs near New Eddystone Rock; spring issuing from pipe below high-tide level. (See Pl. VIII, A.) Supersaturated with carbon dioxide. Also has slight taste of hydrogen sulphide. Deposits iron. Sample collected June 16, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
2. Carbonated springs near Trocadero Bay; principal spring. Supersaturated with carbon dioxide. Sample collected Sept. 14, 1915, by Theodore Chapin; analyzed by S. C. Dinsmore.
3. Zarembo Springs; principal spring. Supersaturated with carbon dioxide; deposits iron. Sample collected June 18, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
4. Zarembo Springs; principal spring. Sample received June 1, 1911, by the Bureau of Chemistry, United States Department of Agriculture; analyzed by J. W. Sale.
5. Carbonated springs near Marshall; spring in saloon. Supersaturated with carbon dioxide; contained 1,340 parts of free CO_2 when tested in the laboratory 3 months after collection. Sample collected by G. L. Harrington Aug. 25, 1916; analyzed by R. B. Dole and Alfred A. Chambers.
6. Carbonated springs near Bering; principal spring. Supersaturated with carbon dioxide; deposits considerable calcium carbonate and iron. Sample collected Aug. 31, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.

Besides the principal springs on the north side of the creek, considerable carbonated water probably escapes along the southern bank of the creek; for sloughlike pools along this side are cloudy, probably due to finely divided iron carbonate in suspension; and an iridescent film of iron oxide covers the quieter surfaces.

The rocks of the bluff north of the springs consist of laminated slate and limestone, assigned provisionally in reconnaissance studies of the Geological Survey to the Silurian and Ordovician geologic ages.[1] These old sedimentary rocks are intruded by small areas of volcanic rocks (greenstones) that in places form typical flat-topped, cone-shaped hills, which in the field strongly resemble volcanic cones. In the geologic mapping, the greenstones coincide fairly well with the tops of the hills. Two of these hills rise southeast of the carbonated springs. (See Pl. VII, *B*, p. 74.) The intrusion of the volcanic rock into the older rocks containing limestone might plausibly account for the production of carbon dioxide, either by heat alone or by chemical reactions that release this gas from the limestone. No close relation between the volcanic intrusives and the position of the carbonated springs was observed, though such a relation may exist.

OTHER CARBONATED SPRINGS ON SEWARD PENINSULA.

Carbonated springs similar to those near Bering were reported at six other places in the region—near Coyote Creek (7), near Igloo Creek (8), near Agiapuk River (5), near Dese Creek (9), near Budd Creek (10), and near Noxapaga River (14).

The carbonated springs near Coyote Creek (7) are 4 miles southeast of Teller. Their flow is said to be small but strongly carbonated. This water is locally considered to be less palatable than that of the springs near Bering.

Near Igloo Creek, 1½ to 2 miles above its mouth and about 7 miles northeastward across Grantley Harbor from Teller, small carbonated springs (8) are reported, but no details concerning them are at hand.

A group of carbonated springs (5) of fairly large flow issues near the south or west fork of Agiapuk River, 1½ to 2 miles above its junction with the main stream, or 10 miles in a direct line north of Teller. The springs have been seldom visited, however, and little attention appears to have been paid to them.

Some carbonated springs (9) about 8 miles southeast of Teller, near Dese Creek, 2 miles above its mouth, are locally considered to be as large and to yield as palatable drinking water as those near

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, pl. 10, 1908.

Bering, but on account of their greater distance and less accessibility from Teller they have been seldom visited.

A small group of mineral springs (10) is reported near Budd Creek, a tributary of American River, 35 miles in a direct line northeast of Teller. In an area about 10 feet in diameter there are said to be several cool springs, noticeably different in taste, though the characteristic tastes of carbon dioxide, hydrogen sulphide, and iron are said to be the most prominent.

About 65 miles in a direct line north of east from Teller, near Turner Creek a mile above its junction with Noxapaga River, a tributary of the Kuzitrin, there are carbonated springs (14) that are said to be similar to those near Bering.

So far as is known from reconnaissance geologic studies on the peninsula, all of these carbonated springs issue from the same general series of Silurian and Ordovician limestones, slates, and schists as do the carbonated springs near Bering.[1]

SULPHUR SPRINGS.

DISTRIBUTION.

Cool sulphur springs seem to be uncommon in Alaska, and the few that are reported are widely scattered. Those mentioned in the following pages are the only ones learned of by the author. Probably numerous other mildly sulphureted springs exist in various parts of the territory but they have received little attention from prospectors or trappers.

SULPHUR SPRINGS ON REVILLAGIGEDO ISLAND.

The only developed cool sulphur springs (108) of which information was obtained are situated west of George Inlet of Behm Canal, about 10 miles north of east from Ketchikan.

The springs are on the Peterson lode claim, in an area of crystalline schist.[2] The water issues mainly from a fissure in schist that dips 80° N. 65° E., at a point about 100 yards from and 50 feet above the shore, on the side of a small creek, 25 feet above the stream. Minor seepages of water issue from the banks a few feet away. In 1915 a small bathhouse with a wooden tub stood near the springs. One pipe conducted a part of the water directly to the tub, and another was connected with a coil in a small furnace beside the

[1] Collier, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, pls. 10 and 11, 1908.

[2] Wright, F. E., and Wright, C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pl. 2, 1908. Smith, P. S., Lode mining in the Ketchikan region: U. S. Geol. Survey Bull. 592, p. 90, 1914.

house for heating the water for bathing. Two prospectors' cabins stood near the shore below the springs.

The total flow of the springs was about 4 gallons a minute, and the recorded temperature was 57° F. This temperature is probably 10° or 12° above the mean annual temperature of the region.[1] It may be due in part to the fact that the water rises from a considerable depth, where the earth's crust is considerably warmer; or it may be due wholly or in part to the heat of chemical reaction, principally the oxidation of pyrite (iron sulphide), a mineral which the schist contains in abundance.

The water is clear, with no bubbling. It tastes noticeably of hydrogen sulphide; and a white sulphur-secreting algal growth, a common accompaniment of cool sulphur springs, lines its run-off channel.

The following analysis shows the water to be of low mineral content, calcium carbonate in type, with an amount of silica that is high in proportion to the total solids:

Mineral analysis of water from principal sulphur spring on Revillagigedo Island, southeastern Alaska.[2]

[Parts per million except as otherwise designated.]

