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THE SCOTTISH GEOGRAPHICAL MAGAZINE.

ALASKA: ITS PHYSICAL GEOGRAPHY.

By ISRAEL C. RUSSELL.

(*With Map.*)

THE following account of the geography of Alaska is based to a considerable extent on personal observations, but includes also information obtained from books of travel, and from conversations with explorers, miners, navigators, traders, and missionaries in various parts of the country.

It has been my fortune to make three journeys in Alaska, each of which revealed something of the geography of that most interesting land. The first of these journeys was made in 1889, in connection with an expedition sent out by the U.S. Coast and Geodetic Survey for the purpose of determining the localities where the Alaskan-Canadian boundary crosses the Yukon and Porcupine rivers, respectively. We first touched the Alaskan shore at Unalaska, the principal commercial station on the Aleutian Islands, and from there crossed Bering Sea to St. Michael; we then ascended the Yukon by steamer to Selkirk House, in the North-west Territory of Canada, a distance of, approximately, 1500 miles, making on the way a trip up Porcupine river to near the 141st meridian. After reaching Selkirk House, I continued on up the Yukon in an open boat with a party of miners for about 500 miles, to Lake Lebarge, and, crossing the mountains on the south to the head of Lynn Canal, proceeded thence by canoe with a single Indian to Juneau.

The second and third journeys, in 1890 and 1891, comprised two expeditions to Mount St. Elias, which were put under my direction by the U.S. Geological Survey and the National Geographic Society. These expeditions were made for the purpose of climbing Mount St. Elias, of studying the geology and geography of that instructive region, and,

especially, of obtaining a better knowledge of the vast glaciers which cover it.

The more thoroughly one becomes acquainted with Alaska the more pronounced appear the contrasts in its physical features and in its plant and animal life. Owing to its high latitude, the summers are short and the winters long. In the northern portion, in summer, there are many weeks during which the sun does not set; and again, in winter, there are many weeks during which it does not rise. The climate of the south coast is mild and equable, while in the interior the winters are severe and the summers hot. The mountains on the south coast are the loftiest on the continent; but low moss-covered plains, featureless as a prairie, fringe the borders of Bering Sea and the Arctic Ocean. The central and southern portions are covered with dense forests, while the Alaskan peninsula, the Aleutian Islands, and the broad tundras at the north are treeless. In summer the lower slopes of the mountains are brilliant with fields of flowers; while the peaks towering above these smiling gardens are covered with snow and ice throughout the year, and form desolate, frozen solitudes in which not a trace of life can be seen. In places along the south coast great glaciers break off in the sea and send thousands of bergs afloat; while on the adjacent shore vegetation of tropical luxuriance overhangs the water. The south coast is fringed with thousands of islands, and its shore-line is one of the most intricate in the world; but the coast of Bering Sea and the Arctic Ocean is nearly free of islands, and is without inlets and harbours. The animals of this great northern land are clothed with warm furs which are among the most valuable that man has adapted to his use; but the birds are largely summer migrants from more sunny lands. Its native people are Eskimos and Indians. The white men who have wandered there are from every land and form a cosmopolitan band, in eager search for gold, silver, copper, coal, furs, fish, oil, whalebone, ivory, lumber, and other products of the land and sea. Missions have been established by many Churches, and the natives are being taught many religions. Portions of the land have been inhabited by Europeans for more than a century, while other portions have never been trodden by man, either civilised or savage. The south-eastern coast is visited every year by hundreds of tourists in quest of pleasure or of health; but in the interior there are tribes, speaking unknown tongues, who probably have never seen a white man.

Enough is not yet known of this remote corner of the world to enable one to thoroughly discuss the origin and history of its physical features, which is the aim of a geographer; but we can group together a limited number of facts bearing on various geographical questions, and reach certain general conclusions, and, perhaps, point the way for future study and exploration.

AREA.—In the absence of a survey of Alaska its area cannot be accurately stated, but is believed to be somewhere about 578,000 square miles, or approximately one-fifth as large as all the other States and Territories of the United States combined, and over eighteen times the area of Scotland. The general coast line is 4000 miles long, and,

including the shores of the bays and islands, is estimated to measure between 11,000 and 12,000 miles. These figures are so great that they will perhaps fail to convey any definite meaning. The vast extent of the territory belonging to the United States north of latitude $50^{\circ} 40'$ may best be realised by comparing a map of Alaska with a map of Europe, both drawn on the same scale.

BOUNDARIES.—The boundaries of Alaska were stated in a convention between Great Britain and Russia in 1825,¹ but have thus far been marked on the ground at only three points; these are where the 141st meridian crosses Forty Mile creek, the Yukon and Porcupine rivers respectively. In the treaty referred to it is stated that the eastern boundary, commencing at the southern point of Prince of Wales Island, in latitude $54^{\circ} 40'$, shall ascend Portland Channel to a point on the continent where it meets the 56th degree of north latitude. From there the line of demarcation shall follow the summit of the mountains situated parallel to the coast as far as the point of intersection with the 141st meridian; the said meridian shall then be the boundary to the Arctic Ocean. It is further stated that, whenever the summit of the mountains which extend in a direction parallel to the coast between latitude 56° and the intersection of the 141st meridian shall prove to be at a distance of more than ten marine leagues from the ocean, the limit between the British possessions and the strip of coast now belonging to the United States shall be formed by a line following the windings of the shore and not more than ten marine leagues therefrom.

The interpretation of this treaty is now a matter of international consideration, and need not be discussed here. But it is proper to direct the attention of both Canadian and American geographers to the fact that our knowledge of the region through which the boundary passes is exceedingly meagre. Before the questions in dispute can be settled, both of the "high contracting parties" must acquire more definite knowledge than they now have of the geography, mineral wealth, timber, and other resources of the region, as well as of the character and the rights of its native inhabitants. This can only be done by a systematic and comprehensive survey. In the absence of such a survey, not only will it be impossible to establish the boundary line designated in the treaty, but no modification of the treaty can be made which will be both practicable and just.

The western boundary traverses the waters of Bering Sea and the Arctic Ocean, and its determination does not involve the partitioning of valuable territory.

DRAINAGE.—Alaska is drained principally by one great river, the Yukon, which rises in the north-western part of Canada, flows westward across the Territory, and empties itself into Bering Sea. Alaska is divided by this noble river into two approximately equal portions.

¹ The text of this treaty may be found in a report of the Boundary Line between Alaska and British Columbia, Fiftieth Congress, second session, *Ex. Doc.* No. 146, Washington, 1889.

