SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOLUME XLIX

Smithsonian Exploration in Alaska in 1904, in search of Mammoth and other fossil remains

BY

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No. 1584.

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

1905

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SMITHSONIAN EXPLORATION IN ALASKA IN 1904 IN SEARCH OF MAMMOTH AND OTHER FOSSIL REMAINS

By A. G. MADDREN

I. Introduction

The notes herewith presented are the result of an expedition to Alaska and adjacent territory made during the summer of 1904, under the direction of the Secretary of the Smithsonian Institution, through Dr. George P. Merrill, Head Curator, Department of Geology, U. S. National Museum. Conclusions are also in part based on observations made in 1899, when the writer travelled the length of the Yukon River; in 1900 when various points on the coasts of Bering Sea, eastern Siberia, and of the Arctic ocean as far east as Cape Beaufort were visited; and 1902-03 when a year was spent in residence on the Alaska peninsula. During these previous years ice in various forms was frequently noted, but not until the summer of 1904 was it made a special object of notice in relation to the Pleistocene deposits.

The object was to find, if possible, complete skeletons of the mammoth and other large extinct mammals reported as occurring in that region or at least a locality promising enough in its indications to warrant further investigation. This search was confined to the Pleistocene deposits of northern Alaska in which most of the Mammoth and other vertebrate remains occur. Hence the following observations treat of these formations and the criteria by which they are to be distinguished from the more recent ice and alluvial deposits which have been variously noticed and discussed by travellers and writers. The present writer has been able to verify many of the observations previously recorded and he hopes that the following review of the subject to date in the light of his own observations may elucidate some of the debated questions regarding the character and origin of the arctic Pleistocene deposits. The classification of the ice deposits, their relation to the Pleistocene, with the opinion concerning the ice beds of Eschscholtz Bay, about which there has been much discussion, is advanced tentatively with

the diffidence and reserve with which doubtful facts involving any generalization ought always to be expressed.

The problems of geographic distribution of the animal and vegetable life of North America in Pleistocene time with the disturbance of faunas and floras caused by the widespread glaciation during that period and their subsequent readjustment over the glaciated area, all combine to form a complex arrangement, to solve which will require large collections of specimens from the Pleistocene deposits of the unglaciated area of Alaska and the adjacent Canadian territory. For at present our knowledge of this fauna and flora is very limited. As far as we know, only one species of elephant (*Elephas primigenius*), the Mammoth, inhabited Alaska and Siberia during Pleistocene time.

In 1850 Dr. C. C. A. Grewingk[1] brought together all the records then known of the occurrence of Mammoth remains in Alaska. On pages 290 and 291 of the 1850 edition of his work he summarizes this information. On pages 78 and 79 he gives a review of the discovery of Mammoth remains on Eschscholtz Bay by Kotzebue in 1816, and on pages 81, 82, and 83 presents the results of Beechey's expedition to that locality in 1826. He refers the elephant remains enumerated by Buckland to *Elephas primigenius* and doubtfully to *Elephas indicus*.

He continues: "Mastodon ribs, tibia, and tusks of *Elephas primigenius* and *E. indicus* (?) were collected by Wossnessenski from Cape Nugvulinuk (near Tolstoi Point), Norton Sound."

"Mastodon bones and tusks are common along the coast between Bristol Bay and Norton Sound (see Veniaminoff, Notes on the Unalaska District, St. Petersburg, 1840, p. 105); furthermore they have been found on the Pribilof Islands, and lastly also on Unalaska (Island) according to Dr. Stein."

On page 68 he says: "On a stream having the same name as this cove (apparently Golsova river of present maps, Topanika Creek of Dall) were found in alluvial deposits of clays and sands, the ribs, tibia, and tusks of *Mastodon* which were collected by Wossnessenski in 1843 and sent to the Academy of Sciences (at St. Petersburg)."

"These specimens appear to resemble the living elephant more closely than they stand to the mammoth."

[1] Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nord-West Küste Amerikas mit den anliegenden Inseln. Verhandl. Russ. k. mineral. Gesell. zu St. Petersburg, 1848, 1849, also separates, 1850.

On page 124 "and in Dr. Stein's memoir (Trudi Mineral, Obs. CII, 1830, pp. 382, 383) it is stated that somebody, probably a Promishlenik (a trader), found *Mammoth* tusks and molar teeth on Unalaska Island in 1801." On page 190 "Mammoth tusks were found on the island of St. George (Pribilof group) in the year 1836 according to Veniaminoff."[2]

It may thus be seen that Grewingk makes no distinction between the terms *Mammoth* and *Mastodon* and apparently is not satisfied that the fossil elephant of Alaska is the typical *Elephas primigenius* of Siberia.

Later Dall[3] appears to accept this latter view of Grewingk and mentions that Wossnessenski collected tusks, teeth, and bones of the *Elephas primigenius* and *Elephas columbi* near Topanika Creek, Norton Sound. We think the identification of *E. columbi* needs verification before it is assigned to Alaska. M. T. Obalski[4] mentions the occurrence of the *Mastodon* in the placer gravels of the Klondike region, but this statement, which the writer understands is not based on the identification of specimens, appears to be an error. Obalski makes another statement that does not appear to be founded on fact. He says ivory tusks 6 meters (19.6 feet) long occur in the Klondike gravels. This statement is an exaggeration. The longest tusk so far reported from Alaska is one 12 feet 10 inches (about 4 meters), measured along the outside of the curve. Remains of the rhinoceros have not been reported with those of the mammoth in Alaska, as in Siberia, and it also appears that the remains of the mammoth in Alaska are not in as fresh a state of preservation as those found in Siberia, which points to the surmise that the mammoth became extinct in Alaska before the last of the species succumbed in Siberia. Associated with the mammoth were herds of large bison and horses. This species of horse may have been the last native to North America, the rear guard of the last migration of these animals across the region of Bering Straits to Asia before the land connection disappeared. There was a species of musk-ox together with sheep and bear. Descendants of these last three forms have by adaptive changes survived in these northern regions down to the present time.

The relation that the fauna and flora north of the area occupied

[2] Notes on the Unalaska District, St. Petersburg, 1840, I, p. 106.

[3] Report on Coal and Lignite of Alaska. Seventeenth Ann. Rep., U. S. Geol. Survey, 1896, p. 856.

[4] Les grand Mammifères fossiles dans le Yukon et l'Alaska. Bull. du Mus. d' Hist. Nat., Paris, 1904, No. 5, pp. 214-217.

by glaciers bore to that in the region of the United States before, during, and after separation by the snow and ice fields; also the relation of forms in Alaska to those of Siberia, with the time and duration of the land connection across Bering Straits and their subsequent separation, form a complex problem, the solution of which will require the accumulation of much material.

The writer takes this opportunity to express his thanks to the members of the staff of the U. S. Geological Survey engaged in Alaska for valuable suggestions; especially to Mr. A. H. Brooks, in charge of geological work in Alaska, for the use of data presented on the accompanying map together with the photographs used as illustrations, and to Mr. A. J. Collier for looking over the manuscript.

II. ITINERARY

The party consisted of the writer and one man employed as camp-hand and boatman; the plan being to employ natives for additional labor as found necessary. We travelled by steamer from Seattle, Washington, and arrived at Skagway, Alaska, May 28. Thence by rail over White Pass to the town of White Horse, Northwest Territory, Canada, the terminus of the railway and head of steamboat navigation on the Yukon River. Here we were delayed several days waiting for the water of the river to rise sufficiently to allow stern-wheel steamboats which draw twenty-six inches of water to proceed down stream. We left White Horse June 6 and reached Dawson June 8. Our inquiries here pointed toward the fact that no complete skeletons of mammoth have been found in the mining diggings of the Klondike, though scattered fragments of this and other Pleistocene mammals are of common occurrence as will be mentioned later. Without delay a "poling" boat thirty-five feet long was purchased and with this, travel was continued down the Yukon.

Circle City was reached on June 18. Here inquiry was made to learn the identity of the "Kotlo River" of Dall.[5]

[5] This name was first used by Dall to designate a stream shown on his map, published in "Alaska and Its Resources" in 1870, and also in Bull. 84, U. S. Geol. Surv., 1892, pl. III, draining the general area of the valley of the present Birch Creek and indicated by him as emptying into the Yukon about thirty miles below the site of the present settlement of Circle. The writer was informed that a little-used Indian portage exists across the low bottoms of the Yukon Flats from the Yukon to Birch Creek on approximately the same route marked by Dall for the lower course of the "Kotlo" river and undoubtedly in compiling his map he misinterpreted information intended to convey the location of this portage for the course of a river.

It was found to be the stream shown on recent maps of Alaska as Preacher Creek, so named by pioneer prospectors after the Rev. R. McDonald, Chaplain of the Hudson Bay Company and missionary to the Indians, who first reported the occurrence of placer gold in the basin of this stream. Preacher Creek is a tributary of Birch Creek, which flows into the Yukon River about thirty miles below Fort Yukon. Under the name of "Kotlo" River Dall reports Preacher Creek as a locality where Mammoth remains occur in abundance. This report was substantiated, but we did not make a personal investigation since we were told by Indians of a much more promising locality on Old Crow River, a tributary of the Porcupine. As there was not time to visit both localities we chose the latter because of assurances that the abundance of fossil mammal remains on the Old Crow River far exceed those of any other locality known to the Indians of this region, whom it must be conceded are in position to be best informed about matters pertaining to remote parts of this region.

We arrived at Fort Yukon at the mouth of the Porcupine River on June 21 to find an epidemic of diphtheria prevailing among the Indians of this settlement, causing much alarm by the number of deaths resulting from the disease, and making it impossible to procure guides or adequate assistance for the trip up the Porcupine River. A scarcity of essential provisions also existed here at this time owing to the retirement from business of the only commercial establishment at this place at the time of our visit. This made it necessary to prosecute the journey up the Porcupine away from any other source of supply without sufficient supplies for an extended period of work. We left Fort Yukon with about one hundred and twenty pounds of provisions the most conspicuous item of which was fifty pounds of flour; the remainder being made up of rice, beans, bacon, sugar, tea, and a few pounds of dried fruit. With fish, geese, and two caribou we were able to shoot, this amount proved sufficient for two persons for forty days, but the time was not sufficient to permit of a thorough exploration of the Old Crow basin. In fact it was found possible to make only a very preliminary examination.

Through fortunate cooperation with a white trapper, who was ready to ascend the Porcupine to his winter hunting ground, we were enabled to continue with the large boat purchased at Dawson, but after reaching the Ramparts where our companion wished to stop, we were compelled to exchange this large boat, which proved too heavy for two persons to propel with the ease essential to the rapid progress necessary under the circumstances, for a canoe.

The ascent of the Porcupine was commenced June 23, progress being made by "tracking" and "poling." The lower one hundred and twenty-five miles of the Porcupine, from Fort Yukon to the Lower Ramparts, flows by a tortuous course through the low forested region known as the Yukon Flats. Its course forms a series of curves of one to three miles' radius alternately sweeping from right to left, the channel being entirely confined by banks of unconsolidated alluvium nowhere exposing rocks older than Pleistocene age. The banks are of an average height of about twenty feet above the normal level of the river, but are seldom sufficiently elevated to prevent their overflow by the spring floods. The difference of level between the mouth of the Porcupine and a point one hundred and twenty-five miles above produces a gradient over which a torrential current is only prevented by the extremely tortuous course followed by the river over its flood plain. The current averages about three miles an hour through this part. It presents the typical features of meandering erosion, cutting away the banks on the concave side and depositing the material removed lower down on the opposite convex side or bars. These bars are quite shallow in most cases and being frequently strewn with stumps and stranded trees necessitate continuous wading on the part of the "trackers" with the attendant annoyance of the tow-line frequently becoming fouled with entangling branches, roots, etc. These features present a marked contrast in the character of the banks. Those of the outer curves are precipitous, owing to the undermining and consequent crumbling of the banks. Being frequently covered with a thick growth of spruce the river cuts a path through the forest leaving the trees standing as grain does beside a clean cut swath. Frequently the sections give exposures of solidly frozen peaty layers and also the edges of lenticular beds of clear flood-plain ice. The shimmering silence of the nightless days of summer in these arctic solitudes is often harshly broken by crashing splashes along these undercut banks where massive blocks of frozen earth topple over with their incumbent trees to disappear with muddy gurgles beneath the silt-laden current. In plate 1, fig. 1, is shown a cut bank in Yukon Flats, with timber and overhanging mantle of tenacious turf characteristic of all river banks of Alaska where unconsolidated deposits are undermined by the current.

On the inside of the curves are the low, gently sloping banks of recent flood-plain deposits known as bars. In typical sequence these are current-bedded gravels succeeded at a higher level by sand beds which in turn pass beneath deposits of fine silts. The gravels

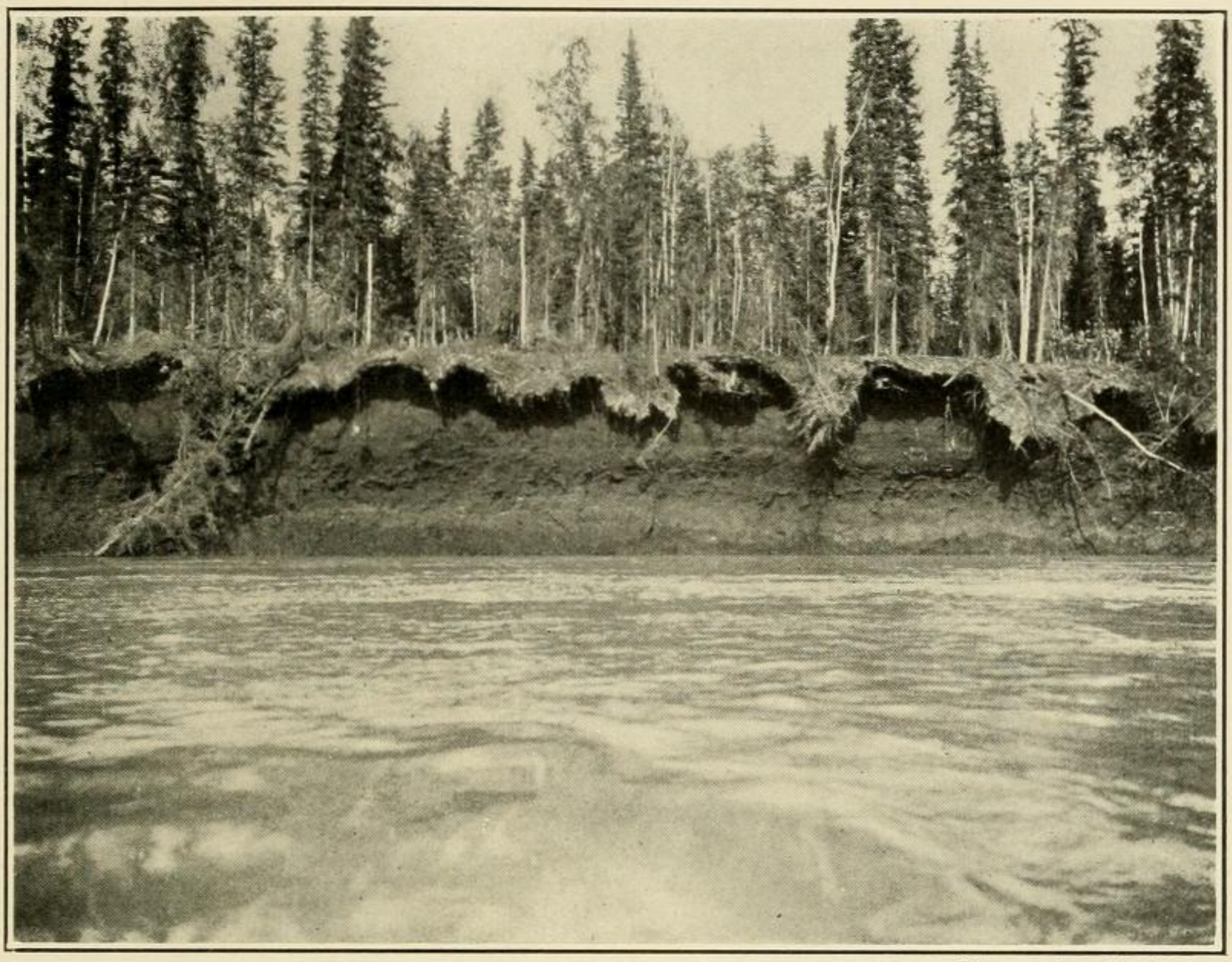


Photo. by Collier.