Silica (SiO_2)	31
Iron (Fe)	.5
Calcium (Ca)	15
Magnesium (Mg)	2.6
Sodium and potassium (Na+K)	[3]8.3
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	51
Sulphate radicle (SO_4)	16
Chloride radicle (Cl)	5.5
Nitrate radicle (NO_3)	.0
Borate radicle (B_4O_7)	.0
Total dissolved solids at 180° C	122
Temperature (°F.)	57
Chemical character	Ca-CO_3

The sulphate constituent in the water is probably derived largely from the pyrite in the schist. The reaction is not simply one of oxidation of the pyrite (iron sulphide) to iron sulphate; it probably involves not only the change of the pyrite to iron sulphate but also the reduction of part of this sulphate to soluble sulphides, which are pres-

[1] According to tables published by the Wrights (U. S. Geol. Survey Bull. 347, p. 29, 1908), the mean at Port Angeles, Wash., is 46.1° F., and at Wrangell, Alaska, 43° F. The mean near Ketchikan is probably between the two, or about 45° F.

[2] Tastes distinctly of hydrogen sulphide but has no appreciable odor. Sample collected June 15, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.

[3] Calculated.

ent in the water, together with sulphates, as it issues at the spring. During the time intervening between the collection of the water sample and its analysis, however, original sulphides may have become oxidized to sulphates and possibly some sulphate changed to sulphide. On this account the separate laboratory determination of sulphide was not made, all sulphur being reported as sulphate.

SULPHUR SPRINGS ON PRINCE OF WALES ISLAND.

W. G. Weigle, of the Forest Service, reports that sulphur springs (94) issue on the northwest shore of Prince of Wales Island, bordering El Capitan Passage. The flow is said to be about 15 gallons a minute of strongly sulphureted water. No spring deposits are reported, nor is the water believed to be notably mineralized except by the sulphide gas.

The rock formation of the locality has not been examined in detail by the United States Geological Survey, but reconnaissance studies show that the region consists of limestones, slates, schists, and other rocks of Carboniferous and older geologic age, intruded by masses of granitic rocks.[1] Such an intrusive mass occupies a considerable area on each side of El Capitan Passage, and may account for the issuance of the sulphur water. The position of the springs with respect to the contact zone between the old sediments and the intrusive granite was not learned.

SULPHUR SPRINGS NEAR MOUNT EDGECUMBE.

George Willett, of the United States Biological Survey, reports that there is a seepage of mineralized water (90) on the rocky beach near the base of Mount Edgecumbe, at the southern end of Kruzof Island, about opposite the islet of St. Lazaria.

The springs are covered by the highest tides, however, and the flow is too small to make it of more than local interest. The water has the characteristic odor of sulphureted hydrogen, but it appears not to be strongly mineralized.

The springs issue from the recent lava and volcanic tuff of Mount Edgecombe, which covers the southern portion of Kruzof Island.[2] The sulphide constituents in the water may be derived from sulphur compounds in tuffaceous phases of the rock, or it is possible that hydrogen sulphide gas is given off in small quantities and is taken directly into solution by the spring water.

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

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

SULPHUR SPRINGS ON BERING RIVER.

G. C. Martin,[1] of the United States Geological Survey, has noted cool sulphur springs (50) of moderate flow, which issue for a distance of nearly a mile along the north bank of Bering River near its mouth. W. G. Weigle, of the Forest Service, also reported to the writer the presence of a number of sulphureted springs in the neighborhood of Bering River and Bering Glacier. None of these springs appears to have received special notice from either the whites or the natives, and little if any use has been made of the mineralized waters.

The rock formation of the locality is composed of shales and sandstones of Tertiary geologic age that yield seeps of oil at some points.[2] In such rocks in other regions sulphur waters are fairly common, so their presence in the neighborhood of Bering Glacier is not unusually remarkable.

SULPHUR SPRINGS NEAR ILIAMNA LAKE.

Cool sulphur springs (80) have been observed by C. E. Giffin, of the United States Geological Survey, on a small creek near the eastern end of Iliamna Lake, in the eastern part of the Alaska Peninsula. The water is rather strongly sulphureted, but special attention was not paid to the other characteristics of the springs.

According to reconnaissance studies of the geology of the region, the springs issue in an area of basaltic lava of Tertiary age, which covers a number of square miles near the eastern end of the lake.[3] The relation of the sulphur water to the basalt is not clear, though it is possible that exhalations of hydrogen sulphide, representing a final stage in the volcanic activity, may supply the sulphide constituents in the water.

SULPHUR SPRING NEAR LITTLE SUSITNA RIVER.

A strong-smelling sulphur spring (49) near Little Susitna River has been visited by C. E. Giffin, of the United States Geological Survey. The water bubbles up from a hole perhaps an inch in diameter, in a marshy area near the river. Its temperature was not measured, but it is cool, and no algal growths nor deposits of mineral matter were observed.

The rocks of the region consist mainly of a series of sandstones and shales of Tertiary geologic age, which in places contains beds of

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[1] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, p. 22, 1905.

[2] Idem, pl. 3.

[3] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pl. 2, 1912.

coal.[1] Sulphureted waters are fairly common in such sedimentary rocks, and sulphur springs probably issue at other places in the basin of the Little Susitna.

SULPHUR SPRINGS NEAR SKILAK LAKE.

F. H. Moffit, of the Geological Survey, has observed seepages (48) of cool sulphur water on the western portion of the southern shore of Skilak Lake, on Kenai Peninsula. The springs were found by whites largely because they have been resorted to by moose as drinking springs or mineral licks. Hunters have built a small cabin near by, in which to wait for the game.

The water probably issues from glacial and terrace gravels overlying lignite-bearing clays and soft sandstones of Tertiary age.[2]

"Sheep licks," where mineralized earth is found, are reported at a number of places on the mainland of Alaska. One such locality is about 70 miles south of Nenana, near the line of the Government railroad that is being built from Seward to Fairbanks. This lick has afforded a good place to shoot wild sheep, but so far as reported there is no appreciable amount of sulphureted or other mineralized water.

SULPHUR SPRING ON ELDORADO CREEK.