The Yukon ranks with the great rivers of the world. Among those of this continent it is second in drainage area. Its length is about 2000 miles, and its hydrographic basin, half of which lies in Alaska, is approximately 440,000 square miles in extent.

The valley of the Yukon is bordered by gently rolling uplands with a well-developed secondary drainage, showing that it has a long history, during which a large part of its appointed task of reducing its drainage basin to a plain surface has been accomplished. During its life, however, changes have occurred which have modified its action and greatly increased the amount of excavation and transportation that it has to do. Mountains have been upraised across its course, as at the Lower Ramparts, which have changed the grade of the stream and caused it to spread out a vast sheet of sediment above the obstruction, and form a plain through which the river now flows in many intersecting passages. Lakes were also formed by the warping of the river valley, but these are now drained, and stream channels have been excavated through the thick horizontally stratified sediment that they left. In these deposits of clay and sand the bones of many large animals, now extinct, were entombed. In some places, as at the mouth of Pelly river and again at Miles Cañon, lava streams have descended into the previously excavated channel, and formed level-floored valleys, bordered by the walls of the ancient stream. These sheets of hard basalt, in one instance several hundred feet thick, have been cut through by the river, forming cañons, the walls of which are still vertical. These obstructions of volcanic rock also led to the formation of lakes above them, in which thick sheets of fine, light-coloured, evenly stratified sediment were deposited, as may be seen along the beautifully terraced banks of the various branches of the main river to the east of the Alaskan boundary. The country drained by many of the southern feeders of the main stream was at a recent date covered by a northward-flowing ice-sheet, and its history still further modified.

These accidents, as they may be called, affected especially the upper portion of the drainage system, and left its lower course comparatively free to broaden its channel and cut away the land between its many branches. The lower Yukon valley is so broad in many places that to an observer standing on its northern margin the uplands bordering it on the south are beyond the reach of vision. In this ancient valley, owing to a moderate change of level, sediment has been laid down, forming vast swamps through which the stream now winds, and which are overflowed during spring freshets. A vast delta has been formed where the mighty river empties itself into Bering Sea, comparable in extent and in character with the alluvial lands near the mouth of the Mississippi. Near the head of its delta, and more than a hundred miles from the sea, the Yukon divides, and its diverging branches again subdivide, so that its brown waters are discharged through many mouths. The distance between the extremities of the channels into which the river separates is over seventy miles. Seaward from where the mouths of the river are now located the water is shallow, owing to the vast amount of fine silt that is dropped when the currents of fresh water meet the saline water into

which they flow. It sometimes happens that a vessel in approaching the delta finds itself aground so far from land that no shore is in sight. Large quantities of drift-wood are carried down by the river from the forested region drained by it, and cast ashore on distant islands and along barren beaches, hundreds of miles from the delta, and furnish the only wood supply for many Eskimo villages.

On the Yukon, as on many rivers flowing northward, the changes of the seasons are first felt on its head waters. Vast floods, accompanying the breaking-up of the ice in the spring and early summer, inundate broad areas of the valley bottom and frequently form ice-dams, thus still further increasing the height of the annual floods. The spectacle presented by the swollen river when crowded with broken ice is said to be among the most striking of natural phenomena.

Among the many tributaries of the Yukon the most important is the Tannah, which rises on the northern ice-covered slopes of the Alaskan mountains, and, flowing north-west through a broad forest-covered valley, joins the main stream over six hundred miles from its mouth.

Another important tributary, known as Porcupine river, rises far to the north-east, near the lower course of the Mackenzie, flows south-west, and joins the Yukon below the site of Fort Yukon, or nearly a thousand miles from Bering Sea. The land drained by the Porcupine is north of the Arctic Circle, but in general character differs but little from many regions in more favoured latitudes. During my first trip to Alaska I ascended the Porcupine for about 150 miles. The river is swift, and flows with many windings through a forested land, which has a history inscribed in its hills and valleys that tells of many changes. Its lower course is through flat bottom land, which has been filled in with sand and gravel by its own waters; but about seventy-five miles from its mouth the uplands on each side come close together, and above that point the stream flows through a well-defined valley, separating grass-covered hills. Sand and gravel deposits, seen in a few places on the uplands, suggest that the general plateau surface is an old river valley of great width or an ancient base-line of erosion, in which the present stream has sunk its bed to a depth of, perhaps, two hundred feet.

In July, the month in which I saw the Porcupine, the country presented a charming picture of rounded hills, covered with a luxuriant growth of grasses and flowers, overlooking flat bottom lands densely covered with spruce trees and aspens. The swift-flowing river in places gleamed brightly in the sunlight, and again was lost in the shadows of the overhanging forest. The hills were just changing from green to brown, and a dash of yellow here and there amid the foliage of the river-bank told that the short, hot, dry summer, during which the sun did not set, was drawing to a close. The fair landscape gave no suggestion of Arctic severity, but was so mild and peaceful, so rich in colour and pastoral in character, that it lacked but a farmhouse here and there to make one fancy that a part of New England was spread out before him.

The most distant sources of the Yukon are in numerous lakes on the northern slope of the mountains bordering the southern coast, among which the scenery is unsurpassed in picturesqueness and variety. The

lakes on its head-waters are in a region formerly ice-covered, and many of them owe their origin to the scooping-out of basins by glacial action, and to the obstruction of drainage by glacial deposits. Some of the broad sheets of placid waters are clear and blue, and surrounded with dense vegetation, while others, situated in a desolate area above the timber-line, receive the drainage of glaciers, and the transparency of their waters is changed to yellowish-green by fine sediments. The presence of glaciers on its head-waters accounts in a great measure for the muddiness of the stream throughout. In all its lower course it is as heavily charged with sediment as is the lower Mississippi or the Missouri. In voyaging up the great river one is struck with the fact that nearly all the tributaries from the south are heavily loaded with silt, while those from the north are clear and limpid. This is because all of the larger streams emptying into it from the south have their sources in the immediate proximity of existing glaciers, the drainage of which is always turbid; while the streams from the north drain a forested and moss-covered region in which there are no glaciers, and the water, having to filter through dense vegetation before reaching the drainage ways, is exceptionally clear, although frequently of an amber hue on account of the vegetable products in solution. The muddiness of the tributaries from the south, however, is not due entirely to the presence of rock-flour ground fine by glaciers, but is owing in part to a widely spread layer of volcanic dust, which has been recently deposited over thousands of square miles of territory, and is so easily eroded that it is washed into the general drainage by the rains. As has been shown by Dr. C. Willard Hayes, this is the principal cause of the extreme turbidity of White river, which, as its name suggests, is of a whitish colour, and owes its muddiness to the immense amount of volcanic ash and glacial mud that it carries.