1. Cut Bank in Yukon Flats.

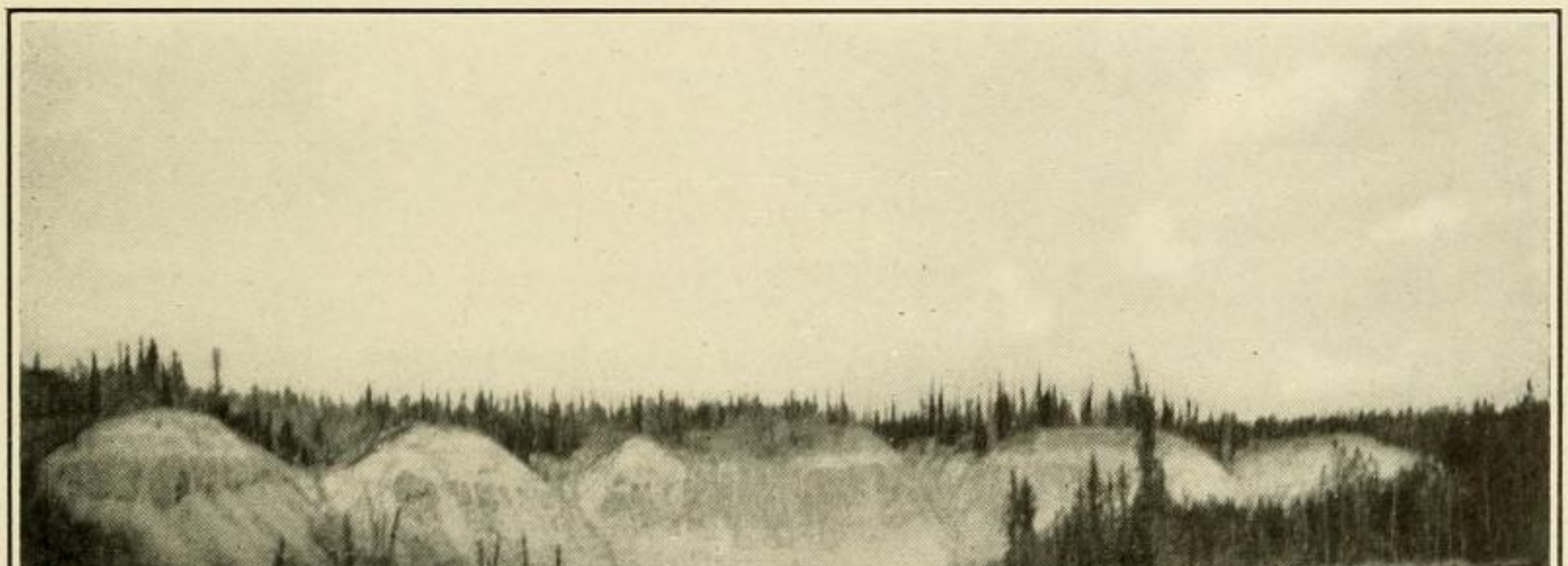


Photo. by Collier.

2. Bluffs of Pleistocene Silts below Lake Lebarge, Yukon River.

are deposited by the swift waters along the border of the main channels while the finer superimposed strata are laid down in the slack water on the inner margins of curves during flood stages, and it is here that pieces of ice floating down on the spring floods become stranded as the waters recede, and melting deposit any freight in the shape of fragments of fossil bones, teeth, etc., that may be frozen within or borne upon them. Below the level of flood these bars present a surface of gravels, sands, and mud bare of vegetation but strewn over with stumps, logs, and drift brush. Back of this comes a strip covered with grasses and a variety of equisetum called "goose-grass" because it forms the chief food of these birds during their molting season. Above this belt comes a growth of young willows which as they recede from the river increase to a height of twenty to thirty feet. Mingled with the willows and replacing them on the landward side are clumps of alders and groves of poplars which in turn are succeeded on higher, better drained lands by spruce forests extending away to mingle with the birch growing on the distant hills. Below the depth of a foot or two the soil is everywhere frozen.

Above the Yukon Flats the Porcupine flows from a considerably contracted valley called "the Ramparts." This is a name introduced by the northern fur-traders to designate a contracted, walled, or cañon-like valley and has been applied by them to similar physiographic features on the Mackenzie, Porcupine, and Yukon rivers. On the Porcupine, Upper and Lower Ramparts are differentiated and the portions of the valley so named are very picturesque. In passing through the Ramparts the river contracts considerably, not exceeding seventy-five yards in width in places. The current becomes more rapid, flowing from three to four and a half miles an hour with occasional short riffles where the velocity is much greater, being estimated at seven or eight miles per hour, but there are no obstructions or rapids which would prevent a small light-draft steamer with requisite power from navigating the river (plate 1).

The change in topography in ascending from the Yukon Flats into the Lower Ramparts is ushered in gradually by a belt of Pleistocene deposits several miles wide rising thirty to fifty feet above the river, followed by several ranges of low hills leading up to the abrupt walls of the entrance to the contracted portion of the valley. The river flows through the Lower Ramparts for about twenty-five miles. The rocky walls, generally disconnected and low, are composed for the most part of limestones seldom abruptly developed on both sides of the river so as to form a cañon. Thus a shore is

presented along which one is able to "track" with only occasional interruptions at precipitous places, where it becomes necessary to carry the tow-line along the top of a cliff or force the canoe against the swift eddies invariably occurring at these places by vigorous use of the oars accompanied by dexterous manipulations of the "pike-pole."

Above the Lower Ramparts the river swings in wide sweeping curves as it flows for about twenty-five miles through an alluvial channel across a basin filled with Pleistocene silts, down into which it has cut about one hundred feet. These silts appear to fill the basin of a former fresh-water lake that was barricaded from the extensive Yukon Flat Basin to the west by the low range of the Lower Ramparts and bounded on the east by the higher plateau of the Upper Ramparts. While this basin does not present a great width where the Porcupine flows across it there is every indication that it occupies considerable areas both north and south of the Porcupine and that the considerable stream called the Coleen drains the area occupied by the northward extension of these sediments. For this reason it appears convenient to designate this area of Pleistocene sedimentation between the Lower and Upper Ramparts as the Coleen Basin. The sediments are unconsolidated silts, sands, and gravels and in one exposure thin seams of lignite were observed. Older rocks similar to those of the Lower Ramparts with some basalt occasionally outcrop along this reach. After making a wide bend to the north through which the channel is divided by alluvial islands with strong currents the valley contracts again to abrupt bounding walls. The rocks here are a massive basalt that forms the western limit of the Upper Ramparts. The walls are higher and more abrupt than those of the Lower Ramparts. They rise from three to five hundred feet above the river and extend to a point about twenty miles above the international boundary or approximately sixty miles. As is to be expected the river follows a more direct course across this area of hard rocks. It is through this part the river contracts to its narrowest dimensions and reaches its greatest velocities. The basalt extends upstream apparently as a continuous sheet for about thirty miles, or nearly to the boundary line between Alaska and Canada. This basalt sheet edged with vertical cliffs is the conspicuous feature of the river for this distance. The valley gorge is bounded by even, precipitous walls carved out of this rock, which from their dark color lend a sombre appearance to the landscape. The lower surface of the basalt undulates as the older underlying rocks rise or descend along the bottom of the

valley. The uniformity of the walls is also broken at intervals by deep gashes cut by tributary streams through the basalt sheet. Above the upstream limit of the basalt sheet low mountains rise a short distance back from the valley walls near the boundary line. From here to the upper limit of the Ramparts the green slopes which replace the basalt walls are frequently broken by shattered pinnacles, bold crags, and minarets of brilliantly tinted rocks.

About ten miles above the lower entrance to the Upper Ramparts, opposite the mouth of Salmon-Trout River on a small bench of Pleistocene fluvial sediments that rise about forty feet above the river level, the Hudson Bay Company formerly maintained a trading post called Rampart House. Later this settlement was moved up the Porcupine about thirty miles to remove all doubts about its position in regard to the boundary line. This establishment was designated New Rampart House and the former site was known as Old Rampart House. New Rampart House is situated a short distance east of the 141st meridian of longitude that separates Canada from Alaska and about two hundred and ten miles by river from Fort Yukon at the mouth of the Porcupine, on an elevated bench of Pleistocene silts similar to that where the older post was located. These are the only two areas of such deposits of any extent throughout the Upper Ramparts. The Hudson Bay Company have discontinued trading posts on the Porcupine River for the past eight or ten years and for this reason apparently it has been abandoned by Indians, who now frequent it only upon occasional hunting excursions.

Above the Upper Ramparts which terminate about twenty-five miles east of the international boundary the river meanders out into another basin filled with Pleistocene silts. This area appears to be much more extensive than the Coleen Basin and the designation Bluefish Basin is suggested for it because it appears to be drained largely by that river. The Porcupine flows along its northwest margin, the channel frequently abutting directly against the old limestone formation of the Upper Ramparts, the higher extension of which along the north side of the valley forms the Old Crow Mountains, the summits of which attain elevations of about two thousand feet along the river. The river presents the same features as already described for its course through the Yukon Flats and the Coleen Basin except that greater thicknesses of silts are exposed. Here they rise to heights of one to two hundred feet above the river and present almost vertical exposures on the concave sides of the banks. On some of these high bluffs elevated ice-beds were

observed and the ability of the cliffs to maintain their vertical fronts appeared to be due to the fact that their mass is solidly frozen. It was noted that bluffs facing the south appear, under long exposure, to thaw out sufficiently to allow their escarpments to crumble down into gentle slopes. Shallow quicksand bars were encountered along the thirty miles below the mouth of the Old Crow River.

The Old Crow River flows from the northwest into the Porcupine about sixty miles above New Rampart House. It enters the main river with a bluff along its right bank that exposes hard dark shales rising about twenty feet above the river for half a mile, overlaid by one hundred and fifty feet of the unconsolidated Pleistocene silts already described. Its left bank is bounded by a low wooded flat extending east across the mouth of the valley to a range of high hills about five miles distant. As we ascended this river the following features were noted. After passing for ten miles through a flood plain eroded across the above mentioned silts three distinct terranes have been exposed by the down cutting of this stream. As one ascends the river these are, first, a series of limestones, intersected with calcite veins, extending for about eight miles; then a belt of granitoid rock that confines the river to a gorge estimated to occupy about five miles of its course; and third, an outcrop of sandstones or quartzites three or four miles wide. This series of hard rocks extend, apparently as an anticlinal uplift, across the lower part of the Old Crow Valley to connect the mass of the Old Crow Mountains, bounding the north side of the Porcupine Valley to the west, with a low range of mountains that trend to the northeast to bound the expanse of the Old Crow Basin on the east. Before the river cut through this ridge of rocks it formed the lowest part of the southeastern rim of a large Pleistocene lake that had an approximate extent of one hundred miles north to south with a width of sixty miles east to west. Today this former lake area lies as a vast elevated undulating plain surrounded by mountain ranges on all sides. Its frozen lacustrine silts have been dissected to the depth of one to two hundred feet by the Old Crow River and its tributaries, which meander through this extensive flat basin in the most intricate manner, presenting many examples of former wanderings in the occurrence of crescent shaped lagoons or ox-bow lakes at present flood-plain and higher levels.

The lower banks support dense growths of willows and alders while the higher levels are interspersed with shallow lakes, groves of poplars, considerable patches of spruce, and a scattered growth of birch. The two latter kinds of tree are confined mostly to the higher, better drained areas.

The course of the Old Crow River was ascended about one hundred and seventy miles by following its winding series of incredible and complicated curves, though the extreme point reached was estimated to be not over half that distance from the mouth of the river in a straight line. Along their southern margin the unconsolidated deposits that fill the Old Crow Basin present at first a terrane such as is to be expected along the shore of a lake. Considerable thicknesses of gravels and sands were noted for about fifteen miles, until passing more towards the center of the basin area the sediments changed to homogeneous gray clays in which gravel was totally absent, and where only small quantities were occasionally observed on the bars associated with fragments of fossil mammal bones that have been deposited during spring floods by floating ice from the headwaters of the river. As the course of the river winds through these frozen silts it generally presents bold escarpments along the concave sides of the curves, with muddy bars overgrown by dense thickets of willows opposite. It is on the tops of these high silt bluffs the beds of elevated ice are exposed and their more recent relation to the silts themselves so clearly demonstrated.

These ice-beds are not extensive sheets covering large areas but rather restricted masses, rarely exposing over one-half mile of continuous ice, that appear to be frozen ponds, ox-bow, or other lakes, that remained in the low parts of the undulating surface of the lake bottom when it was drained. As their mode of origin and formation will be discussed later we may pass them with the statement that the Old Crow Basin presents this phase of elevated Pleistocene silts with ice on top developed to a greater extent than the writer has seen or read of anywhere else. Beds of ice were observed as far as we were able to ascend the Old Crow River. They appeared on top of the banks, always at elevations of one hundred or more feet above the stream, for a distance of more than one hundred miles along the stream and no doubt continue to the northern limit of the basin. The ice varies greatly in color, structure and thickness. Some is of a brownish hue having much the same color as peat water and containing quantities of comminuted vegetable matter, in some parts distributed evenly through the mass, and at other places concentrated in thin layers like sheets of paper between thicknesses of clear ice. Some is whitish and granular, especially at its surface, and often contains numerous cavities of gas bubbles. At other places masses of green and blue ice were observed. In some exposures all three kinds of ice are associated within one hundred

yards of each other with all intergradations of physical characteristics represented. All this goes to show that apparently there is only one criterion upon which to base a classification of the ice deposits of these northern regions, and this is, *position*.