J. D. Courtney, who formerly resided at Glacier, in the Kantishna River basin, southwest of Fairbanks, reports that cold sulphur water (41) issues 21 miles south of Glacier, on Eldorado Creek 1½ miles above its junction with Moose River. A large flow of water rises on the right edge of the creek. The run-off channel is rust-colored with iron oxide, and the water is therefore probably carbonated as well as sulphureted, for iron is commonly deposited in this manner from carbonated waters, on the escape of carbon dioxide.

The region is known from reconnaissance studies to be largely covered by deposits of gravel of Quaternary geologic age, but south of Glacier a considerable area of schist is exposed.[3] It is probable that the sulphureted and carbonated water rises through a fissure in the schist, though the surface may be covered by glacial gravels.

SULPHUR SPRING NEAR NENANA RIVER.

F. H. Moffit, of the United States Geological Survey, has noted a small mildly sulphureted spring (43) near Yannert Fork of

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[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pl. 3, 1912.

[2] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pl. 3, 1915.

[3] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pl. 9, 1911.

Nenana River. The water is cool and not unpleasant for drinking, and the spring is regularly used as a drinking place by animals.

The spring is in an area of glacial gravels overlying conglomerate, graywacke, and shale of Eocene geologic age.[1] The water probably rises through a shaly bed, as such rock usually contains more or less sulphur-bearing material.

SULPHUR SPRING NEAR PLATINUM CREEK.

A spring (44) similar to that near Nenana River, that is more easily found as the trails of wild sheep and other large animals lead to it, has been noticed by Mr. Moffit near Platinum Creek, a tributary of Nabesna River. The temperature of this spring is not unusual, but the water appears to be rather strongly mineralized, possibly by sulphates and other alkaline constituents rather than by sulphides, and it was discovered largely because it is used as a lick by the sheep.

The spring issues in a locality of slates and other sediments of Carboniferous geologic age.[2] The water comes forth from the rock, well above the creek channel, probably from slaty material.

SULPHUR SPRINGS ON COAL CREEK.

Fred Brentlinger, of Circle, reports sulphur springs (35) about 50 miles southeast of Circle, on Coal Creek, 4 miles above its junction with Yukon River. The flow of water is small, but the sulphureted odor is very evident for a distance of 50 yards or more down the wind.

Reconnaissance studies of the geology along the lower portion of Coal Creek[3] indicate that the water probably issues from the rocks of Paleozoic geologic age that border the northwest side of the stream.

SULPHUR SPRINGS SOUTH OF CIRCLE.

C. H. McCartney, who has prospected in the region south of Circle, reports small, distinctly mineralized springs on the east side of Yukon River, about 15 miles above the town. The water issues on the slope near the river, half a mile below a prominent exposure of yellow material that is probably volcanic tuff. From the description given by Mr. McCartney of the taste of the water, it is probably rather strongly sulphureted, and may also contain unusually high

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[1] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pl. 2, 1915.

[2] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, pl. 2, 1910.

[3] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pl. 2, 1913.

opposite bank of Tanana River. (See fig. 10, p. 58.) The spring is accessible only at low-water stages of the river, when a brown scum and deposit form that are very probably of iron hydroxides. This water doubtless issues from the clay and fine sand of the river valley, and the iron may be derived directly from an iron-bearing clay.

Iron-water seeps, or pools containing iron deposits, were noted by the writer at several places, but they appeared to be more common in the northern moss-covered regions than in the southern timbered sections. Iron water seemed to be especially common on Seward Peninsula along small creeks in the tundra area between Iron Creek and Nome. Iron Creek was so named, however, because of the abundant nodules of iron ore in its upper course, and not because it contains flocculent deposits of iron oxide. The presence of iron in the surface waters at and near Nome is shown by deposits of the brown hydroxide and by iridescent films of the oxide in pools and along the gutters. Iron pipe and other iron articles seem to rust very quickly at this place. In the early days, before a water supply was brought down to the town from "Moonlight Springs," a small lake 3 or 4 miles away (see analysis 4, p. 108), domestic water was obtained from shallow pools in the tundra. It is said that a prospector who left his water pail partly filled while away from his cabin for a week or two on prospecting trips was often surprised on returning to find that a pale rust-colored, stringy or slimy growth (of iron-secreting *Crenothrix*) had been formed in the pail during his absence. *Crenothrix* develops especially well in waters that contain iron and organic matter, and the tundra water near Nome apparently contains both of these substances in amounts amply suited to the needs of the organism.

In the more northerly part of Seward Peninsula iron water is found at many places. A small stream 2 miles south of Teller contained a considerable deposit of iron in the summer of 1915. The iron deposits at the carbonated springs near Bering (6), 3 miles farther south, have already been mentioned, and also a deposit of iron at Kruzgamepa Hot Springs (13), a number of miles to the east.

The gravelly shore of Yukon River near Kokrines is in places cemented into a conglomerate by iron oxide that is evidently deposited by iron-bearing waters that seep from the adjacent banks.

Along small stream channels near the trail that leads northward from Kokrines to Melozitna Hot Springs (20) many seepages of iron water were seen issuing from the black muck and fine alluvium of the creek valleys.

On Little Chena River near Charles Main's roadhouse, 13¼ miles east of Fairbanks (see fig. 8, p. 55), the river gravel is deeply iron stained, apparently by water that seeps from the nearly vertical banks between which the stream has entrenched itself.

amounts of alkaline salts. The substances in solution may be derived directly from the volcanic tuff, as such material often contains sulphates and other soluble salts.

SULPHUR SPRINGS NEAR IGNAK RIVER.

E. de K. Leffingwell, who has spent several years in exploration along the Arctic coast of Alaska, has noted two small sulphur springs (1) near Ignak River, about 6 miles above its junction with Canning River and 50 miles from the coast.

The springs issue respectively on the north and the south sides of a small drainage divide in a swale at the west end of Sadlerochit Mountains, at an elevation of 600 or 700 feet. The waters of these two springs are probably appreciably above the normal summer temperature of the surface waters, for they emerge beneath snow banks and keep narrow strips of ground bare of snow for several yards below their points of issuance.

The springs are in a region that is probably composed largely of Cretaceous sediments.[1] The sulphureted water possibly issues from a shaly bed in the Cretaceous sediments, for such rocks in many places contain sulphur compounds and yield sulphur waters.

IRON SPRINGS.

Although iron waters, or waters in which there is either a considerable precipitate of rust-colored iron oxide or a growth of the iron-secreting vegetable organisms, *Crenothrix* and its allied forms, are common in Alaska, only three springs of cold water containing notable deposits of iron oxide were observed by or reported to the writer.