The great divide of the Alaskan region is along the crest of the mountains close to the south coast. In many places the rain falling on the southern side of this sharp crest-line reaches the ocean within less than a score of miles, while that falling on the north side finds its way to the Yukon, and has to travel more than two thousand miles before reaching the sea.

The Yukon has been ascended by stern-wheel steamboats of light draught as far as Selkirk House, a distance of about 1500 miles from Bering Sea, and is known to be navigable to a still greater distance. The current towards its head-waters, however, is so swift in places, that steamboats more powerful than those now used would be needed for its navigation. With the exception of the rapids at Miles Cañon, where for a mile the stream rushes through a narrow gorge in basaltic rocks, the river is navigable as far as Lake Tagish, on the Pelly, and to Lake Ahklen near the source of the main stream. Many of the tributaries are also known to be navigable, although only a few have been systematically examined. Thousands of miles of inland waters there await the coming of explorers and traders, but owing to the severity of the winter climate they can only be traversed during a few months each year. In summer these rivers are the highways for the native inhabitants in their birch-

bark canoes; and in winter they are no less favourable lines of communication, as they can then be traversed with facility by means of sledges drawn by dog-teams. Should reindeer be introduced into Alaska, as is now hoped, the rivers may be followed with even greater facility in winter than in summer. The importance of the streams to the traveller is enhanced by the fact that there is not a road in the country, and scarcely a trail, that can be followed when the dense vegetation is not deeply snow-covered.

The drainage of the southern coast, from Dixon's Entrance to the end of the Alaskan peninsula, is mostly performed by high-grade streams issuing from beneath glaciers; but there are a few rivers which cross the mountain barrier near the coast, and afford means of communication with the interior. These are the Stikine, Taku, Alsek, and Copper. The Stikine has been ascended by steamboats for a distance of about two hundred miles, but the others have never been navigated, except by canoes. It is known that steamboats could ascend the Taku for a distance of about forty miles, but the Alsek and the Copper are too swift for this purpose. These streams are without broad valleys, but are bordered by exceedingly rugged mountains, and are surrounded by some of the most magnificent scenery in the world. Their present channels have many of the characteristics of young rivers, but the deep fiords at their mouths and their glaciated walls show that they have undergone a recent change, which has removed to a great extent the records of the tasks they have already accomplished.

North of the Alaskan peninsula, and emptying into Bering Sea, there are several important streams, although appearing insignificant when compared with the great Yukon. Of these the Kuskokwim is the largest. It rises among the ice-filled valleys on the west slope of the Alaskan mountains, and drains an area of about 800,000 square miles. To the north of the Yukon there are several small rivers as yet only partially explored; the largest of these, the Kowak and the Noatak, as shown by the explorations of Lieutenants Cantwell and Allen, are navigable. The Arctic coast of Alaska is but little known, and no streams of importance have been discovered there. Their supposed absence may be due to lack of information, or possibly to the fact that the country for a long distance inland is a low, moss-covered, swampy area, in which even important streams may spread out and lose their individuality.

MOUNTAINS.—The vast cordilleran system which follows the west coast of both South and North America traverses southern Alaska, and, bending westward, follows the coast to the end of the Alaskan peninsula. The partially submerged continuation of the same system forms the Aleutian islands, more than a thousand miles in length. The culminating points of this great system in North America are two rival peaks, Mt. Logan, 19,500 feet high, and Mt. St. Elias, 18,010 feet high. A host of neighbouring peaks, several of which exceed 14,000 feet in elevation, make this region one of the most rugged and impassable in the world. For fully three hundred miles from Cross Sound westward the mountains rise precipitously from the sea to great heights, and above an elevation of

about 2500 feet are always snow-covered. In vast *névé* fields, filling the valleys and depressions among the higher peaks, thousands of glaciers have their birth, and flow both north and south. Among those on the southern slope of the mountains there are hundreds which practically reach sea-level, and scores that discharge into the waters of the Pacific. These mountains are portions of a great system, but many independent ranges are known, and it is probable that future explorations will show that they have an extremely varied and, perhaps, a very long history. In the neighbourhood of Mt. St. Elias the ranges are monoclinical, and agree in general structure with the Great Basin system more closely than with any other mountain type now known. In common with all lofty mountains, St. Elias is young. The foot-hills near the ocean have been elevated at least 5000 feet during the existence of species of marine molluscs now living in the adjacent waters, and it is probable that the main uplift received an important increment at the time the foot-hills were raised above the sea. Since the mountains were uplifted, ordinary stream erosion seems to have had but little to do with their sculpturing; glaciers took possession of the depressions as soon as they were raised above the ocean, and the subsequent modifications of their forms have been largely due to ice-action. A novel feature in their history is the fact that the ice-drainage is consequent upon the prevailing geological structure. Too little is known, however, of this exceedingly rugged region to allow us to speak with much confidence concerning its geological history. North of Mt. St. Elias there is an extremely rugged country where man has never penetrated. This region bristles with lofty peaks overlooking ice-filled valleys, from which many magnificent glaciers flow. A lofty peak, in about latitude $63^{\circ} 30'$ north and longitude 147° west, has been seen from a distance by a few trappers and traders, and is thought to rival even Mt. St. Elias in height and magnificence. Problems of great geographical and geological interest there await the explorer, and in no other portion of our country can one expect to obtain a greater return for hardship and exposure than in this wild, ice-bound land.

The mountains on the Alaskan peninsula and the principal peaks of the great Aleutian chain are many of them surprisingly rugged, and rise to great heights; but as yet little definite knowledge is available concerning them. Many of the mountains are known to be of volcanic origin, and some are still active volcanoes. As seen from the ocean, the land appears wonderfully rugged and magnificent.

To the north of the great system of mountains fringing the Pacific coast there are many minor uplifts reaching elevations of probably 4000 or 5000 feet, the summits of which are above the timber-line and add variety and beauty to the great inland region. But none of these peaks has been climbed, and but few intelligent white men have ever seen them. Their outlines and distribution have never been mapped, and their heights are known only by estimate. They are bare of snow in summer, and no glaciers exist upon them. They do not possess the graceful double curves typical of volcanoes, but frequently present the outlines of uplifts that have been long exposed to atmospheric erosion. When they become

known it will probably be found that they are composed of older rocks than the higher mountains in the south, and belong to a more ancient chapter in the earth's history.