During the first week of our ascent of the Old Crow the river steadily subsided. As the waters became lower widely scattered parts of the skeletons of the large fossil mammals we were searching for, were left exposed on the clay banks below high water mark. In this way several of the large leg bones of the mammoth together with specimens of its teeth and bones of horse and bison were picked up. About one mile above the mouth of the first tributary coming into the Old Crow from the left we found the badly mutilated skull of a mammoth. It showed every evidence of rough treatment by the ice of one or more spring break-ups. The tusks were absent and their sockets badly broken away, the teeth were gone, and it was clearly evident that this skull had come from a considerable distance upstream. We left it on the water's edge imbedded in the tenacious gray clay. When we returned to it a week later on our way down stream it was covered by six feet of water. For after leaving that spot on our way upstream we daily experienced heavy rains, frequently accompanied by thunder, that appeared to originate in the mountains surrounding this basin and give that particular area the whole benefit of rainfall. In consequence the country became inundated, caused the river to rise very rapidly, and also increased the current so as to make upstream progress slower. Finally on July 23 an inventory showed about six pounds of flour, a couple of handfuls of tea with some partly dried deer meat not in too savory a state of preservation, to be the remaining stock of provision. This with the fact that we were about four hundred miles from the nearest settlement, Fort Yukon, determined us to turn back. It was with much reluctance we did so for nearly every mile of the last one hundred travelled on the Old Crow River had yielded increasing evidence, in the shape of a tooth, a horn core, or a bone lying on the banks below high-water mark, of the existence of deposits containing considerable remains of the skeletons of large Pleistocene mammals. Every mile of the last one hundred was travelled with the expectation of discovering a place of primary entombment of these remains. Under the circumstances it became necessary to abandon further exploration with the hope of returning another year to fully investigate this locality. It was on this river the remains of mammoth were reported to be abundant, and as we have just pointed out, all the

evidence coming under our observation leads to the conclusion that an extensive deposit of large Pleistocene mammal remains, represented principally by mammoth, bison, and horse, exists on the headwaters of the Old Crow River.

In 1873 Rev. Robert McDonald presented a collection of remains of Pleistocene mammals to the British Museum. The locality given for them is the Upper Porcupine River and it is probable a more definite locality for this collection may be the Old Crow River, a tributary of the Porcupine. They have been enumerated by Lydekker in the Catalogue of Fossil Mammalia in the British Museum, Part II, pages 26, 27, 39, 78, 86, and 87; Part IV, page 204. Leith-Adams also mentions three left lower molars of the mammoth from this collection in his work on British Fossil Elephants, page 117.

Our return to Fort Yukon, by the same route we had ascended the river, was accomplished in eight days, and beyond one mishap, in which our canoe rolled over in a shallow riffle, that resulted in the loss of two sacks of bones that were not lashed in the canoe, together with some photographic plates that became wet, was accompanied by no extreme inconvenience.

The journey down the Yukon River was continued to examine other localities reported as productive of Pleistocene mammal remains. This necessitated travelling by steamer and small boat alternately. A locality about thirty miles below Fort Hamlin on the right bank of the Yukon was visited as was also Little Minook Creek near the town of Rampart where elevated fluvial sediments containing scattered Pleistocene mammal remains occur. From Fort Gibbon where the Tanana River joins the Yukon the trip was continued by small boat to give opportunity of stopping at the "Palisades" or so-called "Bone-Yard" about thirty-five miles below.

This locality is described by Russell,[6] later by Spurr,[7] and also by Collier.[8]

The escarpment called the Palisades is from one hundred and fifty to two hundred feet high, composed mostly of fine, light colored, unstratified silts. Back from the bluff is a level, densely wooded table land, with swamps and ponds, bordered on all sides, except that adjacent to the river, by low hills. The Palisades proper are washed by the river and are bare precipitous bluffs of frozen silt.

[6] Notes on the Surface Geology of Alaska. Bull. Geol Soc. Am., Vol. I, 1890, p. 122.

[7] Geology of the Yukon gold district. Eighteenth Ann. Rep. U. S. Geol. Survey, pt. 3, 1898, pp. 200-221.

[8] Bull. No. 218, U. S. Geol. Survey, 1903, pp. 18 and 43.

This fact accounts for their steep face. The same escarpment extends some ten miles up the river, with a wooded flood plain along its base. There is a little ice on top of these bluffs but nothing like the extensive development exposed in the Old Crow Basin. The under-cutting of the river causes large slabs and blocks of the frozen silts to fall into the river and it has been reported that numbers of bones, teeth, and tusks are thereby exposed, which has given this locality the name of "Bone-Yard." The writer found only a few scattered fragments in 1904 (pl. II, fig. 1).

G. M. Dawson says:[9]

"In 1886 the Geological Survey of Canada acquired from Mr. F. Mercier, who had spent many years as a trader in the Yukon region, a number of bones, tusks, and teeth of the Mammoth. These were chiefly obtained by Mr. Mercier near the mouth of the Tanana River." It is probable the "Palisades" is the locality where these specimens were gathered.

The Palisades form a typical exposure of the lacustrine phase of the deposits Spurr and Collier designate the "Yukon Silts" and which Dall has called the "Kowak Clays." They are for the most part of Pleistocene age as is shown by the bones of mammoth and other large mammals besides the shells of freshwater and land molluscs represented by living species contained in them. All phases of "Yukon Silts" grading from coarse gravels to clays are distributed as fluvial and lacustral deposits throughout the Bering Sea and arctic drainage basins of Alaska and adjacent territory. Their elevation and dissection by the present streams has produced the bluffs and terraces that form such a conspicuous feature along most of the rivers.

At a settlement called Kokrines, steamer transportation was resumed to Kaltag, a small trading post where the government telegraph line and winter mail trail that extends down the river leaves the Yukon, ascends Kaltag river to near its head, then crosses the divide to Unalaklik River, and descends that stream to Norton Sound, a total distance of about one hundred miles. At Kaltag the services of two natives as packers and guides were engaged and on August 14 with two additional Eskimos engaged to pack for the first fifty miles, the party commenced an overland trip which occupied thirty-one days and extended, for nearly three hundred miles, across the drainage basins of the Ungalik, Inglutalik, and

[9] Quart. Jour. Geol. Soc., Lond., Vol. 50, p. 2, see also Lambe in the Ottawa Naturalist, Vol. XII, Oct. and Nov., 1898, p. 136.

Koyuk rivers. The camp equipment for this trip was reduced to a minimum. It consisted of a tent made of balloon silk weighing twelve pounds, measuring eight feet square on the floor, with a waterproof canvas ground cloth. A light robe made of four large caribou skins, sewed together, served as a common mattress for all, and a blanket apiece completed the bedding. Three kettles, a frying pan, with a tin cup and spoon apiece were all the utensils found necessary. The provisions carried, exclusive of the supplies required for the two additional packers, consisted of one hundred and fifty pounds of flour, thirty pounds of rice, thirty pounds of beans, sixty pounds of bacon, twenty-five pounds of sugar, three pounds of tea, two pounds of baking powder, and two pounds of salt. Three hundred pounds altogether or seventy-five pounds to each man, or an average of two and a half pounds per man per day. This supply, supplemented by a few fish and a number of ptarmigan shot from day to day with a light 22 caliber rifle carried for this purpose, proved ample. With the help of the two additional packers engaged to accompany the party the first fifty miles, who returned to Kaltag, no difficulty was experienced in making satisfactory progress. The greatest annoyance experienced was that caused by the frequent rains that made the swollen streams difficult to ford.

The route, indicated on the accompanying map, was followed in the hope of locating a place of primary interment of mammoth remains where there might be the likelihood of obtaining a skeleton. We were unsuccessful in the desired object, observing only scattered depositions of bones and teeth, and these not in quantity that offer much promise of future success in finding a complete skeleton in this area. An Eskimo village called Isaac's on Norton Bay was reached September 14 and passage to St. Michael secured on a small trading schooner. From here Nome was reached on September 20 by local steamer.

In the curio shops at Nome we found many sections of mammoth tusks in a good state of preservation, said to have been obtained on King Island, which lies in Bering Sea about forty miles southwest of Port Clarence. An attempt was made to secure passage to King Island, but as the stormy autumn season was advanced and the island affords no landing or shelter to an approaching vessel, an examination into the occurrence of these remains had to be postponed. For the same reason a visit to the historic locality on Eschscholtz Bay, Kotzebue Sound, was found impracticable. We therefore took passage by ocean steamer from Nome on October 9 and Seattle, Washington, was reached on October 20.

III. THE FIELD OF SEARCH

I. PRIMARY AND SECONDARY DEPOSITIONS

All the recorded occurrences of Pleistocene mammal remains in Alaska and adjacent Canadian territory known to the writer are what may be termed, for convenience, *scattered* depositions. That is, in no case known may we be sure in stating that the remains are found where the animal actually died and was entombed. It is true some of the specimens of bones examined are in such good condition they cannot have travelled far from their original place of deposition. But on the other hand all of the material found is dismembered and the bones scattered, while most of it is water-worn and shows other evidence of having travelled, in some cases considerable distances. These scattered depositions of remains occur as separate bones, teeth, tusks, skulls, horns, etc., throughout both the Pleistocene and recent lacustral and fluvial formations. No *original* interment, that is, where the approximately complete remains of skeletons occur within reasonable compass, of any Pleistocene mammal is known, to the writer, to occur in Alaska or adjacent territory. But certainly such original or primary deposits must have existed and some of them may be found intact if sufficient search is made for them.

We may note the occurrence of scattered remains of the mammoth on some of the islands in Bering Sea. The Pribilof group has yielded the most evidence. In 1836 it is said a tooth was found on St. George Island,[10] and a tusk has been reported from St. Paul Island. Stanley-Brown says:[11] "There are two fragments of paleontologic evidence connected with the islands which, as they have been used by writers, demand a cautionary word. The tusk of a mammoth was found in the sands of Northeast Point on Saint Paul Island, and the tooth of one is reported as coming from the shores of Saint George. As there is not a foot of earth on either island, save that which has resulted from the decomposition of the native rock and the decay of vegetation, the value of such testimony is questionable."

Dawson[12] makes reference to these occurrences of mammoth remains and appears to favor the view that they are derived from

[10] Dall. Bull. 84, U. S. Geol. Survey, 1892, p. 266 and Seventeenth Ann. Rept. U. S. Geol. Survey, 1896, p. 858.

[11] Bull. Geol. Soc. America, Vol. 3, 1892, p. 499.

[12] Quart. Jour. Geol. Soc. London, Vol. 50, 1894, p. 6.

animals that actually lived on what are now the islands. More recently fresh evidence has come from this group. "Mr. F. A. Lucas[13] noted 'the Occurrence of Mammoth Remains on the Pribilof Islands,' stating that Mr. R. E. Snodgrass and the party from Stanford University had, in 1897, obtained two teeth of the Mammoth and bones of a bear, apparently distinct from the existing Polar Bear, from a lava cave on Bogoslof Hill (St. Paul Island). He was of the opinion that possibly the presence of these bones in such a situation might indicate the comparatively recent connection of the island with the mainland."

Mr. Bristow Adams, artist to the Fur Seal Commission that investigated the Condition of the Pribilof Islands in 1897, was one of the discoverers of this cave and the remains above mentioned. In a conversation with the writer he says: The cave is apparently formed by a contraction of the lava that forms the entire mass of Bogoslof Hill, which is about six hundred feet high and at least one-half mile from the nearest part of the seashore. The cave is up well towards its top. The cavity is not a large one, for its greatest dimension is not over forty feet and its height only about eight or nine feet. It has two openings. A large one in the roof about six feet in diameter by which nothing might enter the cavity without making a shear drop of twelve feet and by which it is impossible to make an exit; and a small opening at one end barely large enough for an average sized man to squeeze through. It was by this smaller opening the party entered the cave. The floor of the cave was entirely composed of pulverulent organic humus and it was from this the mammoth teeth and bear bones were disinterred. The depth of the humus floor deposit was not determined and as only a limited time was spent in the cave no extensive excavations were made. The remains found were situated at the end of the cave farthest from the openings as if they had been dragged there. As it is not stated whether the mammoth teeth are those of the upper or lower jaws we are unable to say whether the evidence points towards the presence of the whole skull or only the lower jaw of the animal in the cave. It seems impossible that the skull of the mammoth could have been dragged into the cave and remains of it not be found with the teeth, but it would be an easy matter for a detached lower jaw to be transported to the cave by a bear.

With these facts we leave each one to draw such conclusions as may suit his fancy. But we suggest that it will require more evi-

[13] Science, Nov. 18, 1898, p. 718.

dence than is afforded by this occurrence of mammoth remains to justify the assertion that the Pribilof Islands, as they stand today, have ever been part of a continental area during the time the mammoth lived, and we must not be too hasty in picturing the elevation of the northeastern portion of Bering Sea 300-400 feet that " would convert most of the present sea bottom into a vast verdure-covered *tundra,* whose gentle undulating surface would be dotted with lakes and intersected by sluggish winding streams." Though such an elevation of the land to form a connection between Asia and Alaska, with migration to the south in North America cut off by a barrier of glaciers, would throw these two regions into the same faunal province and appears to have been the condition that prevailed at some time, we are far from sure that the outflows of eruptives that entirely form the Pribilof group,[14] where every scrap of physical and petrographical evidence indicates the recency of the islands' formation, existed at an early enough date as a land surface for mammoths to roam over them. These islands have probably risen quite recently from the shallow sea floor.

It is well to remember that the two most indestructible structures of the mammoth skeleton are the teeth and tusks and that these are the parts found most widely scattered through recent deposits because, on account of their hardness, they will stand more frequent transportation by ice and water. Such remains may be carried from the streams of the continent in spring by ice and be drifted for miles about the sea, by currents or the gales that prevail at that season, to the shores of islands.

There is also the record already given from Grewingk that Dr. Stein [15-16] reported the discovery of teeth and tusks of the mammoth on the island of Unalaska in 1801. In 1904 the writer saw sections of mammoth tusks in the curio shops at Nome that had been polished and carved by the Eskimo of King Island in Bering Sea. The fact that natives from that place sold these to dealers in Nome is the basis for the statement, by the dealers, that the ivory comes from King Island, but it appears most likely that the tusks were obtained from the Alaskan mainland, which is visited each summer by these islanders, and carried to their settlement for the purposes of manufacture and thence to Nome for sale.