Richard Creighton, of Fairbanks, told the writer that springs (37) yielding water "red as blood" issue from conglomerate on Michigan Creek opposite Nation River, on the south side of Yukon River 50 miles below Eagle. The water has been used to a slight extent by prospectors as a mineral water, but it tastes so strongly of iron as to be unpalatable.

Near the right bank of Chena River, about 6 miles above the mouth of Colorado Creek, a small creek or slough (28) contains a thick deposit of iron oxide. It is beside the trail between Fairbanks and Chena Hot Springs (29), and has been observed to remain unfrozen throughout the winter. The summer temperature of the water, however, is not abnormal.

John Vachon, merchant at Tolovana, reports a spring (26) of bad-tasting water one-quarter of a mile above the village, on the

[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pl. 21, 1906.

SALT SPRINGS.

Only one locality (11) of salt springs in Alaska was reported to the writer. This is between 3 and 5 miles downstream from Arctic Hot Springs (12), where W. S. Thompson, of Kokrines, says there are a number of salt-water springs. This region is known to consist of altered rocks, largely limestones, slates, and schists of Silurian and Ordovician age.[1] The salt springs probably issue from slates, as these altered sedimentary rocks are more apt to contain salt than are the other known rocks of the vicinity.

Only two other springs were noted whose waters are notably salty. These are Kruzgamepa Hot Springs (13), on Seward Peninsula, and Sitka Hot Springs (92), in the southeastern part of the Territory. At the former spring the water contains 3,450 parts per million of chloride and tastes distinctly salty; and several patches in the lowland near the creek below the springs are whitened by a saline efflorescence. (See Pl. VII, *A*, p. 74.)

At Sitka Hot Springs, though the water is distinctly salty to the taste and contains 2,740 parts per million of chloride, no deposit was noted, nor is one probably formed, as the rainfall in the vicinity is so abundant as to keep the surface well washed.

The Kruzgamepa Hot Springs are in a flat river valley, about 12 miles in a direct line from tide water and perhaps 100 feet above sea level. Sitka Hot Springs are only 75 to 125 yards from salt water, but issue 55 to 80 feet above high-tide limit. In neither place does it appear probable that the salt is derived from sea water, however, as the chemical composition of the spring waters does not admit of such an hypothesis.

[1] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 2, pl. 3, 1902.

At several places along the margins of Tatalina River a short distance above its junction with Tolovana River (see fig. 10, p. 58) there are also iron seepages from the bordering gravel banks.

Three wells have been sunk at Tanana, 10 or 15 yards back from the bank of Yukon River. All yield very cold water (33° to 34° F. in August, 1915). Each well is housed, equipped with a hand pump, and used for domestic supply. Two of the wells yield good water, but the central one, in front of the Tanana Commercial Co.'s store, furnishes water that is locally considered very hard. The analysis of water from this well (analysis 1, below) and analyses of water from a well at Anvik and from Yukon River show that the Tanana well water, although it resembles the river water in being of the calcium carbonate type, is very different in mineral content. The well water contained about four times as much mineral matter as the river water taken a few miles upstream on the same date, and chloride was a fairly large constituent of the well water, though a very small one in the river water. The well water was similar in character and mineral content to the water of a well at Anvik mission, 400 miles downstream. The Anvik water contained a considerably greater proportion of chloride, which may have been derived in part from salt water that infiltered from the river bank, where salmon were being salted and packed. The presence of borax in the Tanana well water and its reported absence from the Anvik water are worthy of mention.

Mineral analyses of waters from Yukon River basin, Alaska.

[Parts per million except as otherwise designated.]

Constituents.	1	2	3
Silica (SiO_2)	23	72	8.8
Iron (Fe)	2.7	5.0	.20
Aluminum (Al)	1.5	2.3	
Calcium (Ca)	116	128	30
Magnesium (Mg)	33	38	6.0
Sodium (Na)	9.4	25	5.4
Potassium (K)	2.4	10	
Carbonate radicle (CO_3)	.0	.0	Trace.
Bicarbonate radicle (HCO_3)	387	456	103
Sulphate radicle (SO_4)	7.8	4.3	14
Chloride radicle (Cl)	69	78	Trace.
Nitrate radicle (NO_3)	1.5	Trace.	
Borate radicle (B_4O_7)	Present.	.0	
Total solids at 180° C.	458	553	124
Suspended matter at 180° C.			235
Temperature (° F.)	35	38	62.5
Chemical character	Ca-CO_3	Ca-CO_3	Ca-CO_3

1. Well in front of Tanana Commercial Co.'s store, Tanana. Deposits iron. Sample collected July 19, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
2. Well at Anvik Mission, Anvik. Sample collected Aug. 21, 1915, by G. A. Waring; analyzed by S. C. Dinsmore.
3. Yukon River 12 miles above Tanana. Sample collected July 19, 1915, by G. A. Waring; analyzed by R. B. Dole and Alfred A. Chambers.

CHEMICAL CHARACTER OF SOME SURFACE WATERS OF ALASKA.

By Richard B. Dole and Alfred A. Chambers.

GENERAL CHARACTER OF SURFACE WATERS.

This short report brings together the available analyses of Alaskan surface waters in order that they may serve as a nucleus for amplifying the rather meager knowledge now at hand regarding the chemical composition of streams in a subpolar region. Most of the analyses represent samples collected by exploring parties of the United States Geological Survey in 1914 and 1915. Seventeen spot samples from different points in Yukon River and several others from large or potentially important tributaries of that stream were collected in the summer of 1915 by G. A. Waring. The surface waters of Seward Peninsula were sampled by H. M. Eakin in 1914, and a few other waters from widely separated localities have been examined. Samples of water were collected daily from Yukon River at Anvik, from August 23, 1915, to April 19, 1916, and from June 14, 1916, to August 16, 1916, and the analyses of these samples will form part of a special report on the quality of the surface waters of Alaska.

The few analyses available for this report show a favorable condition of the surface waters. They indicate that the streams in general yield supplies moderate in mineral content, low in chloride and sulphate, and essentially calcium carbonate in character. All the supplies tested are low enough in mineral matter to be useful for domestic and industrial use, and they resemble in composition the least mineralized waters of the United States.

YUKON RIVER.

CHARACTER OF THE BASIN.