VOLCANOES AND HOT SPRINGS.—The only active volcanoes in the United States are in Alaska. In the Alexander archipelago, on the Alaskan peninsula, on the Aleutian and neighbouring islands in Bering Sea, there is a large number of mountains of volcanic origin, about ten of which are now active; those that now show no signs of activity are proved by their symmetrical and uneroded contours to be of very recent date.

In the Alexander archipelago volcanic energy is now dormant, and the mountains are silent and cold; but some of them are reported to have been in eruption during historic times. The mountains from which lava and volcanic ashes have been ejected within the past few years are situated west of Cook's Inlet on the Alaska peninsula, and on the Aleutian islands. Frequent eruptions in this region are reported to have occurred within the past hundred years, some of which would have been very destructive had they occurred in more thickly settled regions. Fragmentary accounts of these catastrophes, obtained principally from the Russians, have been summarised by Dall; and observations made since the country came into the possession of the United States show that the subterranean energies have by no means been exhausted. Within the past few months a volcanic eruption of marked violence has occurred in Shumagin island, where similar phenomena were previously unknown. The most beautiful of volcanic mountains now known is Mount Shishaldin, on the island of Unimak. This mountain is about 8000 feet high, and is a symmetrical cone with gracefully curving sides of the same type as Fusi-yama. The wreath of steam emerging from the crater at the summit can be seen for scores of miles out to sea, and, like the light in the sky above Stromboli, is a beacon eagerly looked for by mariners. Another volcano, known as Pogumnoi, on the same island, is also reported to have been in action in recent years, and has been the centre of severe earthquakes. Mount Makushin, on the Unalaska islands, is the only volcano in the region which has been climbed. It is known to have been mildly active for many years. The greatest eruption in modern times has been from a small volcano known as Bogoslof, some 60 miles west of Unalaska. Remarkable changes in this island have been noted from time to time by officers of the U.S. Revenue Marine, and showers of ashes erupted from it have darkened the sky over hundreds of square miles in its vicinity, and in a few instances have fallen to a depth of several inches at Iluiliuk, and on the decks of vessels still more distant.

The greatest eruption of volcanic dust which has occurred in the Alaskan region in recent geological times took place from an unknown crater supposed to be located about 75 miles north of Mount St. Elias, and was carried north-eastwards by the prevailing air-currents to a distance of fully 100 miles, covering an area of not less than 20,000 square miles to a depth varying from a few inches to 50 feet.

In the volcanic belt extending from the Alexander archipelago to the end of the Aleutian Islands there are many hot springs, some of which

are highly charged with mineral matter, and are used as medical baths by both Indians and white men. This great belt, over 2000 miles long, has also been visited by several earthquakes from time to time, and in certain instances these disturbances are known to have been directly connected with volcanic eruptions. The history of these various phenomena has been but imperfectly noted, and their geological records have not been studied; but enough is known to show that important changes are in progress which are well worthy of the attention of the geographer and geologist.

TUNDRAS.—In contrast with the lofty mountains on the south coast, and illustrating the diversity so characteristic of Alaska, are the low, nearly level, moss-covered plains from 70 to 100 miles broad, forming the shores of Bering Sea and the Arctic Ocean. Possibly a comparatively recent and very moderate elevation of the gently sloping shores has taken place, forming plains, broken in some places by low volcanic mountains. On these desolate moorlands there grows a low, dense vegetation peculiar to high latitudes.

The word *tundra* is used in Siberia to designate the vast, treeless, moss-covered plains bordering the Arctic Ocean, and has been adopted for similar regions on the northern shores of America. During the summer the tundra is a swampy, moderately level country covered with mosses, lichens, and a great number of small and exceedingly beautiful flowering plants, together with rushes and ferns. The most conspicuous plants are dwarf willows, which attain a height of, perhaps, two feet. The soil beneath the luxuriant carpet of vegetation is a black humus, and at a depth in general exceeding a foot or thereabouts is always frozen. On the surface of the tundra there are many lakelets and ponds, surrounded by banks of moss, which grows even more luxuriantly than on the adjacent areas. The dense tundra vegetation extends up the sides of the hills that occasionally break the monotony of the plain, and is very similar to the deep mat of living plants decked with Alpine flowers which add such an indescribable charm to the mountains of southern Alaska at the upper limit of timber growth. The dense vegetation forming the tundra changes by imperceptible gradations to dead and decaying matter a few inches below the surface, and finally becomes a black, peaty humus, which retains but few indications of its vegetable origin. In many instances, observed near St. Michael and on the delta of the Yukon, the depth of the peaty layer was from 2 to more than 15 feet. In other localities a depth of 150 to 300 feet has been reported. The accumulation of this highly carbonaceous layer depends on the fact that vegetation grows luxuriantly at the surface, while it dies and partially decays below, but is frozen before complete decomposition takes place. This process is similar to that which occurs in the formation of peat bogs, except that a great variety of plants take the place of *Sphagnum*, and the subsoil is always frozen.

Over hundreds of thousands of square miles on the bleak Arctic coast, both of America and Europe, deposits of vegetable matter are accumulating in the manner just described, which rival in extent and thickness

the greatest coal-fields in the world. The suggestion naturally follows that coal may in some instances have originated under conditions similar to those now admitting of the formation of tundras.

ISLANDS.—Should a deeply dissected mountain range adjacent to the ocean be depressed a few hundred feet, the valleys would become flooded and form bays, straits, and sounds, surrounding bold islands and headlands. It is generally true that the submergence of a coast tends to the formation of islands, and that, conversely, emergence tends to unite previously outstanding areas with the mainland. This proposition, to which there may be many exceptions, is illustrated on our north-west coast. From Puget Sound to Glacier Bay and Lynn Canal the coast is fringed by hundreds of islands forming an archipelago more than a thousand miles long. Mount Tacoma and Mount Fairweather are monuments marking the extremities of a vast system of land-locked ocean waters through which the largest ships can sail for a thousand miles in one general direction without entering the open sea. The magnificence of this celebrated "inland passage" is already well known to thousands of tourists, and has been amply described by writers who are better able than myself to give graphic pictures of its many attractions. This vast archipelago owes its origin to a recent subsidence of the coast, which has changed glaciated river valleys into placid waterways. West of Mount Fairweather to beyond Mount St. Elias, the coast for a distance of more than 300 miles is practically free of islands, and the mountains on the border of the continent rise boldly from the ocean. There is evidence of a recent rise in the land of this region which may account for the unbroken character of its shore line. West of Mount St. Elias the island-fringed coast again begins, and extends to the end of the Alaskan peninsula, beyond which lie the Aleutian Islands, forming a narrow chain over a thousand miles long, where only the summits of the higher mountains rise above the ocean's surface. Terraces in this region at elevations of a few hundred feet above the sea show that a reverse movement has been initiated, and that future changes will be in the direction of uniting the various detached land areas.