Mr. E. A. Preble of the U. S. Biological Survey informs the

[14] For an account of the geology of the Pribilof Islands see Stanley-Brown, op. cit.

[15-16] Trudi mineral Obst., St. Petersburg, 1830, pp. 382, 383.

writer that in a museum maintained at the Hudson Bay Company's post at Fort Simpson on the Mackenzie River he observed teeth of the mammoth *(E. primigenius)*. These specimens have no definite localities assigned them, but it is presumed they were found in the region of the lower Mackenzie Valley.

In this connection it appears opportune to call attention to a fact that apparently has been lost sight of by recent observers on the ethnology of the Alaskan Eskimo. This is the use by these people of a *blue pigment* derived from the decomposition of mammoth tusks. Sir John Richardson makes a note of this in his work on the Zoology of the Voyage of H. M. S. Herald, 1854; page 61, he says: "Several of the mammoths' tusks also have exfoliated, and a beautiful blue phosphate of iron has formed between their plates. This is evidently the blue pigment used by the native tribes on the coasts of Beering's Sea, and which has passed from tribe to tribe by barter in small quantities as far as the banks of the Mackenzie. It is mentioned by Cook, but its origin was unknown until now. Dr. Davy had the kindness to analyze this substance at my request, and he found that the first portions I sent to him were accompanied by a greater proportion of carbonate of lime than a recent tusk should contain. The iron may have been derived from the red gravel bed, associated with the bones; * * * * * * * Having sent a second specimen of a decaying tusk to Dr. Davy, he says, 'It is stained by peroxide of iron without any phosphate. I cannot find in it any mass of carbonate of lime. The proportion of animal matter in it is large, sufficient to preserve the form of the fragment after the removal of the phosphate of lime by an acid. Probably complicated affinities are engaged in the production of the blue phosphate, and carbonate of iron is concerned (not carbonate of lime). Perhaps the protoxide of the carbonate may combine with the phosphoric acid of the bone (ivory), and the carbonic acid of the former with the lime of the latter; the animal matter present in the bone in clay preventing the higher degree of oxidation.'"

IV. THE GLACIAL PERIOD AND THE MAMMOTH

I. RUSSELL QUOTED

Without entering into a discussion of the geologic time limits of the mammoth in Alaska it is well to note the facts in regard to its geographic range and that of the great glaciers. I. C. Russell[17] is

[17] Notes on the Surface Geology of Alaska. Bull. Geol. Soc. America, Vol. I, 1890, p. 123.

the first observer to call attention to this: "It is an interesting fact that all the bones of the mammoth and of other large animals that have been found in Alaska occur, as far as I am aware, in regions not glaciated during the Pleistocene period. The relation of mammoth remains to the distribution of glaciers in Alaska acquires additional importance in view of the fact that no evidence of glaciation has been reported in northern Siberia, where similar mammalian remains are also abundant.

"The study of glacial records by various observers has shown that the great Pleistocene glaciers of this continent extended outwords in all directions from two main centers of accumulation, one in Labrador and the other in the northern part of the Rocky Mountain region. During their greatest extension these two great glacier systems seem to have been confluent so that a vast ice field stretched across the continent from ocean to ocean. The northward movement of the ancient ice sheet was not sufficient in all places to reach the Arctic ocean (see map). In view of this fact, it may be suggested that the abundance of mammalian bones is due to the crowding northward and final extinction of land animals of the Pleistocene period by the advance of continental glaciers from the south."

2. DAWSON QUOTED

G. M. Dawson[18] substantiates Russell's observations in "Notes on the Occurrence of Mammoth remains in the Yukon District of Canada and in Alaska." He says in part:

"The writer in 1887 travelled through the valleys of the Pelly and Lewes rivers, but did not go below the confluence of these streams. In the whole region thus traversed no Mammoth remains were met with nor was their presence reported by such of the gold-miners as had worked in parts of these valleys; though some of the same men had frequently noted Mammoth bones farther down the Yukon valley, particularly in the vicinity of Forty-Mile Creek.

"Within the area which was covered by the great Cordilleran Glacier, remains of the Mammoth are either entirely wanting or are very scarce. The reported finding of a tooth on the southern part of Vancouver Island, and a portion of a large bone of doubtful determination in gravels worked for gold on Cherry Creek, Okanagan District, British Columbia, are the only possible exceptions known to the writer."

The tooth from Vancouver Island may no doubt be referred along

[18] Quart. Jour. Geol. Soc., Lond., Vol. L, 1894, pp. 1-9.

with a tooth from Whidby Island, Washington, and now in the U. S. National Museum, to *Elephas columbi* and not to the true Mammoth *(Elephas primigenius)*. Several additional occurrences of scattered mammoth remains within the general limits of glaciation are the part of a tooth found in the drift about six miles above Edmonton, Alberta, Canada,[19] and on Snow River, at the head of Lake Kenai, Kenai Peninsula, Alaska.[20]

In Science[21] under the heading "Geographical Notes," an anonymous writer mentions that Lieut. H. T. Allen observed remains of mammoth, presumably, on the Copper River, Alaska. This appears to be an error, for Lieut. Allen[22] makes no reference to such remains having been seen on the Copper River, but he says, that on the Koyukuk River, which flows into the Yukon from the north, six miles above the mouth of the Allenkakat River, a tributary of the Koyukuk, he found the *os pubis* of a mammoth. He also makes a note on his map No. 1, of "Ice banks—Mammoth remains" at the mouth of a stream he names the "Atutsakulakushakakat" that flows into the Yukon from the south about eighteen miles below the mouth of the Tozi River. This is the general locality of the Palisades already mentioned.

V. HORIZON OF MAMMOTH IN ALASKA

I. REMAINS CARRIED OUT ON LAKES BY FLOATING ICE

The lowest horizon in Alaska to which Mammoth remains may be referred are the lacustrine facies of the "Yukon Silts" or the "Kowak Clays."[23]

These deposits form an extensively developed Pleistocene feature in Alaska. Scattered through them occur fragmental remains of mammoth skeletons, isolated teeth, tusks, and bones, which are exposed where the streams undermine the silts by lateral cutting.

[19] Lambe: The Ottawa Naturalist, Vol. XII, 1898, p. 137.

[20] The Nome Semi-Weekly Nugget, Sept. 24, 1904.

[21] Vol. VI, October 30, 1885, p. 380.

[22] Report on an Expedition to the Copper, Tanana, and Koyukuk rivers in Alaska in 1885. Senate Ex. Document, 2d Session, 49th Congress, 1886-'87, Vol. 2, p. 99.

[23] For a description of these deposits see Spurr, Geology of the Yukon gold district. Eighteenth Ann. Rep. U. S. Geol. Survey, pt. 3, 1898, pp. 200-221.

Collier, Bull. No. 218, U. S. Geol. Survey, 1903, pp. 18 and 43.

Dall, Bull. 84, U. S. Geol. Survey, 1892, pp. 265-266 and in a Report on the Coal and Lignite of Alaska, Seventeenth Ann. Rep. U. S. Geol. Survey, 1896, p. 856.

The fragmental condition and scattered positions of these remains places them in the category of *secondary depositions.* The state of preservation of bones from these situations indicate they have not been carried far. Generally they are unbroken (pl. II, fig. 2).

2. SEARCH FOR SKELETONS SHOULD BE MADE ON LAKE SHORES

That the fluvio-glacial Pleistocene lakes of Alaska were subject to annual winter freezing, at least at various stages of their existence, there appears no doubt, because scattered apparently indiscriminately through the clays at varying depths and considerable distances from the former shore lines of these basins are some mammal remains. Their positions can only be accounted for by supposing they were carried out on the waters of the lakes from the adjacent shores or tributary streams by ice during spring breakups and freshets, there to be dropped by its melting to their present positions interbedded in the silts. There appears no other logical way of explaining the presence of these bones in the lacustrine areas. While their presence under these circumstances points towards the lakes freezing over in winter we do not wish it understood by this that Alaska then had winters as severe as those of the present time, or that it was ice bound for the greater part of each year, but that conditions were more nearly as they are in temperate regions today. The main point is that the remains occur in the silts as scattered depositions. The animals from which they are derived probably died about the shores of these lakes and it is these Pleistocene lake shores we must examine carefully if we are to obtain anything like complete remains of the mammals inhabiting the region at that time.

VI. PLIOCENE IN ALASKA

1. DEPOSITS. PROBABLE CHANGES OF LEVEL

No extensive developments of Pliocene have been identified in Alaska. Whether Pliocene time was mostly one of denudation over this great area, ending with a subsidence accompanied by changes in relief forming barriers across the main drainage courses of the country, which in some cases appear to have been augmented by flows of eruptives, remains to be shown. At any rate there were barriers that localized the retention and deposition of the Pleistocene lacustrine silts and clays throughout the drainage basins in the majority of cases. In other instances the coarser silts along valleys appear to have formed by a clogging of the channels by

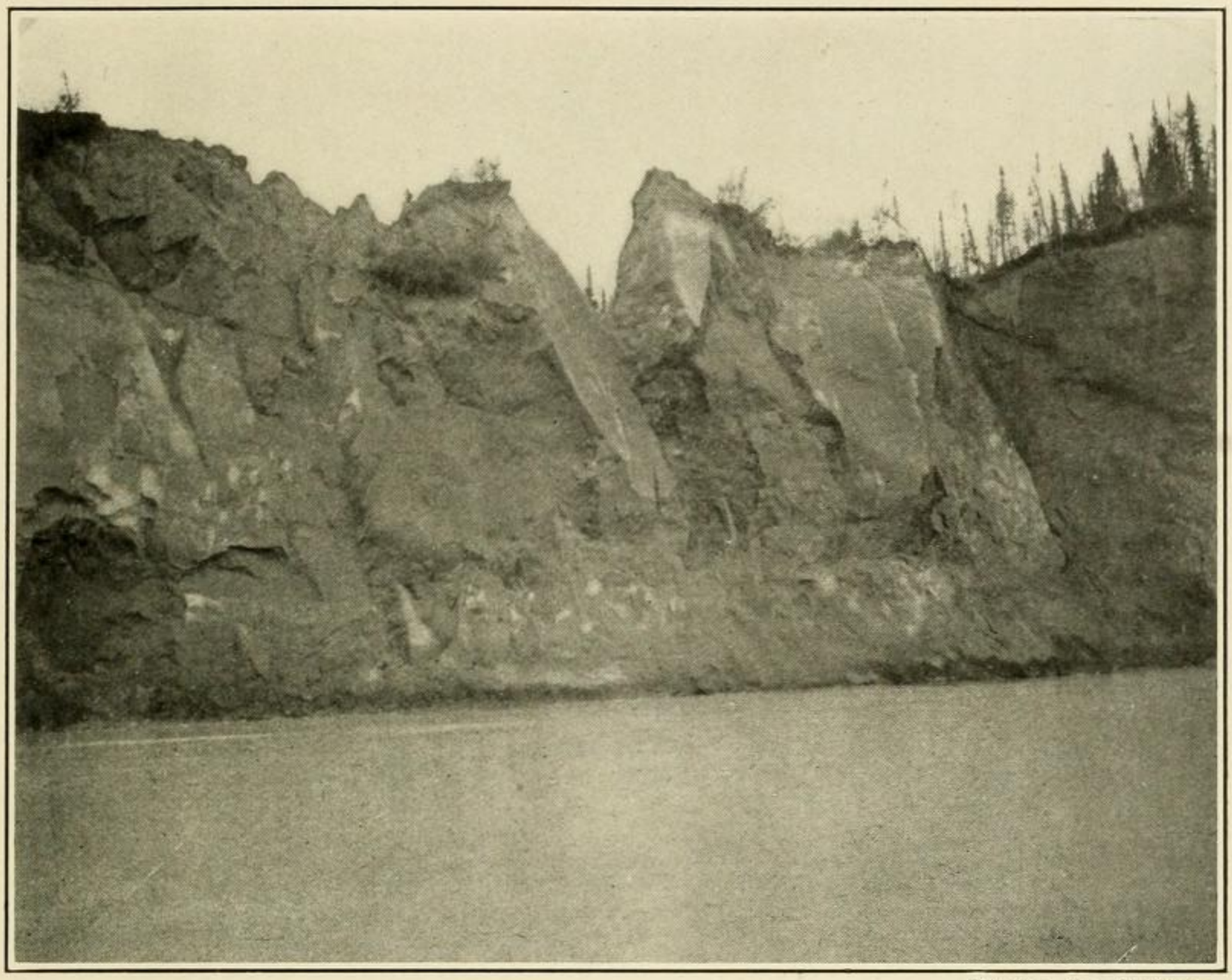


Photo. by Collier.

1. Palisades on the Yukon River thirty miles below the mouth of the Tanana River, showing blocks of frozen silts as they are undermined and subside into the river.