The climatic and geologic conditions in the basin of Yukon River are particularly interesting in a study of the quality of the water.

The basin [1] is bounded on the north, southwest, and east by ranges of high mountains, some glacier covered, all generally above the timber line. The mountains west and south of the upper basin consist largely of granitic, volcanic, and other slightly soluble silicate rocks. So far as is known the sedimentary rocks of these ranges are arenaceous rather than calcareous. The mountains on the north consist of sedimentary rocks with perhaps a greater proportion of limestone than those on the south.

Approximately two-thirds of the drainage basin between the bordering ranges is a dissected plateau that is deeply covered by mica schists, quartz schists, quartzite, some limestone, and considerable areas of granitic intrusives. The annual precipitation is relatively low. At White Horse, Yukon Territory, it is 8 to 10 inches; at Eagle, Alaska, about 12 inches, more than half of which occurs in June, July, and September; and at St. Michael, near the mouth of the Yukon, about 22 inches. The mean annual temperature at Eagle is 24° F. and the mean monthly temperature ranges from 24° below zero in January to 58° in June.[2]

As a result of the high elevation and the paucity of the rainfall timber is not abundant on this plateau. The surface is generally covered with a dense growth of moss, grass, and similar vegetation, which readily absorbs and retains much of the precipitation, thereby reducing the immediate run-off and the water available for slow percolation into the deeper strata. In addition to this the subsoil and alluvium throughout the basin and on Seward Peninsula are permanently frozen to bedrock. Excavations made at Fairbanks, for example, have shown that permanent frost exists to depths of more than 300 feet. Though there are small areas in which ground water circulates to some extent, these peculiar frozen conditions result in a general absence of the circulating ground water that contributes so markedly to the mineral content of streams in regions of higher temperature and more humid conditions. Consequently, the perceptible effects of erosion are largely confined to the exposed bedrock on the crests of ridges and mountains and to the local deposits along the rivers. The smaller streams have cut to bedrock, which they are now eroding, but the beds of the larger streams are filled with alluvium, and bedrock is exposed in but few places along them.

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[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, 1906.

[2] Porter, E. A., and Davenport, R. W., The discharge of Yukon River at Eagle, Alaska: U. S. Geol. Survey Water-Supply Paper 345, pp. 68–70, 1915.

MINERAL ANALYSES OF WATER OF YUKON RIVER.

The following table gives the results of analyses by R. B. Dole and A. A. Chambers, in the laboratory of the United States Geological Survey, of 17 samples of water from Yukon River, collected by G. A. Waring during July and August, 1915. The analyses were made in accordance with the methods outlined in Water-Supply Paper 236.[1] Though great accuracy could not be attained in some of the determinations, as each sample measured less than 2,000 cubic centimeters, the results are reasonably precise and concordant.

[1] Dole, R. B., The quality of surface waters in the United States: Part I, Analyses of waters east of the one hundredth meridian: U. S. Geol. Survey Water-Supply Paper 236, pp. 9–26, 1909.

Mineral analyses of water of Yukon River, Alaska, in 1915.

[Parts per million except as otherwise designated. R. B. Dole and Alfred A. Chambers, analysts.]

Location.	Date.	Temperature of water.	Condition of current.	Stage of river.	Suspended matter at 180° C.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K)	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Dissolved matter at 180° C.
		°*F.*													
At Whitehorse, Yukon Territory	July 5	61.5	Swift	High	11	8.0	Tr.	14	2.0	3.4	0.0	49	6.0	Tr.	59
3 miles below mouth of Teslin River, Yukon Territory.	July 6	60.5	...do	...do	10	10	0.08	14	1.6	4.2	.0	55	6.0	Tr.	66
1 mile below Fivefinger Rapids, Yukon Territory.	July 7	61.0	Moderate	Medium	26	10	Tr.	17	3.8	3.7	.0	65	6.5	Tr.	74
Near Selwyn, Yukon Territory	...do	61.5	...do	...do	32	11	.02	18	4.5	3.9	.0	71	9.6	Tr.	84
One-half mile above mouth of Stewart River, Yukon Territory.	...do	61.5	...do	...do	1,100	15	.10	31	6.4	6.8	Tr.	113	17	Tr.	137
10 miles below Stewart River, Yukon Territory	...do	62.0	...do	...do	510	9.7	.13	26	6.0	4.8	Tr.	100	18	Tr.	116
1 mile below Dawson, Yukon Territory	July 8	61.0	...do	...do	685	8.6	.09	23	5.8	5.5	Tr.	107	16	Tr.	123
At Eagle, Alaska	...do	63.0	...do	...do	770	9.6	.10	27	6.2	6.2	Tr.	98	16	Tr.	121
At Circle, Alaska	July 9	63.5	Sluggish	...do	680	8.8	.10	26	5.8	5.0	Tr.	98	16	Tr.	117
Do	July 17	62.0	Moderate	...do	590	8.7	.06	28	6.4	5.2	Tr.	104	16	Tr.	125
About 15 miles below Fort Yukon, Alaska, above mouth of Chandalar River.	July 18	63.0	...do	...do	615	9.7	.11	27	6.7	6.7	Tr.	102	17	Tr.	120
About 20 miles above Dall River, Alaska	...do	62.0	Sluggish	...do	260	9.2	.04	29	5.6	5.2	Tr.	107	14	Tr.	122
6 miles above Rampart, Alaska	July 19	61.5	Moderate	...do	236	14	Tr.	29	6.6	....	Tr.	102	15	Tr.	127
12 miles above Tanana, Alaska	...do	62.5	...do	...do	235	8.8	.20	30	6.0	5.4	Tr.	103	14	Tr.	124
30 miles below Tanana, Alaska	Aug. 17	59.0	....	Rising	285	7.1	.10	26	5.4	6.1	Tr.	93	17	0.5	113
100 miles above Anvik, Alaska	Aug. 19	60.0	....	....	360	6.0	.12	29	5.4	7.1	Tr.	108	16	.8	120
20 miles below Andreafski, Alaska	Aug. 23	58.0	....	....	610	7.6	.10	30	6.3	6.6	Tr.	105	18	.8	....