The continental plateau to the north of the Aleutian Islands is submerged to a depth of from 200 to 500 feet, and is occupied by the waters of Bering Sea. On this plateau there are a few volcanic mountains of recent date which rise above the ocean surface, but no remnants of true mountain uplifts. A more detailed survey of Bering Sea may show that its bottom is traversed by stream channels, and may thus, perhaps, furnish physical evidence of a recent land connection between America and Asia.

All of the west and north coast of Alaska is remarkably free from islands, which suggests, as do many other facts, that the land has there experienced but moderate changes of level. The contrast between the island-fringed shores of Southern Alaska, together with the extension of the same system of archipelagoes to the westward, where the continental plateau is below sea-level, and the comparatively unbroken coast-line forming the shores of Bering Sea and the Arctic Ocean, where there

is scarcely a harbour in which a ship may take refuge, suggests many lines of inquiry.

CLIMATE.—The climate of Alaska, like its physical features, presents marked contrasts. On the south coast the rainfall is excessive, amounting in some observed instances to more than 100 inches in a year. A series of observations made at Sitka by Russian observers for twenty years gave a mean annual precipitation of over 83 inches. A belt of extreme humidity extends westward along the coast, probably increasing in breadth until Mount St. Elias is reached, and then diminishing in the vicinity of the Aleutian Islands. In the interior it is much drier, as is known from the experience of travellers, and also from a limited number of observations. At Camp Davidson, where the Yukon crosses the 141st meridian, as observed by Mr. M'Grath, of the U.S. Coast and Geodetic Survey, the precipitation from September 14, 1889, to June 22, 1891, was but 19·05 inches; for the year 1890 it was 13·55 inches. On the northern coast, in common with other portions of the Arctic zone, the annual precipitation is small; at Point Barrow, as observed by the International Polar Expedition in charge of Lieutenant Ray, the rainfall for 1882 was a little over 8 inches.

The aridness of the interior and northern portion of Alaska may thus be compared with that of the arid region between the Rocky Mountains and the Sierra Nevada. The humid region along the south coast is a continuation of the rainy belt of Oregon and Washington. The excessive rainfall on the southern coast is accompanied by cool summers and by remarkably mild winters. The mean annual temperature at Juneau and Sitka is about 50° F. The temperature seldom falls below zero (F.). The winters are milder than at Chicago or Boston, and are not marked by the extremes experienced in New York or Washington. In the interior the summers are warm, and occasionally the temperature rises to between 90° and 100° in the shade; but in winter the cold is excessive, and a temperature 40° or 50° below freezing-point is frequently experienced for many days in succession. The difference in climate between the coast and the interior is, perhaps, most strongly indicated by the character of the vegetation. On the coast east of Mount St. Elias the forests are dense, the trees are large, and the undergrowth nearly as impenetrable as in the Tropics. In the interior the forests are almost entirely of spruce trees of small growth, which are confined to the river valleys, while the hill-tops and mountain-sides are bare of trees and covered with luxuriant grasses.

The marked climatic differences between the coast and the interior also find expression in the distribution of the glaciers, which are of great extent among the mountains on the coast, but are entirely wanting on elevations 4000 or 5000 feet high, situated near and even north of the Arctic Circle.

OCEAN CURRENTS.—The principal cause of the great contrast between the climate of Southern Alaska and of the interior is to be found in the currents of the Pacific. A great current of warm water comparable with

the Gulf Stream is described by hydrographers as starting in the neighbourhood of Japan, and flowing eastward and northward across the Pacific to within 800 or 900 miles of the American coast, where it divides, one portion turning north and bathing the southern coast of Alaska. The mean temperature in the path of this river in the ocean near the Alaskan coast is about 50° F. The effect of such a vast perennial supply of warm water impinging upon the land is to warm the atmosphere and charge it with moisture. The prevailing winds, at least in summer, are from the south, and are warm and moist. Blowing against lofty ice-covered mountains, they are forced upward, and become cooled, part with their moisture, and envelop the land in mists and clouds. Descending to the lower region in the interior, they become dry winds, which instead of giving out moisture promote evaporation. A more complete knowledge of the ocean and atmospheric currents in this region would throw much light on the origin of glaciers and the conditions which initiate glacial epochs.

GLACIERS.—The ice-fields of Alaska are a portion of a great system which begins at the south in detached masses of ice on the summit of the High Sierra in California in about latitude 37°, and extends northward along the cordilleran system through British Columbia and Southern Alaska to the end of the Alaskan peninsula, embracing also some of the islands of the Aleutian chain. This belt reaches its maximum development in the St. Elias region, where the mountains for fully 80 miles inland from the coast are literally buried beneath vast *névés* from which great glaciers flow both north and south. This ice-covering diminishes in breadth towards the west, and on the Alaskan peninsula and the Aleutian Islands becomes broken into detached glaciers of the Alpine type. In the High Sierra the lower limit of the glaciers is from 12,000 to 13,000 feet above the sea, but they descend lower and lower as one follows them northward, until, in Southern Alaska in about latitude 57°, they flow into the ocean and become "tide-water glaciers." In the St. Elias region there are hundreds of magnificent ice-streams which come down practically to sea-level, while many enter the ocean, and, breaking off, form cliffs of clear ice from 200 to 300 feet high. Farther westward the lower limit of the ice again rises, and glaciers are found only on the mountains.

The glaciers of Alaska are, with the exception of those of Greenland, the largest and most instructive in the Northern Hemisphere. The snow falls in vast quantities, and accumulates year after year and century after century, and would build up the mountains to vast heights were it not for the fact that it is drained away in ice-streams which play the same part in relieving the mountains from snow as rivers do where the mean annual temperature is higher. The snow, becoming compacted into ice, acquires a motion along lines of depression principally on account of its own weight, and flows like a plastic body through the valleys to lower regions, where it melts away. The glaciers formed among the mountains are of the Alpine type, and are much larger on the southern than on the northern sides of the highlands. Many of the ice-streams, on leaving the mountains and emerging on to the flat lands at their

base, where they have room to expand, spread out in all directions and form delta-like masses of ice of the type illustrated on a small scale by the Rhone glacier in Switzerland. The best-known example of this phenomenon in Alaska is Davidson glacier, near the head of Lynn Canal, which expands into a broad, semi-circular plateau of ice at sea-level. Many of the neighbouring glaciers, as already stated, enter the ocean, usually at the head of wild fiords, and, breaking off, form magnificent ice-cliffs which are among the strangest and most picturesque features of the wild coast where they occur. The most widely known tide-water glaciers are the Taku glacier, at the head of Taku Inlet, and the Muir glacier, at the head of Glacier Bay. Splendid ice-cliffs are also formed by the glaciers which flow into Disenchantment Bay; but the most magnificent example of all occurs where the Malaspina glacier enters the open ocean and forms what is known as Ice Cape, just south of Mount St. Elias.