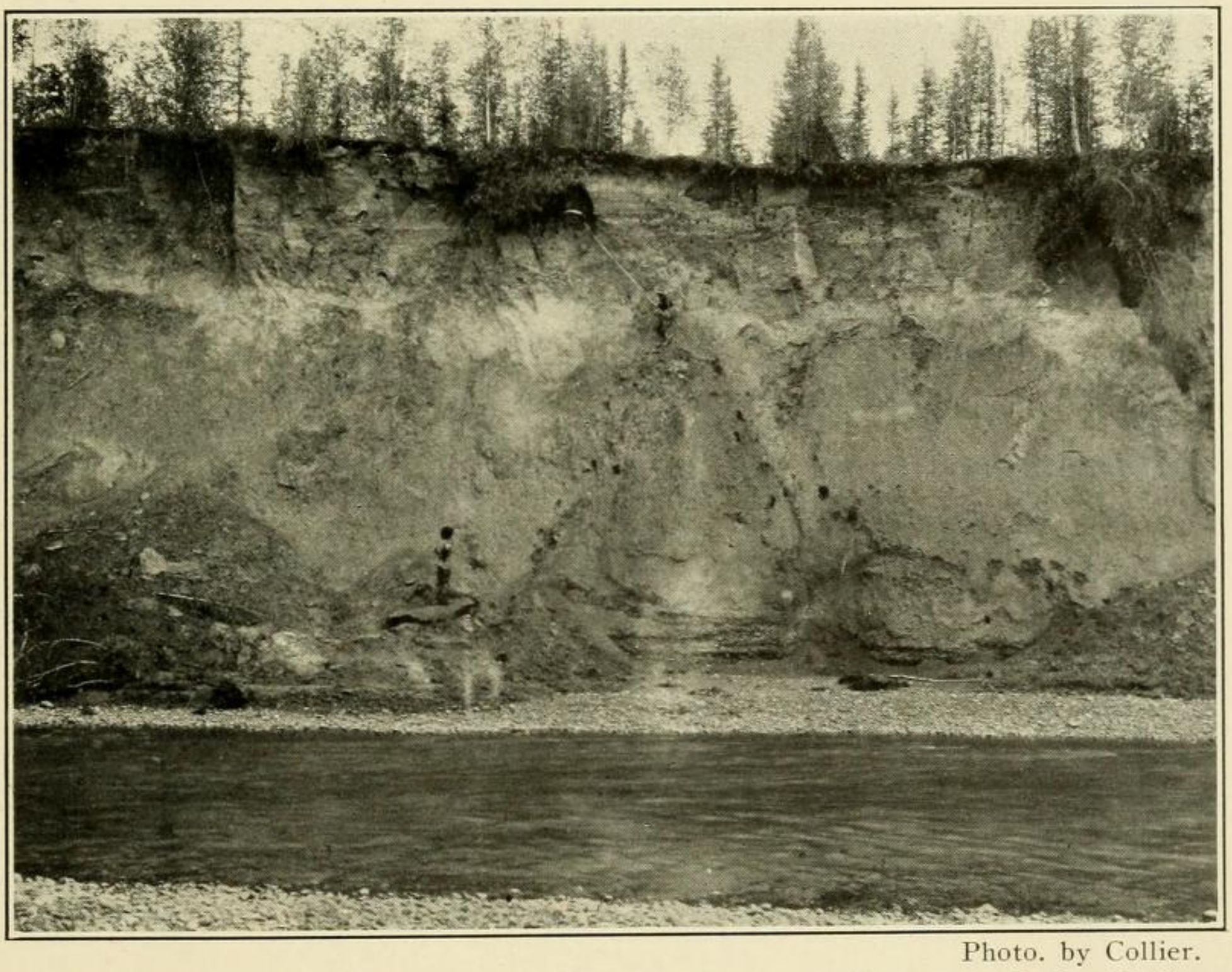
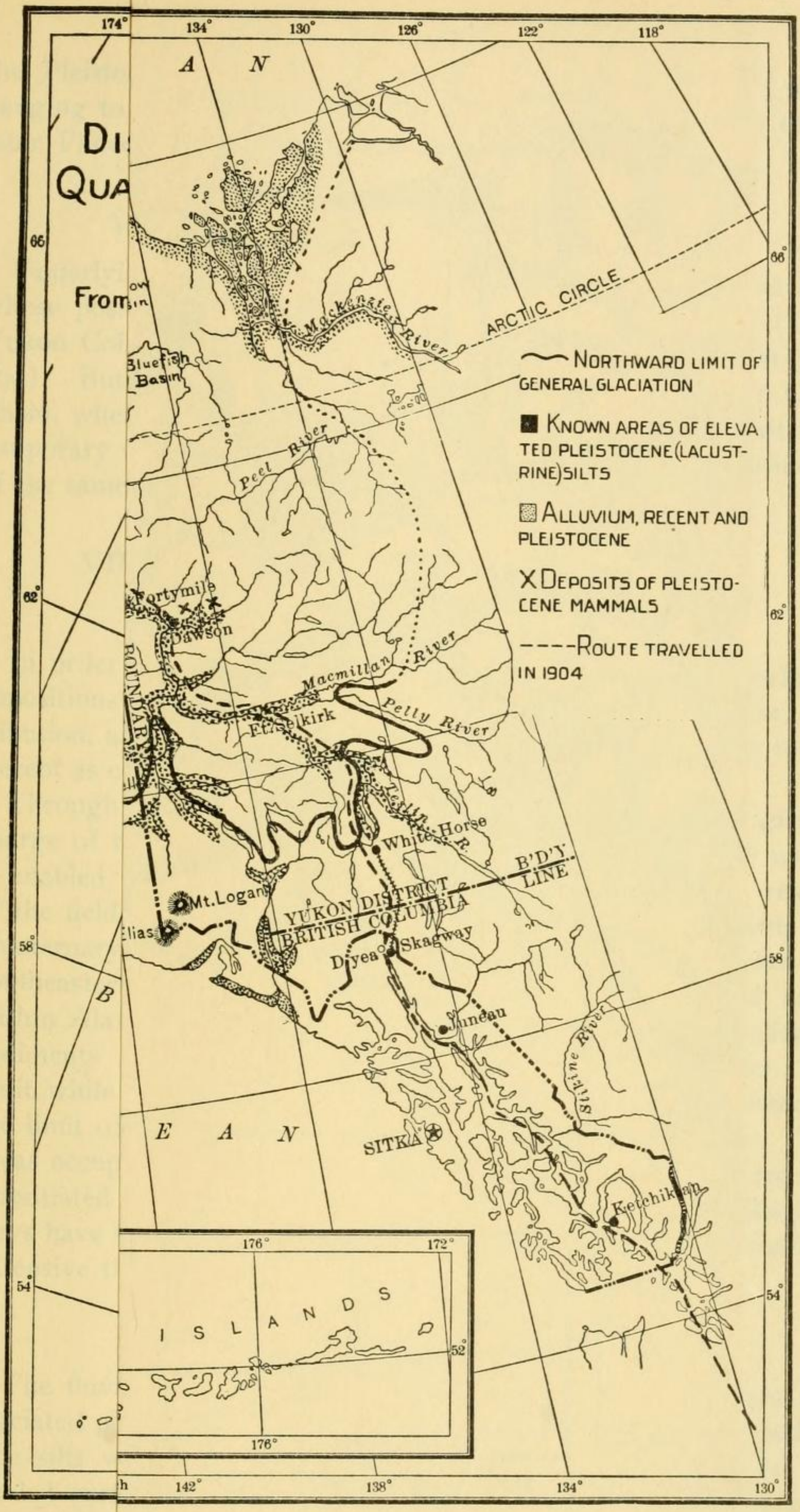


Photo. by Collier.

2. Pleistocene Silt Bluff on the Klalishkakat, a tributary of the Yukon, showing a mammoth tusk protruding from the bank.


174°
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ISLANDS
176°
172°
52°
Mackenzie River
ARCTIC CIRCLE
Bluefish Basin
Peel River
Fortymile
Dawson
Macmillan River
Pelly River
Ft. Selkirk
Teslin
White Horse
B'D'Y LINE
Mt. Logan
YUKON DISTRICT
BRITISH COLUMBIA
Elias
Dyea
Skagway
Juneau
Stikine River
SITKA
Ketchikan
NORTHWARD LIMIT OF GENERAL GLACIATION
KNOWN AREAS OF ELEVATED PLEISTOCENE (LACUSTRINE) SILTS
ALLUVIUM, RECENT AND PLEISTOCENE
X DEPOSITS OF PLEISTOCENE MAMMALS
----ROUTE TRAVELLED IN 1904

APPROXIMATE DISTRIBUTION OF THE TERNARY FORMATION OF ALASKA.

U.S. Geological Survey.

ARCTIC OCEAN

BERING SEA

PACIFIC OCEAN

Pt. Barrow

C. Simpson

C. Halkett

Franklin Pt.

Colville River

Old Crow Basin

Coleen Basin

Bluefish Basin

Porcupine River

Yukon River

Koyukuk River

Tanana River

Rampart

Nome

St. Michael

Anvik

Eagle

Fortymile

Dawson

Peel River

Mackenzie River

Arctic Circle

Mt. McKinley

Mt. Wrangell

Valdez

Tyonek

Cook Inlet

Kenai Peninsula

Mt. Logan

Mt. St. Elias

Macmillan River

Pelly River

Kirk

Wh. Dr. Horse

Dyea

Skagway

Atlin

Telegraph Creek

SITKA

Kodiak I.

Alaska Peninsula

ALEUTIAN ISLANDS

RUSSIA

UNITED STATES

SIBERIA

ALASKA

BOUNDARY LINE

YUKON DISTRICT

BRITISH COLUMBIA

B'D'Y LINE

~ NORTHWARD LIMIT OF GENERAL GLACIATION

■ KNOWN AREAS OF ELEVATED PLEISTOCENE (LACUSTRINE) SILTS

▨ ALLUVIUM, RECENT AND PLEISTOCENE

X DEPOSITS OF PLEISTOCENE MAMMALS

---- ROUTE TRAVELLED IN 1904

Longitude West from Greenwich

Scale 100 0 100 200 300 400 miles

the Pleistocene sediments where remnants of them remain today hanging to the valley sides. Whether these changes belong to the later Pliocene or early Pleistocene remains to be settled.

VII. GRAVELS UNDERLYING PLEISTOCENE SILTS

Underlying the Pleistocene silts in some places are gravel beds whose possible Pliocene age has been suggested by Spurr (Geol. Yukon Gold District, 18th. Ann. Rep. U. S. Geol. Sur., Part 3, p. 199). But from the relation they bear to the silts in the Old Crow Basin, where the gravel terrane forms a typical beach deposit contemporary with the lacustrine silts it appears they may be considered of the same age.

VIII. BRIEF OUTLINE OF PLEISTOCENE OF ALASKA

1. MAP

In order to show more clearly how these scattered and original depositions of mammal remains occur, a sketch of the nature, distribution, and extent, of the Pleistocene, with such reference to the Recent as concerns the Mammoth will be attempted.

Through the kindness of Mr. Alfred H. Brooks, Geologist in charge of the U. S. Geological Survey work in Alaska, the writer is enabled to present a map of Alaska showing the latest results of the field observations of members of that survey as regards the Quaternary. This map (pl. III) shows the boundary between the southeastern glaciated and the northwestern non-glaciated areas within Alaska, together with the distribution of the unconsolidated sediments forming the Pleistocene and Recent. However, this limit while practically a continuous line must not be interpreted as the limit of a continuous ice-sheet, but of individual glaciers. The areas occupied by the "Yukon Silts" and "Kowak Clays" are differentiated in a general way as far as known. These silts and clays have special significance and are no doubt more numerous and extensive than here shown.

2. STRATIGRAPHIC RELATIONS OF PLEISTOCENE

The fluvial and lacustrine beds of Alaska and the adjacent unglaciated portion of Canada represent the whole Pleistocene period. The silts with their occasional gravels rest unconformably on the eroded surfaces of the older formations. They appear most conspicuously as terraces along the sides of the valleys. Where the

valleys widen into basin-like expanses there are typical lacustrine deposits. They are made up of unconsolidated grayish colored sands and clays sometimes underlain by gravel beds which appear to be of contemporaneous age. These silts may usually be differentiated from the Recent alluvium by their lighter color, which also suggests their fluvio-glacial origin. As recognized and described by observers the Pleistocene occurs as deposits of gravels, sands, and clays distributed throughout the drainage basins. In Alaska, as in Siberia, no inter-Glacial deposits appear to occur, and the relations of the fluviatile and lacustrine deposits to the glacial accumulations of the mountains, beyond the general fact that most of the materials of the former are the down-stream residual of the latter, cannot be stated at present.

3. DERIVATION. NATURE. DISTRIBUTION

The events that lead up to their deposition appear to have been a period of general erosion, for the unconformable underlying surfaces of the older rocks are swept clean, and then a time of land depression making transportation and deposition the chief work of the rivers. This subsidence diminished the flow of the drainage, reducing the current to such an extent as to form lakes where there was room for them. Fluvial deposits were laid down along the valleys and lacustrine silts in the expanded basins. Some of the drainage courses were obstructed at intervals by elevations of the older strata and others by flows of basalt that appear to rest directly on the eroded surfaces of the older rocks, thus demonstrating their age, though relatively young, to be older than the silts. In the basins thus formed the finer silts were laid down, while in some cases there appear to have been areas of relatively quiet water caused by the channels through the extensive flood plains clogging with sediment. Thus at the time the "Yukon Silts" and "Kowak Clays" were forming, Alaska, for the most part, was a low-lying country, characterized by enlarged rivers with slow drainage and many lakes. The supply of water was abundant and the flood plains extensive. The present valleys were the drainage channels for the volumes of water that flowed from the great glaciers to the south and east and from the local glaciers within its limits. All these waters were highly charged with silt and the finer sediment was carried far beyond the glaciated areas where today they lie deposited in former lake basins and along the valleys.

The silts are from fifty to two hundred or more feet in thickness and at the "Palisades" on the Yukon and in the Coleen Basin on the

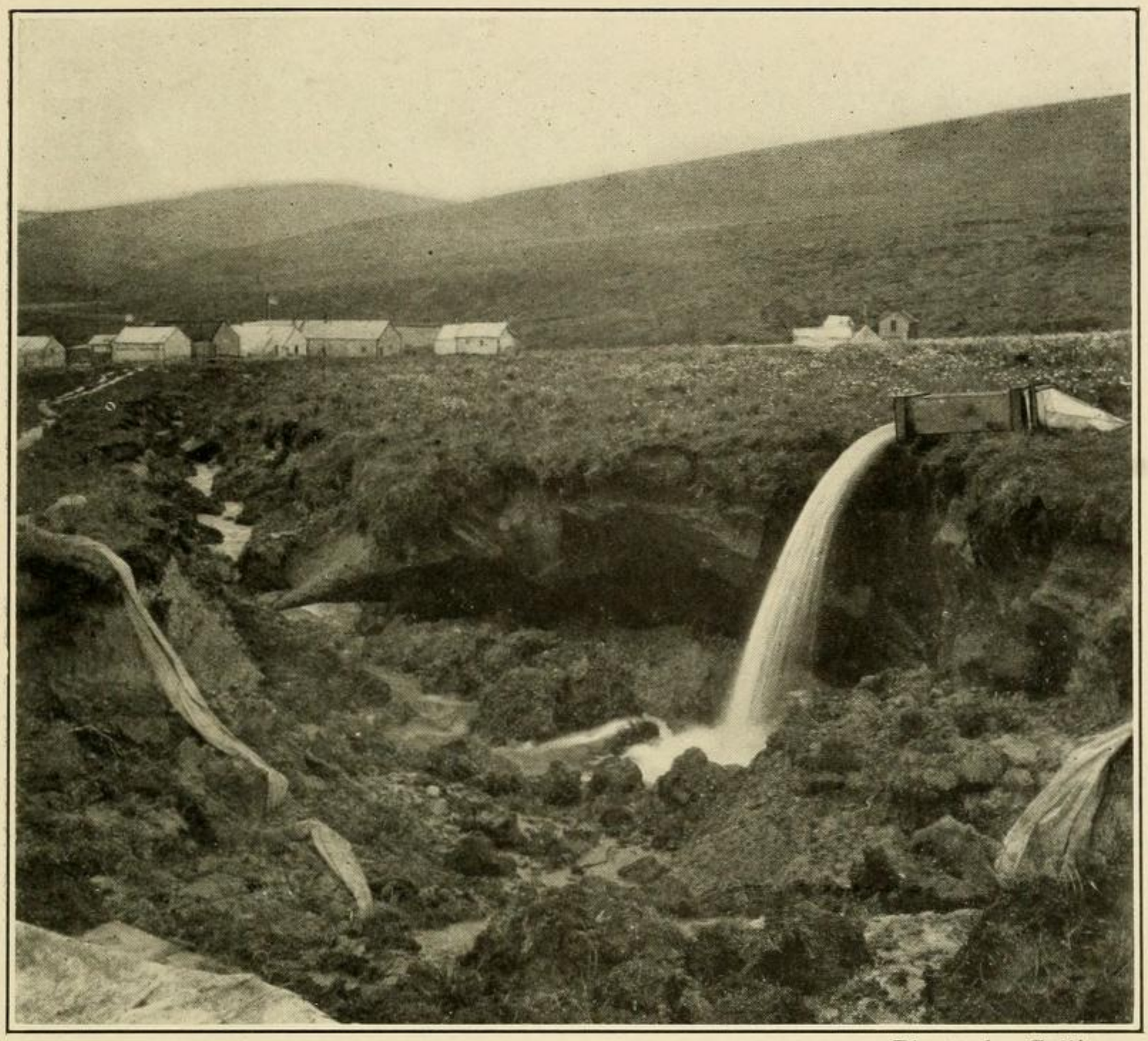


Photo. by Collier.