The analyses are arranged by source in consecutive order downstream and represent the general character of the river water from Whitehorse, near the headwaters in Yukon Territory, Canada, practically to tidewater below Andreafski, Alaska, a distance of more than 1,800 miles by river. (See Pl. I.) As the samples were collected in midsummer within a period of 50 days, they represent fairly well the various changes that the water undergoes because of the entrance of large tributaries and seepage from rocks of different character. From Whitehorse to Selwyn the suspended matter in the water ranged from 10 to 32 parts per million, and was organic and rather flaky. The content of dissolved matter ranged from 59 to 84 parts per million, with a progressive increase downstream, and the type was essentially calcium carbonate, with very little sulphate and almost no chloride. The water in this upper stretch closely resembled that of many mountain streams in New England, northern Minnesota, and western Washington and Oregon, where hard, crystalline, difficultly soluble rocks, such as granite, gneiss, and basalt, abound. Below Selwyn the mineral content of the water was materially changed by the entrance of White River, a large, muddy stream draining part of western Yukon Territory, and the first tributary that contributes a large volume of drainage from glaciers. The suspended matter jumped to 1,100 parts per million, and calcium, carbonate, sulphate, and dissolved matter each increased as much as 60 per cent. These amounts were maintained in fairly regular manner thereafter to the mouth of the river. This striking alteration in mineral content indicates the entrance of water from areas subject to increased erosion. So far as the geology has been studied there is nothing to indicate that the lower part of the basin contains any greater proportion of limestone than the upper part. The deposits of volcanic ash that exist throughout the upper basin[1] and are especially thick in the basin of White River may have an important influence on the suspended and dissolved matter of these streams. Though the entrance of Stewart River from the east above Dawson reduced somewhat the effect of White River, little change was apparent from the entrance of Porcupine River at Fort Yukon and Tanana River at Tanana. Tanana River has many tributaries in the higher ranges and contributes water from glacial sources. The content of suspended matter regularly increased below the mouth of Tanana River from 285 parts near Tanana to 610 parts per million below Andreafski.

The 14 samples collected above the mouth of Tanana River contained too little chloride to titrate in 250 cubic centimeter samples

[1] Capps, S. R., An ancient volcanic eruption in the upper Yukon basin: U. S. Geol. Survey Prof. Paper 95, pp. 59–64, 1915.

concentrated to 25 cubic centimeters. The presence of a trace of chloride was demonstrated, however, by a slight cloudiness with silver nitrate in a 1,000 cubic centimeter composite sample concentrated to 100 cubic centimeters. The content of chloride increased progressively downstream below the mouth of Tanana River, and the increase doubtless represents the effect of cyclic or wind-borne salt from the ocean. The last three stations at which samples were collected are, respectively, 250, 85, and 35 miles in a direct line from Bering Sea, and the chloride contents of the river water at these stations were, respectively, 0.5, 0.8, and 0.8 part per million.

Much of the suspended matter is very fine and difficult to remove by filtration. It is gray and sticky and fuses in the blast to a brown glass. Rough analyses of the suspended matter, apparently clay, in three samples gave the approximate percentage composition: Silica (SiO_2), 40; ferric oxide (Fe_2O_3), 10; aluminum oxide (Al_2O_3), 18; calcium oxide (CaO), 12; loss on ignition and undetermined, 20.

CHEMICAL COMPOSITION OF WATER OF YUKON RIVER.

The chemical composition of the water of Yukon River in its headwater and lower sections is shown in the following table by figures computed by averaging the results, respectively, of the first 4 and the last 13 analyses in the preceding table. For comparison the analysis by George Steiger, of the U. S. Geological Survey, in 1905, of a sample from Yukon River at Eagle, is added.[1]

Average chemical composition of water of Yukon River.

Constituents.	Parts per million.			Percentage of anhydrous residue.		
	1	2	3	1	2	3
Suspended matter at 180° C	20	534				
Dissolved matter at 180° C	71	122	98			
Silica (SiO_2)	10	9.4	7.6	14.2	8.1	7.8
Iron (Fe)	.02	.10		.0	.1	
Calcium (Ca)	16	28	22	22.9	24.1	22.2
Magnesium (Mg)	3.0	6.0	4.6	4.3	5.2	4.7
Sodium and potassium (Na+K)	3.8	5.9	6.0	5.5	5.0	6.1
Carbonate radicle (CO_3)	.0	Tr.		42.9	43.6	46.2
Bicarbonate radicle (HCO_3)	60	103	91			
Sulphate radicle (SO_4)	7.0	16	11	10.2	13.9	10.8
Chloride radicle (Cl)	Tr.	.02	.4	.0	.0	.4

1. Average of first 4 analyses by Dole and Chambers.
2. Average of last 13 analyses by Dole and Chambers.
3. Analysis by George Steiger. Aluminum oxide (Al_2O_3), 1.8 parts per million or 1.8 per cent.

[1] Clarke, F. W., The data of geochemistry, 3d ed.; U. S. Geol. Survey Bull. 616, p. 86, 1916.

All three sets of figures are concordant, and they represent a calcium carbonate water low in mineral content. The river water below the mouth of Stewart River averages about 102 parts per million, or 0.85 pound per 1,000 gallons in its content of scale-forming material, excluding the suspended clay; the scale-forming material, including the clay, amounts to about 640 parts per million, or 5.3 pounds per 1,000 gallons. The chief result of the use of this water in boilers would be the deposition of soft sludge that could readily be blown out. It would be more economical to allow the mud to settle in tanks before introducing the water into boilers than to use the muddy water. The water would not cause foaming or corrosion under normal conditions.

DISCHARGE OF YUKON RIVER.

The total drainage basin of Yukon River covers 320,000 square miles according to Brooks,[1] who has also published estimates of the discharge, ranging from 96,000 to 436,000 second-feet, respectively, at low and high water stages. The mean discharge[2] of Yukon River at Eagle, Alaska, during the 3-year period 1911–1913 was 73,200 second-feet, and the drainage basin above that point covers 122,000 square miles. If the discharge at the mouth is proportionate to that at Eagle, the average discharge at the mouth is about 200,000 second-feet. If the average discharge is 200,000 second-feet, the average content of dissolved matter 122 parts per million, and the average content of suspended matter 500 parts per million the river carries annually into Bering Sea 98,000,000 tons of suspended matter and 24,000,000 tons of dissolved matter, equivalent to 1,600 millionths of an inch as suspended and 380 millionths of an inch as dissolved matter each year, or about 2 thousandths of an inch total. The average rate of denudation in the United States is equivalent to 490 millionths of an inch as dissolved matter and 890 millionths of an inch as suspended matter,[3] or about 1.4 thousandths of an inch total. It appears, therefore, that the removal of material in solution is progressing somewhat more slowly in Alaska than in the United States, because of less precipitation and less underground circulation of water. The estimate of removal as suspended matter is doubtless too high; the analyses on which the estimate is based were made on samples collected in summer, and it is understood that the stream, in its lower portion at least, carries very little suspended matter in winter.