The largest and, from a geological point of view, the most instructive glacier yet discovered in Alaska is the Malaspina ice-sheet, situated on the coast south of Mount St. Elias. The glaciers of the Alpine type, draining the ice-fields on the lofty mountains to the north for a distance of fully 75 miles, contribute to the formation of this great ice-sheet in much the same manner as mountain streams unite to form a lake. The glaciers on leaving the mountains expand and unite on the flat lands adjacent to the sea, and form a nearly level plateau of ice about 1500 square miles in extent. This is the type of a class of ice-masses termed "Piedmont glaciers," which has not been recognised elsewhere. The general elevation of its surface is about 1500 feet. In the central portion it is free from moraines and dirt, and presents the appearance of a vast snow-covered prairie without surface streams and destitute of all traces of life. At its borders it is covered with a belt of boulders and stones, forming a fringing moraine some 10 or 15 miles broad, the outer margin of which is overgrown with dense vegetation consisting principally of spruce trees, in many instances 3 feet or more in diameter. This striking example of a forest growing on a glacier, although novel before the study of the glaciers of the west coast began, is not confined to the example cited, as many of the smaller glaciers in the same region on both sides of the mountains are similarly buried beneath forest-covered *débris*.

The Malaspina glacier is drained by sub-glacial or englacial streams, flowing in tunnels and emerging at the margin of the ice from beneath low archways, or rising under great pressure as immense springs just at the base of the escarpment formed by the border of the glacier. The streams on issuing from the ice bring out vast quantities of gravel and sand from the tunnels through which they flow, and deposit it in alluvial fans, some of which are many square miles in area. These deposits consist of stratified and waterworn material, which in several instances is being deposited over a forest-covered region, and is burying the vegetation in such a way as to form what in formerly glaciated regions is sometimes designated as a "forest bed." The stratified material spread out about the borders of the glacier is more extensive and of greater geological

interest than the *débris* carried upon its surface. Connected with the alluvial fans about the margin of the glacier there are deposits of gravel forming in the tunnels beneath the ice that have many of the characteristics of the "osars" (known in Scotland as "kames," and in Ireland as "eskers"), which have been such a puzzling feature in ancient glacial records both of Europe and America.

Another interesting fact connected with the great ice-belt which has its greatest development in Southern Alaska is, that from one end of the series to the other, a distance of fully 3000 miles, the glaciers are slowly retreating, and probably have been receding for the past one hundred or one hundred and fifty years. The amount of this recession in the case of the glaciers at the head of Yakutat Bay is known to be four or five miles; and at the head of Glacier Bay the retreat is thought to have been not less than fifteen miles during the past century.

Space will not admit of a more extended account of the wonderful glaciers to which attention has been directed; but any one who visits Alaska even as a summer tourist cannot fail to be charmed with the variety and beauty, both of form and colour, which they impart to the stern scenery.

SUBSOIL ICE.—In describing the tundras it was mentioned that at a depth exceeding a foot beneath the surface the soil is always frozen. This condition prevails also in many places in the interior of the country where other characteristics of tundras are absent. In many places along the Yukon for 1500 miles from its mouth the banks are formed of horizontal sheets of ice many feet thick, which is covered with moss and supports a dense forest of spruce trees. The thickness of the frozen stratum beneath the moss-covered flat lands of the interior has never been determined, but in a few localities a depth of more than 25 feet has been penetrated without reaching the bottom. In some instances the frozen layers seem to have been preserved by the deposition of silt and mud over them during spring freshets, thus sealing them up and preserving them until additional layers are formed above, and ensuring their preservation for ages. But many observations, both in the northern part of North America and in Siberia, show that a great depth of subsoil ice frequently occurs in situations where it is not probable that it could have been formed by the freezing of the surface waters during the winter. In such instances it seems that the frozen layer represents the excess of winter freezing over summer thawing for a long period.

A frozen subsoil is a novel feature to most people, and frequently forcibly attracts the attention of travellers in Alaska. Many times during the hot summers, while the temperature is from 90° to 100° F. in the shade, and there is no night to bring relief and rest, one may brush away the moss at his feet and find solid ice beneath. These conditions occur also, as already stated, in the tundras along the shore of Bering Sea and the Arctic Ocean, and probably exist in the flat lands bordering many of the rivers of the interior. On the Kowak river, as described by Lieut. Cantwell, there are bold ice-cliffs from 125 to 150

feet high; these are the most striking examples of frozen subsoil that have been reported.

FORESTS.—The summer traveller to Sitka, Juneau, and Lynn Canal is usually deeply impressed with the extent and value of the forests clothing the shores along which he sails. The most important trees in this region are two species of spruce, but there is in addition the yellow cedar, concerning the value of which much has been written. The yellow cedar is found sparingly throughout South-eastern Alaska, and reaches as far westward as Yakutat Bay. The trees are often fine and large, and reach a height of 150 to 200 feet. The wood is fragrant, light yellow in colour, and very durable. It is said to be especially valuable for ship-building. Unfortunately, the supply is not so great as has frequently been stated, and should the forests of Alaska be thrown open to lumbermen the tree will soon be exterminated. The two species of spruce which make up 99 per cent. of the forests are the Menzies, or Sitka spruce, which is very abundant, and the Marten spruce, or hemlock, which grows luxuriantly, especially in the sheltered valleys among the foot-hills, and forms one of the most beautiful forests of any of the *Conifere*. Besides the trees already mentioned, there are birches, maples, alders, and wild apples, which grow sparingly and have no commercial importance.

Beneath the dense shades of the sombre, moss-draped forests there is a great variety of shrubs, ferns, and lichens, and many bushes which produce edible berries. Of these the huckleberry and salmonberry are in greatest profusion and of greatest value. In open places near the coast strawberries of fine flavour grow luxuriantly. In a grassy meadow bordering the coast south of Mount St. Elias I found luscious strawberries growing in the greatest profusion. The ground was literally white with blossoms in June and pink with ripe fruit in August. Everywhere in the shade of the evergreens the ground is thickly covered with moss and lichens, growing so closely that they form a continuous carpet into which one sinks knee-deep at every step. This brown-green mantle not only covers the ground and conceals fallen tree-trunks, but grows on the trunks and branches of the trees still standing, so that it is one of the most prominent features in the sombre woodlands.