1. Ground sluicing a deposit of flood-plain ice on a placer mining claim on the Seward Peninsula, Alaska. Such ice masses overlain by humus and soil are called "*glaciers*" by the miners.

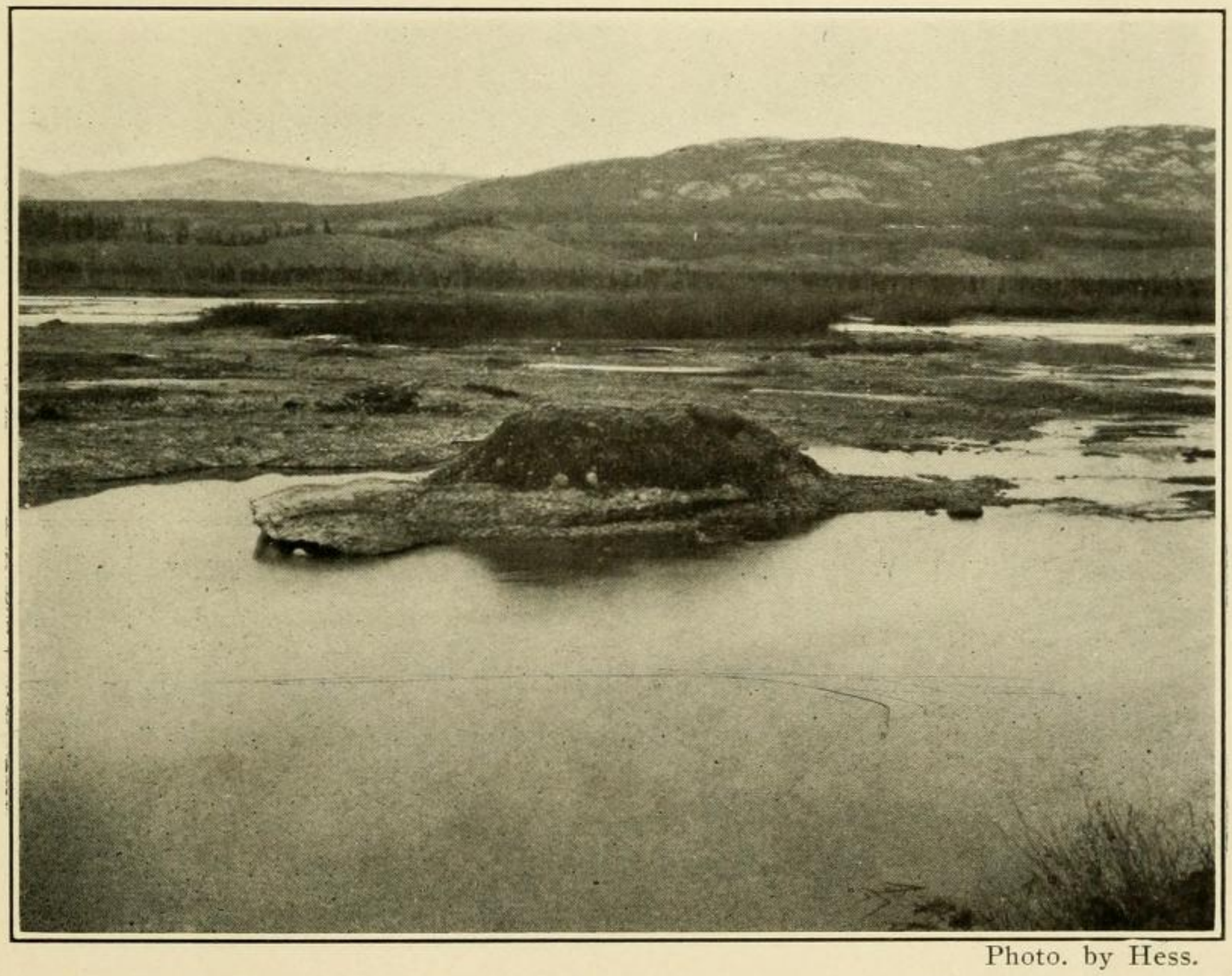


Photo. by Hess.

2. Bar ice on the Yukon River in June overlain by gravels deposited by the flood of the spring break-up.

Porcupine, beds of lignite occur interstratified showing a local drainage or elevation of these basins in the course of their silting up and then further subsidence and deposition.

As noted by Spurr [24] and Collier [25] "The silts, though entirely unconsolidated, are in places thrown up into broad, open folds, and at one locality faulting was observed."

4. SNOWDRIFT OBSTRUCTION OF DRAINAGE

None of the facts as now exhibited in Alaska make it necessary to resort to fanciful pictures of the flood plains of the drainage systems being modified or obstructed by great accumulations of winter snows, either to account for the lacustrine nature of the Pleistocene silts themselves or for the deposits of ice found on top of, but *never interstratified* with, them. Geikie [26] refers to Darwin as having suggested "that valleys might eventually become entirely filled with the blown snows of successive years, so as to compel the rivers in summer to rise in flood, and to reach levels which they might otherwise have been unable to attain. That such changes may have taken place again and again is no mere dream." On page 665 Geikie concludes: "We are justified, therefore, in the belief that the drainage systems in the low grounds must frequently have been deranged by the presence of such congealed snowdrifts," etc.

5. PLEISTOCENE LAKE BASINS

The Pleistocene lake basins in Alaska were formed by barriers across the general drainage systems as they exist today. The barriers vary in nearly every case. The lakes necessarily did not all become barricaded at the same time. In fact there is reason to believe that in different areas these barriers formed obstructions to the general drainage at varying periods throughout the Pleistocene. Consequently the silt deposits, though similar otherwise, because of common origin, are not all of the same age. Neither were all the Pleistocene lakes drained at the same time, for some of the barriers were more resistant to the erosion that set in with the elevation that closed the period and were not cut down sufficiently until a considerable time after other areas were drained. It is in the last drained areas that the remains of elevated ice are freshest.

[24] Geol. Yukon Gold Dist., 18th Ann. Rep. U. S. Geol. Sur., Part 3.
[25] The Coal Resources of the Yukon, Alaska, Bull. U. S. Geol. Sur., No. 218.
[26] Great Ice Age, p. 663.

The sequence of events accompanying the period of elevation and drainage cannot be traced in detail with the facts at hand. They are mentioned here to show there is no necessity for calling in "unusual accumulations of snow throughout successive years" to account for any of the phenomena under consideration.

6. ELEVATION AND DEFORMATION AT CLOSE OF THE PLEISTOCENE

It has already been stated that the Pleistocene silts of Alaska are thrown up into broad open folds. These undulations appear best developed where there are the largest areas of silts or throughout the basin areas of the former lakes. The deformation appears to have developed during the period of elevation that marked the close of the period of Pleistocene deposition. This folding was gentle and formed comparatively small shallow lake and pond areas over the drained bottoms of the former extensive lakes.

7. PROBABLE CHANGE OF CLIMATE

Accompanying this elevation was a change from comparatively mild, temperate conditions, which there is every reason to say existed—for the fauna and flora as far as known demand moderately temperate conditions—to the climate that prevails in these regions today.

As a better idea of the situation may be presented by quoting from one who has given considerable attention to the subject the following is appended from Sir Henry Howorth[27] in an article entitled "The Mammoth Age was Contemporary with the Age of Great Glaciers;" he says: "It is a remarkable fact that if we limit ourselves to the plains of northern Siberia, there is no evidence that a period of severe cold other than that now existing has marked the climate of Siberia since the Mammoth was extinguished. The existence of carcasses in their flesh point to the age they represent having been the last one, the climate having become more and more severe since the Mammoth age. This means, if evidence is to go for anything, that the Mammoth age in Siberia and northeast Europe, which was its last epoch, was contemporary with the Great Glaciers." He quotes Geikie as saying "the Mammoth and the Woolly Rhinoceros may have survived in northern Asia down to a comparatively recent date"[28] and continues: "I cannot see how the conclusion can be avoided, in fact, that in Siberia the Mammoth

[27] Geol. Mag., Lond., 1894, pp. 161-167.
[28] The Great Ice Age, 3d ed., pp. 706-707.

age was strictly contemporary with the development of Great Glaciers in Europe and North America."

"What is true of Siberia is equally true of that outlier of Siberia —Alaska—which resembles it in every way, in the preservation of remains of Pleistocene beasts in a very fresh condition, whose very freshness, as in Siberia, points to their having lived in the very latest geological period, and contemporaneously with the glaciation of the country round Hudson's Bay further east."

On page 164:[29] "If we turn to America and examine the problems, either as presented by the so-called bone licks of Ohio, or by the driftless areas, we shall be constrained to the same conclusion. The bones of the extinct animals in both cases occupy the very latest beds and are found, so far as we can judge, at the precise horizon where elsewhere the drift beds occur."[30]

On page 167:[31] "The view here urged in regard to the contemporaneous existence of the Great Glaciers and a fertile champagne country side by side in the last geological age seems to me to best explain the facts."

"What I do dispute is the inference that they point to the Ice beds being older than the Mammoth beds. Whatever their age, it seems to be quite certain that they must be the result of infiltration, unless trees can grow on blue ice and Mammoths browse on snow."

Further, Howorth[32] remarks:

"To shortly state the general conclusions which I would press:

"I. During the Pleistocene period the Arctic lands, instead of being overwhelmed by a glacial climate, were under comparatively mild conditions, and were the home of a widely spread and homogeneous fauna and flora constituting, perhaps, the best defined life-province in the world.

"II. Since Pleistocene times the climate of these Arctic lands has been growing more and more severe, resulting in the extinction of a portion of their vegetable and animal inhabitants.

"III. The true and the only Glacial climate which we know to have prevailed in the Arctic lands was not during the so-called Glacial age of geologists, that is during the Pleistocene period, but in that which is now current, and which is the product largely, if not

[29] Op. cit.

[30] See Geikie, The Great Ice Age, p. 464.

[31] Op. cit.

[32] The Recent Geological History of the Arctic Lands, Geol. Mag., Lond., 1893, p. 500.

entirely, of changes of level in the earth's crust which have occurred since Pleistocene times."

Howorth's ideas as above expressed are supported by the facts in Alaska as far as known, particularly in his contention that the Ice beds, or so-called "Ground-ice formation" of Dall, or "Fossil-ice" of Baron Toll, did not precede the Mammoth age and, therefore, does not belong to the Pleistocene period.

How generally accepted is the opinion that the Ice beds are older than the Mammoth may be gathered by the following from Geikie:[33]

"There cannot be any doubt, therefore, that this remarkable sheet of dead ice must date back to Pleistocene times, and is obviously of the same origin, as Dr. Penck remarks, as the frozen bottoms or grounds which are so commonly met with in the higher latitudes of North America and Asia. Since the Mammoth and its congeners disappeared, no similar accumulation of ice has formed in that region —the dead ice is not being added to, but is gradually wasting away, and Dr. Penck[34] is clearly right when he says that the ice masses of Eschscholtz Bay belong to an older period, when the climate of those northern regions was considerably colder than it is to-day. The frozen grounds of the far north are, in short, the equivalent in time of the old glacial phenomena of our temperate latitudes. The ice masses of northern Alaska are not the relics of any glacier or ice sheet, for we have no reason to believe that those tracts have ever been glaciated. They simply represent the drifted snows of Glacial times which accumulated in valleys and depressions outside of the ice-covered regions. Protected under a covering of alluvial matter, soil, and peat, they have, in those high latitudes, endured to the present day."

It appears strange that "the drifted snows of Glacial times" should have collected and been preserved only in situations that were at that time without question the bottoms of Pleistocene lakes covered with water.

Thus it is easy to see that the significance of these ice beds has puzzled inquirers a great deal and explanations of their origin hardly less discordant with the facts than those recorded above have been entertained and defended.

[33] The Great Ice Age, 3d ed., p. 665.
[34] Deutsche geographische Blätter, Bd. IV, p. 174.

IX. DEPTH OF FROST IN CIRCUMPOLAR REGIONS

I. STATEMENTS BY RUSSELL

Russell [35] says: "The reason for the great thickness of the frozen layer at these localities seems to be that deposition and freezing went on at the same time. These certainly seem to be the conditions under which the great thickness of frozen material beneath the tundra and in the flood plains of the larger rivers of Alaska have accumulated.

"It seems to me that this must also be the explanation of the origin of all frozen deposits which contain alternating strata of clear ice and of frozen layers of mud and peat like those exposed in the borders of the tundra and along the banks of the Yukon.

"It is recorded by K. E. von Baer that the ground at Yakutsh, Siberia, is frozen to the depth of 382 feet. It has been assumed by various writers that the great depth of ice (frost?) in this and other similar instances is due directly to *surface temperature,* the downward limit to which the winter's cold can penetrate being limited by the internal heat of the earth. Before accepting this explanation as final it should be ascertained whether the strata at the localities where depth of frozen material has been encountered might not have been frozen progressively as they were laid down."

In the Pleistocene lacustrine silts and clays as exposed today to depths of at least one hundred and fifty feet we have examples of deposits of homogeneous material without any interstratification of ice or any other material being in a frozen state. These clays could not freeze while being deposited under water. Consequently they have assumed a frozen state since the waters of the lakes have been drained off. And the cold that caused this freezing is the same that has frozen the ice beds now lying conformably on top of the clays.

On page 130 (op. cit.) Russell gives a mathematical presentation of the subject by R. S. Woodward:

"The considerable depth below the earth's surface to which frost or the temperature of freezing is known to penetrate in the Arctic regions, raises the interesting question of the relation between the thermal properties of the earth's crust and the time and depth of penetration, etc."