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[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 64–66, 1906.

[2] Porter, E. A., and Davenport, R. W., The discharge of Yukon River at Eagle, Alaska: U. S. Geol. Survey Water-Supply Paper 345, pp. 67–77, 1915.

[3] Dole, R. B., and Stabler, Herman, Denudation: U. S. Geol. Survey Water-Supply Paper 234, p. 84, 1909.

COMPARATIVE COMPOSITION OF WATERS OF GREAT NORTH AMERICAN RIVERS.

The composition of the water of Yukon River in comparison with that of other great rivers of North America is shown in the following table. It resembles that of Columbia and St. Lawrence rivers more closely than the others.

Chemical composition of waters of great North American rivers.

Constituents.	Parts per million.					
	1	2	3	4	5	6
Suspended matter	534	46	5,354	2,475	600	Tr.
Dissolved matter	122	93	707	791	166	134
Silica (SiO_2)	9.4	14	....	29	11	6.6
Iron (Fe)	.10	.05	....	*a* 3.6	*b* .13	.05
Calcium (Ca)	28	16	92	104	32	31
Magnesium (Mg)	6.0	4.0	23	23	8.4	7.2
Sodium and potassium (Na+K)	5.9	8.2	113	119	13	6.3
Carbonate radicle (CO_3)	Tr.	.0	2.0	.0	.0	2.9
Bicarbonate radicle (HCO_3)	103	68	233	178	111	116
Sulphate radicle (SO_4)	16	12	184	228	24	12
Chloride radicle (Cl)	.02	2.6	127	164	9.7	7.7
Nitrate radicle (NO_3)	....	.5	.7	....	2.5	.3

Constituents.	Percentage of anhydrous residue.					
	1	2	3*c*	4	5	6
Silica (SiO_2)	14.2	15.2	....	3.8	7.1	5.0
Iron (Fe)	.0	*d*.1	....	*a*.5	*d*.1	*d*.1
Calcium (Ca)	22.9	17.5	13	13.7	20.6	23.6
Magnesium (Mg)	4.3	4.4	3.3	3.0	5.4	5.5
Sodium and potassium (Na+K)	5.5	9.0	16	15.7	8.4	4.8
Carbonate radicle (CO_3)	42.9	37.2	16.6	11.6	34.7	45.7
Bicarbonate radicle (HCO_3)	....	....	....	....	....	....
Sulphate radicle (SO_4)	10.2	13.1	26	30.1	15.4	9.2
Chloride radicle (Cl)	.0	2.9	18	21.6	6.2	5.9
Nitrate radicle (NO_3)	....	.6	.1	....	1.6	.2

a $Fe_2O_3+Al_2O_3$.
b Also Al = 0.4 part or 0.2 per cent.
c Percentage of dissolved matter.
d Fe_2O_3.

1. Average of last 13 analyses of Yukon River by Dole and Chambers, July and August, 1915.
2. Average of 66 analyses of 10-day composite samples from Columbia River at Cascade Locks, Oreg., March, 1910, to August, 1912, by Walton Van Winkle, U. S. Geological Survey.
3. Average of 12 analyses of monthly composite samples from Colorado River at Yuma, Ariz., in 1905, by H. W. Heileman.
4. Average of 37 analyses of 10-day composite samples of Rio Grande at Laredo, Tex., August, 1905, to August, 1906, by H. W. Heileman.
5. Average of 52 analyses of weekly samples from Mississippi River at New Orleans, La., April, 1905, to May, 1906, by J. L. Porter, New Orleans, La.
6. Average of 11 analyses of monthly samples from St. Lawrence River at Ogdensburg, N. Y., September, 1906, to August, 1907, by R. B. Dole and M. G. Roberts.

YUKON-TANANA REGION.

Analyses of 11 samples of water from Tanana River, creeks in the vicinity of Fairbanks, and other streams in the Yukon-Tanana region are given in the following table:

Analyses of waters from streams in the Yukon-Tanana region.

[Parts per million; S. C. Dinsmore, analyst.]

Constituents.	1	2	3	4	5	6	7	8	9	10	11
Silica (SiO_2)	11	28	11	21	11	10	8.0	5.0	12	17	12
Iron (Fe)	Tr.	Tr.	.08	Tr.	.5	Tr.	.05	Tr.	.0	.0	.02
Calcium (Ca)	31	32	30	19	19	17	6.5	12	13	12	19
Magnesium (Mg)	4.9	4.9	5.1	3.8	6.2	4.8	5.4	3.0	5.0	8.0	8.0
Sodium and potassium (Na+K) [a]	4.0	6.2	7.7	5.1	2.3	5.2	7.3	5.0	12	4.0	.5
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	107	109	106	80	76	76	29	49	88	44	85
Sulphate radicle (SO_4)	13	17	21	4.9	10	5.7	2.8	5.3	.0	31	.0
Chloride radicle (Cl)	3.0	4.0	1.6	1.5	2.0	2.5	1.0	1.0	4.0	2.0	8.0
Nitrate radicle (NO_3)	.8	1.0	.2	1.0	3.0	2.0	Tr.	1.5	.6	.5	.5
Total dissolved solids at 180° C.	123	147	130	101	105	107	82	59	140	93	141
Probable scale-forming ingredients [a]	110	130	100	85	75	70	35	45	60	70	80

[a] Calculated.