The dense forests to which attention has been directed are confined to South-eastern Alaska, where the air is humid and the temperature remarkably uniform. It is in this region that by far the most valuable trees grow, and it is here only that timber available for building purposes is likely to be found. To the west, along the coast, the forests come to an end at Kadiak island, and all the land to the westward, including the Alaskan peninsula and the Aleutian Islands, is treeless.

Nearly all the region drained by the Yukon and the neighbouring streams is forest-covered, but the trees have an Arctic character, and except along some of the river bottoms do not usually attain the size necessary for lumbering purposes. The most common—indeed the only tree of importance—in the interior is the white spruce, which furnishes an inferior wood for commercial purposes, and is seldom of large size. It

is frequently stated that Alaska is a great timber reservation; but, so far as my own information goes, this term should be applied only to the coasts and islands of South-eastern Alaska, and even then with limitations.

ANIMAL LIFE.—The large game of Alaska consists of moose and cariboo, formerly abundant throughout the interior; bears of at least two species, the black and the brown, roam over nearly every portion of the mainland; deer live on the islands in the south-east; flocks of mountain sheep and mountain goats graze on the highlands both near the coast and in the interior. Of fur-bearing animals the most important are the sea-otter and fur-seal, land-otters, martens, beavers, minx, ermine, black, silver-crossed and red foxes, besides the bears already mentioned. The commercial value of the furs of these various animals is too well known to call for remark in an article of the present character. Hair-seals occur in abundance along the entire coast-line, and are a most important article of food for a large part of the native inhabitants. When the value of their skins for leather and other purposes becomes more widely known, they will no doubt form an important article of commerce. The Beluga or white whale is a common article of food with the Eskimos, and is taken many miles up the Yukon. Bird life is abundant and varied, and many migrating birds have their summer breeding-ground there. In the autumn immense flocks of geese and crane may be seen high in the air flying southward. Swans are not rare, and ducks of various species abound. Ptarmigan are common both near the coast and in the interior.

Nearly all of the streams emptying themselves into the Pacific and into Bering Sea abound in food fishes. Salmon and sea-trout are to be seen in myriads at certain seasons, and halibut, cod, herring and other fishes may be taken in quantities off the coast. The value of the fisheries of this region is already very great, and in the future will no doubt be the basis of the largest industries of the north-west coast.

MAN.—Alaska, like other portions of America, was peopled by many tribes before the coming of Europeans. The diversity in customs and language, arts and traditions, among these peoples is even greater than among the native tribes of the central and southern parts of the continent; thus indicating that they have been separated into families and tribes for a period sufficiently long for diverse languages and arts to arise. Their tribal life has been in many instances of such long duration that its origin is lost in the obscurity which preceded tradition. Their myths and folklore give but slight, if any, indication whence they came or from what older stock they sprang.

Those who have studied Alaskan ethnology most thoroughly are of the opinion that the north-western portion of this continent was not peopled from Asia, as is popularly supposed, but consider that all of the tribes of Alaska, including even the Eskimos, are descendants from aboriginal stocks in the more central part of the continent.

The natives of Alaska form two main groups or stocks known in popular language as Eskimos and Indians. The natives of the north and west coasts and the Aleutian Islands have been designated as Orarians by

Dall, and have two divisions, Innuits and Aleutians. The Indians are also divided into two principal stocks; those in the interior being known as Tinnéh or Athabaskans, and those of the south-eastern portion as Thlinkets [Tlingit].

The hardy Eskimos have chosen their homes on the bleak, inhospitable north and west coasts facing the Arctic Ocean and Bering Sea, where frozen tundras extend for scores of miles inland, and not a tree breaks the monotony of the sombre moorland. Winter there reigns for eight or nine months, and the summers are rainy and foggy. These people are confined to a narrow strip along the shore, which widens to perhaps one hundred miles where the Yukon and Kuskokwim enter the sea. As is well known, this same great stock extends around the Arctic shores of the continent to Labrador and Greenland. Strange as it may appear to the inhabitants of more favoured lands, these people shun the forests, preferring the open tundras and low bleak coasts, where the only wood for fuel or for shelter is such as is cast ashore by the waves. They are fed and clothed by the products of the sea. The hair-seal is to them what the coconut palm is to many tribes in the Tropics.

Skin boats or kayaks are the most characteristic and typical of the many products of their skill, and compare favourably with, if they do not excel, any similar crafts used by other peoples. These remarkable boats are made of parchment-like seal-skin stretched tightly over a light frame of driftwood, so as to leave only a round hole through which the body of the occupant projects as he sits flat on the bottom. Some of the larger kayaks have two or three openings, and in this respect differ from the similar crafts of the Labrador coast, which, as I understand, are made for a single occupant. These strong, light boats are models of grace and buoyancy. The paddler, clothed in a thin waterproof shirt or *kamleka*, which is tightly lashed about the opening in which he sits, is secure against rain and spray and safe among waves that would swamp many a larger vessel. Kayaks are not made by other races, and are typical, and we might almost say a part, of the Eskimo. To one seeing a native for the first time riding the waves swiftly and safely in his kayak far out on the stormy sea, it seems as if boat and man were one; in the same way that horse and rider were considered as one animal when Spanish horsemen were first beheld by the simple natives of Mexico. These hardy navigators might with propriety be called "kayakers," or the people of the kayak.

The Eskimos live in well-built winter houses and practise many arts and industries which indicate a stage of advancement not attained by many races in more favoured lands. They are separated into many subordinate divisions, speaking somewhat diverse dialects; but in the present sketch we can only direct attention to their more general characteristics and to their peculiar geographical distribution.

The minor division of the Oranian people, the Aleuts, have their homes on the Alaskan peninsula and the Aleutian Islands, and now number about 2000. Their intercourse with Europeans has been longer and more intimate than is the case with any other natives of Alaska, and the change wrought in their lives and character by this contact

has been great. The harsh treatment of the Russians for more than a century stamped out many of their customs and characteristics, greatly reduced their numbers, and contaminated their blood. In more recent years the labours of missionaries, the establishment of schools, and other changed conditions have continued the modification of the race. Many of their arts have been neglected or forgotten owing to the fact that the rewards received for sea-otter hunting, and for killing seals on the Pribilof Islands, have enabled them to supply their wants with articles manufactured by white men. Changes in environment, produced in different ways under Russian and American rule, have conspired to modify this people, so that to-day they seem a different race from that described by early visitors to the wild and strangely magnificent shores on which they live.