"The conclusion reached by Mr. Woodward indicates that the

[35] Notes on Surface Geology of Alaska. Bull. Geol. Soc. Am., Vol. I, p. 129.

freezing of even the deepest ice stratum reported in the Arctic might have resulted directly from a mean annual temperature no lower than *now prevails* in northern Alaska."

The writer thinks it safe to reiterate that the most severe climate we are justified by facts in assigning to the Arctic is that prevailing there today.

Page 132 (op. cit.) "Although the passage of heat through the surface layers in Arctic regions is slow, yet it is apparent that the length of time since a mild climate existed there is sufficient, even under existing conditions, to allow of the freezing of strata several hundred feet below the surface. The mean annual temperature of the non-glaciated portion of Alaska during the Glacial epoch must have been lower than at present—at least such I am confident would be the conclusion of the majority of geologists—and there seems good reason for believing that the freezing of the tundra began in Pleistocene times and continued to the present day. An increase in the thickness of the frozen layer, owing to the influence of a mean annual temperature below 32° F., and the deposition of a succession of frozen layers, as suggested elsewhere, may have combined to produce the results now observed."

The writer cannot agree with the supposition that "The mean annual temperature of the non-glaciated portion of Alaska during the Glacial epoch must have been lower than at present." There are no facts to support such a view. Neither is this surmise justified—"and there seems good reason for believing that the freezing of the *tundra* began in *Pleistocene time* and continued to the present day"—for there is nothing to show that a tundra mantled surface of the non-glaciated area was the condition prevailing in Pleistocene time. In Siberia the flora of Pleistocene time north to the present Arctic coast line was not what is classed as tundra. In Alaska, too, the Pleistocene lignites tend to show that a more temperate flora extended considerably farther north than today and there is nothing to indicate that tundra existed at all until the Recent period commenced. The writer considers that all of the peat and tundra of Alaska belongs to the Recent. That the climatic conditions inaugurating this period were the first of enough severity to suppress vegetation to the character called tundra.

2. A. C. SEWARD QUOTED

A. C. Seward[36] under the heading, "Plants and Low Tempera-

[36] Fossil Plants as Tests of Climate. Cambridge Univ. Press, London, 1892, p. 44.

tures: Arctic Vegetation," summarizes as follows: "In attempting to picture to ourselves the conditions which obtained during the Glacial period, it is frequently forgotten that a very low temperature is not of that importance which it is often considered to be in bringing about an Ice Age.

"Wallace[37] and many others have laid stress on the necessity for a concurrence of several conditions in order to render possible an abnormal extension of snow and ice.

"Whitney[38] in his comprehensive monograph on the climatic changes of later geological times, has argued for the possibility of the former extension of snow and ice without any violent changes in climatic conditions.

"After considering the question at length he remarks, 'The entire body of facts presented brings out most clearly the true condition of things, namely, that the Glacial epoch was a local phenomenon, during the occurrence of which much the larger of the land masses of the Globe remained climatologically entirely unaffected.' As illustrating the possibility of glaciers existing in places whose mean temperature differ by several degrees we may notice some observations given by Woeikof.[39] He shows clearly how other conditions than merely a low temperature are essential to ice extension. Comparing the temperature taken at the lower ends of glaciers in East Siberia and the west of New Zealand, there is found to be a difference of more than 20°; at Irkutsk in East Siberia the temperature recorded being —10.2°, in New Zealand 10°. Glaciers occur in the latitude of Nice and Florence extending to 212 meters above the sea level having at their lower ends a mean annual temperature corresponding to that of Vienna and Brussels, and warmer than that of Geneva and Odessa, with a winter temperature higher than that of Florence.

"There is the often-quoted case of the Tasman glacier descending towards the West coast of New Zealand; here the terminal face of the ice is 705 feet above sea level, and is 'hidden by a grove of Pines, Ratas, Beeches, and arborescent Ferns in the foreground.'

"All these facts show us that the idea of the coexistence in the same region of vegetation—in some cases of an almost tropical facies—and ice fields is not so inconceivable as one might suppose.

[37] Island Life.

[38] The climatic changes of later geological times. Mem. Mus. Harvard Coll., Vol. VII, No. 11, 1882, p. 387.

[39] Gletscher und Eiszeiten in ihrem Verhältnisse zum Klima. Zeit. Gesell. für Erdkunde zu Berlin, Vol. XVI, 1881, p. 217.

A brief sketch of some of the conditions of plant life in Arctic lands will further make this clear, and at the same time bring out a number of facts which have an important bearing on the question of plants and climatic conditions," etc.

X. THE LAND ICE OF ARCTIC AND SUB-ARCTIC REGIONS

Ice deposits may be classified under five heads in chronological sequence as follows:

1. GLACIAL ICE OF SNOW ORIGIN

Glacial ice does not enter into this discussion beyond what has been already said; that its erosive action in the higher lands produced most of the immense quantity of detritus which forms the deposits of the Pleistocene period, and the waters from the melting snow and ice supplied the great volumes necessary to transport this material over the wide areas it now occupies. The ice in this case is of snow origin and its formation has extended from Pleistocene time down to the present.

2. ICE-BEDS OF ELEVATED PLEISTOCENE LAKE BASINS NOT OF SNOW ORIGIN

The older elevated ice-beds as they survive in Alaska today appear to mark the end of the Pleistocene and beginning of the Recent, there being no break between the two periods. This elevated ice marks a colder climate, which accompanied the elevation of the land that drained the large Pleistocene lakes. It also marks the beginning of conditions as they exist today in that region. It is the oldest ice we know of after glacier ice.

The ice-beds are elevated from fifty to two hundred feet above present drainage levels. They rest on the Pleistocene lacustrine clays in hollows or undulations apparently due to gentle folding the silts have undergone in being elevated to present levels. This same elevation being the one that has caused the Pleistocene lakes to drain.

As already remarked it is dead ice gradually wasting away and not, from appearances, being added to in any way. Generally it may be distinguished from the younger ice interstratified, or rather intermingled, with the recent alluviums of the river and coastal plains, by its occurrence in more extensive sheets or beds, its elevation above the present drainage levels caused by the down-cutting of the streams since it was frozen, and in that it rests conformably

upon the Pleistocene lacustrine silts. If a snowdrift deposit, some evidences of unconformity are to be expected. For naturally snowdrifts are likely to sometimes collect on land surfaces thus burying the vegetation previously growing on the land and preserving some trace of it underneath any future beds of ice the snow might form. Some evidences of vegetation are to be expected under the ice-beds where they formed on or near the former lake shores, but the remains in such cases are entirely different from those that snowdrifts might bury. There appears to be no reason for confusing such occurrences. At Eschscholtz Bay the remains of vegetation associated with the silts and ice are composed of sticks and twigs of trees, some of them gnawed by beavers. This is an occurrence to be expected on the shores of lakes in estuaries and near the mouths of small streams. As before stated, when the Pleistocene beds were elevated, and the former lakes drained, the deposits were thrown into gentle folds, and no doubt some irregularities of bottom already existed, such as may be accounted for by irregularities in the deposits due to cross-currents and wave building forming areas favorable for the retention of shallow ponds and lakelets; also ox-bow lakes which are common today in these regions. The hollows of the undulating surface formed shallow basins of varying areas, with impervious clay bottoms. The new land surfaces thus laid bare were diversified by a large number of shallow lakes and ponds spread over the formerly extensive lake bottoms. Today the old dead ice-beds appear to be consistently associated with impermeable clay basins in elevated positions.

The more severe climate that appears to have gradually accompanied the elevation of the land froze these shallow basins of water into the ice-beds we see today. Just as the large lakes were not all drained at the same time neither did the freezing of the ice-beds happen contemporaneously but progressed gradually as it does today. I. C. Russell[40] describes the process. The surface of the new land was carpeted by a layer of moss that surrounded the ponds and lakes. The moss encroached on the lakes from all sides. "As the moss covers the lakelets more and more completely during a series of years, the ice formed by the freezing of the water in winter is more and more thoroughly protected, and is finally completely shielded from the heat of summer. A body of clear ice is thus formed in the tundra, similar to the strata of ice exposed at certain

[40] Notes on the Surface Geology of Alaska. Bull. Geol. Soc. Am., Vol. I, 1890, pp. 99-162.

localities along the coast of Bering Sea and in the banks of the Yukon."

The older elevated ice-beds of the Pleistocene lake basins apparently have been covered and preserved in this way. As exposed today by the lateral cutting of the streams draining their areas the ice-beds have a covering of peat varying from two or three to fifteen feet in thickness. In most cases this protective covering to the ice is composed entirely of vegetable remains. It is only rarely that recent alluvium or soil is incorporated with the peat or humus covering. This is because of the relative positions of the ice-beds with reference to drainage levels that have existed in these areas from the time they formed to the present. This absence of alluvium above these elevated beds of old ice—when examined at the places of their typical development, that is, out on the undulating Pleistocene lake bottoms—distinguishes them from the newer, less extensive occurrences of ice intermingled with the materials of the present flood plains, that are subject to annual overflows and consequent depositions of alluvium.

Only where the ice masses formed near the shore lines of the former lakes, and in places where the land rises more or less abruptly, may we expect to find alluvium derived from the nearby slopes on top of the ice or incorporated with its humus covering.

The ice phenomenon at Eschscholtz Bay seems to be clearly an example of former lake-shore conditions as is also the locality on the Beresowka River in northeastern Siberia described by Tolmatschow.[41]

3. COASTAL-PLAIN ICE-BEDS. NOT OF SNOW ORIGIN

The significance of coastal-plain ice-beds is not clear to the writer. They are not elevated to such a height nor as uniformly or extensively as the beds in the elevated Pleistocene lake areas. They are not of snow origin or we should expect to see the process of their formation going on today. Some tentative suggestions are offered. These deposits occur, as far as known, along the Arctic coast and only in areas that have undergone comparatively recent heavy sedimentation. It is reasonable to suppose that the shifting of the mouths of the rivers and the consequent change of areas of loading have caused a shifting of regions of depression and upheaval during Quaternary times. Thus shallow lakes, bays, or sounds resulted, according to the extent of the uplifting. Wave and floe-ice

[41] Verhand. der Kaiser. Russ. Min. Gesell. Bd. XL, Lief. 2, 1903.

action, together with warping of the sea floor when raised up or unequal sedimentation before elevation above sea level, may also perform a significant part in the formation of ridges that eventually act as barriers to land-locked bodies of water. It is probable the changes of elevation along the coast that have raised and exposed the coastal-plain ice-beds are due to the shifting of the loading point areas of the rivers. None of the exposed ice beds in coastal-plain deposits in Alaska are reported to exceed elevations over thirty or forty feet above the sea level.

Under the conditions of climate and vegetation that have existed along the Arctic coast during the Recent period, ice-beds might be formed in a manner similar to the apparently older elevated ice-beds occurring in the Pleistocene lake areas.

It does not appear that the ice beds along the Arctic coast of Alaska have the continuous or extensive development Dall claims for them, as shown on his map, plate III, Bull. No. 84, U. S. Geol. Survey, 1892; nor with the statement, quoted, from whaling captains, made in his report on "The Coal and Lignite of Alaska:"[42]

"At a depth of two feet is a stratum of pure ice (not frozen soil) of unknown depth. This formation extends, with occasional gaps, north to Point Barrow, and thence east to Return Reef, where the ice layer is about six feet above the level of the sea. It goes south at least as far as Icy Cape without any decided break, and is found in different localities as far south as Kotzebue Sound."

Mr. F. C. Schrader, who travelled along the Arctic Alaska coast from the mouth of Colville River to near Cape Lisburne in 1901 also dissents from the views expressed by Dall.[43] He says: "The observations made by the writer, while boating along the coast, lead to the inference that the ground ice is not of so widespread occurrence as the above quotation indicates. Between the Colville and Point Barrow the ice is possibly more or less continuous along the coast, but of its inland extension we have little evidence. Even along the coast it is not extensively exposed. Here long stretches of the low tundra country are apparently underlain by rock or earthy deposit."

"Of the localities at which the ice was observed, the most important are Cape Halkett and Cape Simpson, at each of which it seems to be practically continuous for a distance of several miles.

[42] Seventeenth Ann. Rept. U. S. Geol. Survey, 1896, p. 855.

[43] A Reconnaissance in Northern Alaska in 1901. U. S. Geol. Survey, 1904. Professional Paper No. 20, pp. 91-93.

Cape Halkett, one of the most prominent promontories along this part of the coast (pl. x, *D*), terminates in an ice cliff rising thirty feet above tide level, and is overlain by a foot or two of muck, which in turn is carpeted by a nap of moss and grass at the surface. Judging from the topography, the ice at this locality may extend inland several miles. Its thickness is not known, since its lower limit lies below tide level. As shown in the view, the cape is being rapidly cut back by wave action, which undermines the cliff at tide level until by its own weight the ice breaks off in large blocks and is ground up by the surf.

"Of the Kowak clay containing Pleistocene vertebrate remains, referred to by Doctor Dall in connection with the ground ice, but little was seen by the writer. Observation, however, has been sufficient to suggest that, if present along the coast between the Colville and Chipp (Ikpikpuk) River, they are not only far from continuous, but are probably of very limited occurrence. Along the northwest part of the coast, the only locality at which what seems with certainty to be the Kowak clay was observed, is at Woody Inlet, about fifty miles southwest of Point Barrow. As this inlet is not far from the seventy-first degree of north latitude it is thought that the deposit may be near that in which Captain Beechey's party obtained elephant remains."

4. PRESENT DRAINAGE FLOOD-PLAIN ICE

All the rivers of Alaska present along their valleys two distinct classes of unconsolidated deposits. One consists of the low banks, which are only ten to twenty feet above the river and which are composed of fine dark alluvium alternating with layers of vegetable matter. Here buried logs and the upright stumps and trunks of trees are frequent, while their surfaces have often a covering of fresh mud, deposited by the spring floods. Lenticular masses of ice are frequently exposed in the banks of these flood-plain alluviums. The other class are the older deposits of higher and lighter colored silts without vegetable matter, which are cut by the rivers more rarely. These vary from fifty to two hundred feet in height.

The newer flood-plain ice occurs unconformably with alluvium and humus. Russell[44] amplifies on the formation of "Stratified Ice in the Tundra" as follows:

"The great number of lakelets on the surface of the tundra ren-

[44] Notes on the Surface Geology of Alaska. Bull. Geol. Soc. Am., Vol. I, 1890, p. 128.

ders it evident that if their extinction and the consequent burial of ice beneath the surface takes place in the manner supposed, sheets of ice, probably more or less lenticular in shape, should form a characteristic feature of tundra deposits. The origin of the lakelets may perhaps be due to the accumulation of snow banks on the tundra which by their late melting enable the moss surrounding them to grow more rapidly than on the more deeply covered areas. In this way a depression in the surface would be formed which would be flooded after the snow melted. A lakelet once started would perpetuate itself from year to year until the growth of moss from the sides led to its burial. An origin of this nature seems probable, as the lake basins (*in the tundra of flood-plains*) are due entirely to variations in the surface growth of vegetation and not to irregularities of the substratum of rock or clay on which the humus layer of the tundra rests. The origin and extinction of lakelets is thus a part of the normal growth of the frozen moss-covered plains."