1. Tanaha River 15 miles below Chena. River at medium stage. Collected by G. A. Waring, July 21, 1915.
2. Tanana River 5 miles below entrance of Kantishna River. River at medium stage. Collected by G. A. Waring, July 20, 1915.
3. Tanana River 5 miles above its mouth. River at medium stage. Collected by G. A. Waring, July 19, 1915.
4. Baker Creek 30 yards above mouth of Eureka Creek. Collected by G. A. Waring, Aug. 7, 1915.
5. Chatanika River one-half mile above its junction with Tolovana River. Collected by G. A. Waring, Aug. 3, 1915.
6. Tolovana River 2 miles above its junction with Tanana River. Collected by G. A. Waring, Aug. 4, 1915.
7. North Fork of Chena River above mouth of Monument Creek. Collected by R. F. Chamberlin, August, 1915.
8. Illinois Creek one-quarter mile above its junction with Yukon River. Collected by G. A. Waring, Aug. 17, 1915.
9. A small tributary of Esther Creek from the south, opposite the mouth of Eva Creek, about 7 miles west of Fairbanks. Collected by H. M. Eakin, Aug. 10, 1914.
10. Ready Bullion Creek near mouth; a tributary of Esther Creek about 8 miles west of Fairbanks. Collected by H. M. Eakin, Aug. 10, 1914.
11. St. Patricks Creek at Esther Siding, about 5 miles west of Fairbanks. Collected by H. M. Eakin, Aug. 10, 1914.

Tanana River drains a large area south of Yukon River in central Alaska. (See Pl. I, in pocket.) The water of this stream is low in mineral content and calcium carbonate in type. It contains almost no iron and little sulphate or chloride. It would form a small amount of soft scale in boilers but would not foam or cause corrosion. The water is moderately hard, but is far softer than many widely used city supplies. The waters of Baker Creek, Chatanika River, and Tolovana River are similar to one another in concentration and composition and are like the water of Tanana River except that they are lower in mineral content. The waters from the North Fork of Chena River and from Illinois Creek are particularly low in mineral content and typify drainage from silicate rocks.

Esther Creek enters Cripple Creek, and that stream in turn enters Chena Slough, which is a tributary of Tanana River, one of the chief branches of Yukon River in central Alaska. These three waters are low in mineral content and are good for boiler use, though that represented by analysis No. 10 is somewhat less desirable than the others because of its relatively high content of sulphate, which would render the scale much harder.

SEWARD PENINSULA.

Analyses by S. C. Dinsmore of 6 samples of surface water from Seward Peninsula (Pl. I, in pocket) are given in the following table:

Mineral analyses of waters from Seward Peninsula, Alaska.

[Parts per million; S. C. Dinsmore, analyst.]

Constituents.	1	2	3	4	5	6
Silica (SiO_2)	5.0	22	17	8.0	25	5.0
Iron (Fe)	.02	.02	.02	.01	.03	Tr.
Calcium (Ca)	9.0	40	48	41	46	27
Magnesium (Mg)	3.0	6.0	5.0	3.0	9.0	6.7
Sodium and potassium (Na+K)[a]	1.0	1.0	16	6.5	1.0	Tr.
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	19	114	178	136	178	76
Sulphate radicle (SO_4)	9.0	.0	.0	5.0	.0	4.9
Chloride radicle (Cl)	8.0	13	21	6.0	6.0	17
Nitrate radicle (NO_3)	1.0	18	.0	4.5	.0	Tr.
Total solids at 180° C.	50	164	224	138	178	98

[a] Calculated.

1. Sutter Creek near mouth, York region, July 16, 1914.
2. Dry Creek, 2 miles above mouth, near Nome, July 20, 1914. A mining plant was in operation 2 miles above the sampling point.
3. Typical water from a pool on the tundra near the mouth of Dry Creek, July 20, 1914.
4. "Moonlight Springs," a surface-water lake, near Nome, July 20, 1914.
5. Large spring at foot of slope below Iron Mine on Sinuk River, September, 1914.
6. Kruzgamepa River opposite Kruzgamepa Hot Springs, low stage, Sept. 2, 1915.

The first five samples were collected by H. M. Eakin and the last one by G. A. Waring. All these waters, except the first and the last, are similar in composition and appreciably higher in mineral content than those from creeks near Fairbanks, and they show the essential characteristics of drainage from limestone. They are moderate in mineral content and calcium carbonate in type; they contain small amounts of sulphate and chloride but almost no iron. In boilers they would deposit a moderate quantity of rather soft scale but would not foam or cause corrosion. Analyses 1 and 6 represent waters much lower in mineral content.

LOWE AND COPPER RIVERS.

Analyses of the water of Lowe and Copper rivers are given in the following table. Lowe River, a glacial stream flowing into Port Valdez (Pl. I, in pocket), drains a region essentially of hard, insoluble silicate rocks and its composition reflects that condition. The water of Copper River, flowing into the Pacific Ocean, was very muddy at the time of sampling, and is noticeably higher in several ingredients than that of Lowe River.

Mineral analyses of waters of Lowe and Copper rivers.

[Parts per million.]

Constituents.	1	2
Silica (SiO_2)	7.0	8.0
Iron (Fe)	.5	.30
Calcium (Ca)	11	32
Magnesium (Mg)	3.0	7.3
Sodium and potassium (Na+K)	[a] 11	11
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	59	110
Sulphate radicle (SO_4)	9.8	18
Chloride radicle (Cl)	3.0	1.6
Nitrate radicle (NO_3)	2.0	.50
Suspended solids at 180° C.	....	1,068
Dissolved solids at 180° C.	87	146
Probable scale-forming constituents [a]	45	115

[a] Calculated.

1. Lowe River near Valdez. Collected Oct. 20, 1915, by B. L. Johnson; S. C. Dinsmore, analyst.
2. Copper River at Flag Point Bridge (mile 30) on Copper River & Northwestern Ry. Collected Sept. 24, 1915, by F. H. Moffit; Alfred A. Chambers, analyst.

STIKINE RIVER.

One analysis of the water of Stikine River, whose mouth is in southeastern Alaska, is given below. The sample was collected June 20, 1915, by G. A. Waring about 15 miles above Wrangell and was analyzed by S. C. Dinsmore. The river is said to be muddy always. The content of dissolved matter is very low, and the water represents in composition the drainage from rather insoluble silicate rocks.

Mineral analysis of water from Stikine River.

[Parts per million.]

Silica (SiO_2)	15	Bicarbonate radicle (HCO_3)	63
Iron (Fe)	.5	Sulphate radicle (SO_4)	15
Calcium (Ca)	21	Chloride radicle (Cl)	1.5
Magnesium (Mg)	3.6	Nitrate radicale (NO_3)[1]	Tr.
Sodium and potassium (Na+K)[1]	1.0	Dissolved solids at 180° C.	81
Carbonate radicle (CO_3)	.0		

[1] Calculated.

INDEX.

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Z.

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