In the interior of Alaska, and confined to the forest-covered region, there are several tribes of Indians which are markedly distinct from the Eskimos. These peoples belong to a stock which extends southward throughout the Rocky Mountain region for many hundreds of miles, and include some of the tribes with which white people coming from the east have been long in contact. The stock to which the Indians of Central Alaska belong is designated by some as the Tinneh and by others as the Athabaskan. These Indians probably number three or four thousand. They live on the banks of the numerous rivers and lakes of the interior, and only reach the coast near Cook's Inlet. In all other portions of the shore-line of Alaska they have been held back and kept from direct commerce with distant peoples by the more intelligent and more progressive Eskimos, and by the still more warlike and aggressive Thlinkets.

The Athabaskans live by fishing and hunting, and it is from them that many of the rich furs so highly prized in Europe and America are obtained. They are river Indians, and do all their summer travelling in birch-bark canoes.

Their canoes are not curved upward at either end as are the more familiar crafts built of the same material in the region of the Laurentian lakes, but are low, sharp-pointed, and have a deck of bark from twelve to sixteen inches long at either end. Occasionally they are tastefully decorated with beads and porcupine quills. These crafts are so light that a man can easily carry one in a single hand, but are strong and serviceable, and seem as well adapted to the requirements of the river travellers as are the kayaks to the needs of the more venturesome Eskimos. The Athabaskans do not yield themselves readily to the advances of civilisation, and are now in a great measure in practically the same condition as when the first white man ventured into the vast wilderness where they have their homes.

Among the numerous islands and along the deeply indented coast of South-eastern Alaska there lives a people second to none of the native tribes of America in general intelligence and progressiveness. These are the Thlinkets. They now number about 4500 souls. They are closely related to tribes in British Columbia which extend up the great rivers, and are associated with, and in some instances merge into, other tribes

which have the commonly recognised characteristics of the Indian strongly pronounced.

The Thlinkets are the only natives of Alaska that tourists by the ordinary steamship routes to Sitka are likely to meet. They have been studied more thoroughly than any other of the tribes of Alaska, and much interesting and valuable information bearing on their customs and traditions, arts and languages, is now available in our libraries.

The placid waters separating the thousands of islands of South-eastern Alaska are to the Thlinkets what the rivers of the interior are to the Athabaskans. The convenience of these widely branching waterways, in a land where the vegetation is so dense as to be almost impenetrable, has led the native inhabitants to acquire great skill in the construction of canoes. Their boats are of an entirely different type from those used on the ice-bound shores at the north, or on the Yukon, but are none the less well adapted to the wants of the brave and venturesome navigators who build them. The canoes are hewn from a single log, and are sometimes 50 or 60 feet in length, and 5 or 6 feet in breadth, while others intended for a single paddler are almost as light as birch canoes of similar size. These boats are not only remarkable for the beauty of their curving lines, but are sometimes richly decorated with totemic designs in colour. They are high at the prow and stern, which gives them something of the appearance of gondolas. When gliding over the placid waters separating shaggy mountains, they add a charm to the wonderful scenery of the Alexandrian archipelago which will never be forgotten by those who have once beheld it.

The houses of the Thlinkets are large, well built, and often richly carved and painted with grotesque designs. In front of some of the older houses carved and painted totem-poles still stand, which record the ancestry of their owners. The totemic system in vogue among this people renders them of peculiar interest, especially as it has led to a development of a truly artistic taste which finds expression in carving on wood, stone, and ivory. Many of the products of this art, apart from their mythical meaning, are attractive by reason of their design and finish. Many other peculiar and interesting characteristics of this race might be enumerated, but a glimpse is all that space will allow.

Brief and imperfect as this essay is, of necessity, yet I trust enough has been said to show that, to the geographer, Alaska is a fascinating land. It holds out inducements to the explorer to tread new soil and behold vast regions on which the eye of civilised man has never rested; to the geologist it offers the keys which will unlock many enigmas in the ancient history of other lands; its living glaciers are now making records which are in every way similar to those left by ancient ice-sheets both in America and Europe; to the ethnologist it presents tribes of men as yet but imperfectly studied or entirely unknown; it is here that the New most nearly approaches the Old World, and thus affords facilities for studying the vexed question of whence came the native tribes of America.

The future of Alaska, and its direct response to the wants of man, do not fall within the scope of this article; but it must not be forgotten that

in the far north-west there is a vast region which is more favourable as an abode for man than many lands now inhabited. When less remote countries are peopled to overflowing, Alaska will cease to be neglected; and its fisheries and mines will be developed, and many of the wants of the people engaged in these and kindred industries will be supplied; by flocks and herds that can be pastured all the year round in the luxuriant meadows here and there along the southern shores and on many neighbouring islands.

A REVIEW OF SWEDISH HYDROGRAPHIC RESEARCH IN THE BALTIC AND THE NORTH SEAS.

By OTTO PETTERSSON.

III.

Changes in the direction of the Baltic Current in the Skagerack caused by the winds
—Effect of the outflowing waters upon the deeper strata—“Reaction currents”
in the Kattegat—Comparison of the Baltic Current and the Polar Ice Stream.

As I have already mentioned, the outflow from the Baltic in spring and summer is sufficient to inundate the entire surface of the Kattegat and Skagerack with water of less than 30‰ salinity. This condition is represented in the map on Plate III. The only exception to this rule is the south-western part of the Skagerack from Hanstholm to the Skaw, where the Danish current sets in from the North Sea, following the coast of Jutland.¹ The North Sea water, on account of its higher density here, generally dips under the Baltic water, and enters the Kattegat as an undercurrent. But during westerly winds the Danish current passes the Skaw as a surface-stream, and fills the shallow western part of the Kattegat with saltier water than that of Baltic origin. This salt water penetrates like a wedge into the midst of the Baltic current in the Kattegat, and occasionally divides it into two parts to the south of Vinga, where a narrow strip of fresher water along the Swedish coast forms a link between the large, superficial layers of Baltic water in the middle part of the Kattegat and the main northern part of the Skagerack. The condition is then the reverse of that represented in Plate III. Instead of a broad flake of yellow (Baltic water) to the west of the Skaw, we ought to have a similar area coloured brownish-green (representing saltier water from the North Sea) extending to the east and south-east of Skagen. This state of things is especially common in autumn, when the westerly gales are strongest. This season is remarkable,

¹ On the coloured maps this part of the sea is marked with blue or green colour (see Plates II., III., and V.), indicating that the highest salinity is always found here in summer as in winter. Hence the North Sea may be said to extend as far eastward as to the Skaw.