Thus it appears the lower level and higher level forms of ice differ in that the presence of the newer is due largely "to variations in the surface growth of the vegetation," while the presence of the older elevated form is due to inequalities caused by slight deformations of the impervious clay deposits of the Pleistocene lake basins.

One phase of the occurrence of ice sheets in flood-plain alluviums which is of wide distribution and much interest is described by J. B. Tyrrell [45] in an article entitled "Crystosphenes or Buried Sheets of Ice in the Tundra of Northern America." As he describes the mode of occurrence of the ice under circumstances where it is most often encountered and observed—the placer mining districts of the region—the following is quoted:

"The Klondike gold-bearing district, to which my observations have lately been confined, and in which the deductions here set down were drawn, is a part of a great unglaciated belt or tract of country lying near the middle of the Yukon Territory in Canada, between the glaciated region which extends on both sides of the 'Chilcat' or Coast Range of mountains to the south and southwest, and the also glaciated region of the Ogilvie or Rocky Mountain range to the north and northeast. It is a country of high, well-rounded hills and deep, though flaring, valleys, in the bottoms of which flow streams with regularly decreasing grades. On one or both sides of these streams are everywhere deposits of alluvial material, varying from ten to a hundred feet in depth, consisting below of coarse sand

[45] Jour. of Geol., Vol. XII, p. 232, 1904.

and gravel, above which are fine sands with peaty and vegetable material, the uppermost layer, locally known as 'muck,' usually consisting almost exclusively of sphagnum swamp. The streams flow on beds of the coarser alluvial gravel or sand, seldom touching the underlying rocky floor, and are at present confined in relatively shallow channels, the sides of which consist of the peaty and finer alluvial material. Ponds or lakes are conspicuously absent.

"The surface of the whole country, whether composed of 'muck,' gravel, or rock in place, is almost everywhere permanently frozen, and while as yet comparatively few shafts have been sunk through this frozen layer, the evidence at hand would seem to show that it has a thickness varying from forty or fifty feet on the higher, uncovered parts of the hills, to two hundred feet in the moss-covered bottoms of the valleys. Here and there, however, there are unfrozen channels in the otherwise frozen layer, through which springs issue from the sides of the hills, carrying water from the deeper saturated, and unfrozen ground through the frozen layer to the surface."

On page 234 Tyrrell proposes the name "crystosphene" (ice wedge) for the underground masses of clear ice found in the Klondike country, and "crystocrene" (ice fountain) for the surface masses of ice formed each winter by the overflow of springs and that melt away each summer.

"Crystosphenes are formed by springs which issue from the rock under the alluvial deposits that cover the bottoms of the valleys. As a rule, they occur as more or less horizontal sheets of clear ice, from six inches to three feet or more in thickness, lying between layers of 'muck' or fine alluvium, usually where the 'muck' is divided horizontally by a thin bed of silt or sand; and most of them, as far as my observation goes, are from two to four feet below the surface, though some are deeper. In area they differ greatly. Those in the bottom lands of the gold-bearing creeks of the Klondike district vary in length from a hundred to a thousand feet, and in width from fifty to one or two hundred feet, as shown by shafts sunk through them at various places."

"Speaking generally, these ice sheets are of very even and regular thickness throughout, though they are not strictly horizontal, but approximate closely to the slope of the surface under which they lie. For instance, the city of Dawson is built on an alluvial bottom land declining gently from the base of a steep hill to the banks of the Yukon and Klondike rivers, and a crystosphene which here underlies the surface at a few feet beneath it seems to have about

the same slope. In another case a crystosphene was encountered on a mining claim three feet below the surface, and it was traced for five or six hundred feet down the valley, being everywhere at practically the same depth, while the surface itself had a slope of about one in a hundred, so that this apparently level sheet of clear ice was five or six feet higher at its upper end than at its lower. Examples of this kind could be multiplied almost indefinitely, showing plainly that these ice sheets do not partake of the character and attitude of frozen ponds or lakes.

"While these crystosphenes, or so-called 'glaciers,' are usually of the nature of nearly horizontal sheets, occasionally they occur as veins or dikes of ice rising through the bed rock into the overlying gravel. . . . . More or less vertical masses of ice are also sometimes met with in the gravels themselves, indicating the positions of former water channels from the bed rock toward the surface."

"In the majority of cases crystosphenes are in the vicinity of springs that can be plainly seen issuing from the bases of the neighboring hills, but in other cases no such springs are apparent. In these latter cases, however, wherever the gravel has been removed, and the underlying rock has been exposed, springs have been found."

"The mode of formation of these underground sheets of ice is therefore somewhat as follows:

"Water, issuing from the rock beneath a layer of alluvial material, rises through the alluvium, and in summer spreads out on the surface, tending to keep it constantly wet over a considerable area. In winter if the flow of water is large, and the surface consists of incoherent gravel, the water will still rise to the surface, and there form a mound of ice. If, on the contrary, the flow from the spring is not large, and the ground is covered with a coherent mass of vegetable material, such as is formed by a sphagnum bog, the spring water, already at a temperature of 32° F., rises until it comes within the influence of the low temperature of the atmosphere above, and freezes. This process goes on, the ice continuing to form downward as the cold of the winter increases, until, a few feet below the surface, but still within the influence of the low external temperature, a plane of weakness is reached in the stratified and frozen vegetable or alluvial deposit, such planes of weakness being generally determined by the presence of thin bands of silt or fine sand.

"As any outlet to the top is now permanently blocked, the water is forced along this plane of weakness, and there freezes; and thus the horizontal extension of the sheet of ice is begun. While thus increasing in extent, the ice also increases in thickness by additions

from beneath, until it has attained a sufficient thickness so that its bottom plane is beyond the reach of the low atmospheric temperature above; after which it continues to increase in extent, but not in thickness or depth.

"With the advent of the warm weather of summer the growth of the crystosphene ceases, but the cold spring water which continues to rise up beneath it has very little power to melt it, and its covering of moss or muck, being an excellent non-conductor of heat, protects it from the sun and wind, and prevents it from thawing and disappearing. Thus at the advent of another winter it is ready for still greater growth."

Ice sheets in alluvium bottoms on gradients appear to bear a certain relation to the isothermal surface marking the plane of division between the constantly frozen substratum and the annually thawed superstratum or surface layer. This thawed surface layer, composed in most cases of peat and growing sphagnum, or tundra ("Cryptogamic plants make more than nine-tenths of its mass, and on their power to grow above as they die and decay below depends the existence of the tundra.") lies like a tenacious wet blanket over the stable frozen substratum of alluvium or bed rock as the case may be. This blanket-like surface layer even where developed only to the extent of an acre or so is conducive to a condition of capillary saturation and hydrostatic semi-flotation. For in these Arctic regions the cold of winter penetrates into the saturated earth and converts it annually into a solidly frozen mass. However warm the short summers may be it is insufficient to melt more than a superficial portion of this boreal blanket, so only a swampy carpet of moss may flourish upon the constantly frozen substratum. Through this the standing water cannot sink. As the weather is never warm enough to carry it off by evaporation, these marshes extend far and wide, even up the sides of the hills and mountains.

An hypothesis to explain the occurrence of ice sheets under a mantle of moss under some of the circumstances where it is met with, especially on sloping surfaces such as Tyrrell describes for the Klondike region and which are common elsewhere in Alaska, is similar to a suggestion made by Lieutenant Belcher.[46]

The water sinks through the moss blanket from the surface and also seeps underneath it from higher levels. This tends to lift the living moss with its thawed underlying layer of vegetable humus or

[46] Beechey's Voyage to the Pacific and Beering's Strait, Vol. I, pt. II, Appendix, p. 600.

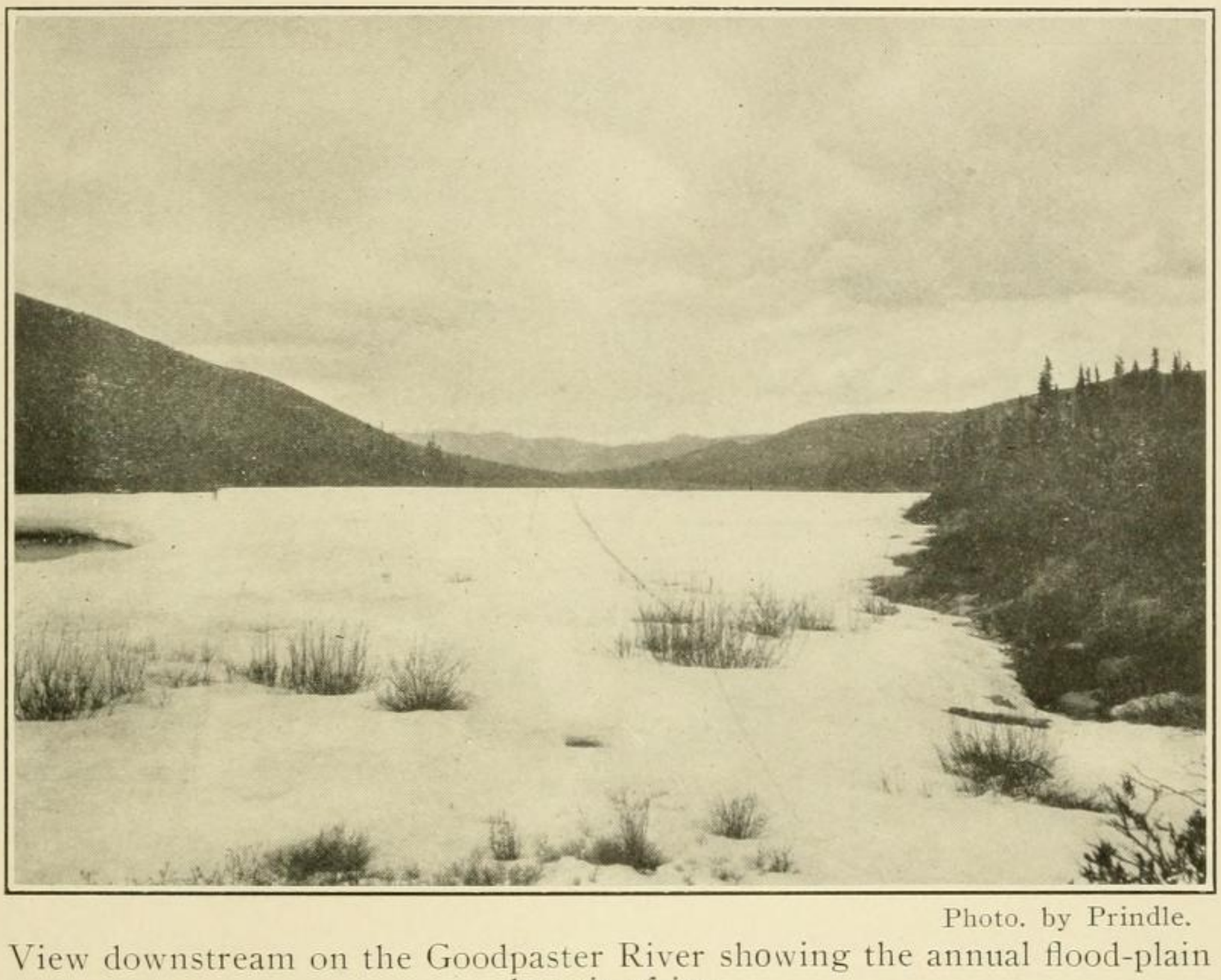


Photo. by Prindle.

View downstream on the Goodpaster River showing the annual flood-plain deposit of ice.

peat, floating it in a state of semi-buoyancy above the frozen substratum of alluvium or peat so the ice may accumulate season after season, as long as there is a growing and buoyant equilibrium maintained between the annually thawed peaty superstratum and the constantly frozen substratum.

The condition of semi-buoyancy or flotation frequently exists in bogs in temperate latitudes where the cold of winter is not sufficient to freeze the water underneath the peat, or at least where the annual result of such freezing they may be subjected to does not permit of ice surviving from year to year in whole or in part as it does in higher latitudes.

The Solway Moss in Cumberland, England, is a familiar historical instance of a semi-buoyant bog without ice underneath. It is of tradition that at the defeat of the Scots in this locality by the English in 1542, a troop of horsemen heavily mounted and heavily armored was put to rout. In the panic of their flight they ran headlong into this peat bog and became engulfed. More than two hundred years later, at the end of the eighteenth century, it is recorded that a digger of peat came upon a man and his horse supposed to be one of this troop, for both were in complete armor and preserved from total decay by the antiseptic qualities of the peat. In 1771 this bog, surcharged with the water of heavy rains, rose, swelled, burst, and swept over houses and trees in its course. It is easy to see how bogs similar to this might, if subjected to a climate as severe as that now prevailing in the Arctic regions, exist as an icy mass.[47]

The tundra mantle that covers practically all of this northern region, with the conditions it imposes upon the drainage of the country together with its properties as an insulating material are important if not the chief factors in the formation and preservation of ice. In considering its total and generalized effects there are presented a variety of conditions and probabilities upon which there is no data. Some of them are: the continuous summer heat and its total thermal effect, absorption, radiation, etc. The heat involved in the growing of the cryptogams that make up the large bulk of the tundra, and whether the effects are appreciable. Spontaneous combustion of peat, chemical decomposition of vegetable matter generating gases and heat and what effect these may produce in floating bogs and the ice they protect from disintegration.

[47] See interesting notes about bogs in "Facts About Peat," T. H. Leavitt, Boston, 1867. Third edition.

The views of the flood plains of the Goodpaster River, presented in plates V and VI, show the annual deposit of ice formed by the freezing of overflow water and snowdrifts saturated by the same. Deposits of this kind are spoken of as "*annual glaciers.*" It is seldom that even remnants of them survive from one year to the next. As a rule such accumulations entirely disappear each summer to form again the following winter. This is a transitory form of flood-plain ice and belong to the same class as river ice, for it has a similar mode of formation. The persistence of this form of ice through the summer is due simply to the fact that the spring freshets are too feeble to disintegrate such winter accumulations on the smaller streams as do the floods of the larger rivers.

Mr. A. J. Collier has observed underground drifts made during mining operations fill with water by infiltration and freeze in the course of one winter so the workings are completely blocked. E. S. Balch, in a work entitled, "Glacières or Freezing Caverns," Philadelphia, 1900, gives data on the causes of subterranean ice, pages 109-161, and on page 115, speaking of ice sheets says: "In northeastern Siberia, a form of permanent surface ice is found, which the Tungusses speak of as *tarinnen,* which means 'ice troughs' or 'ice valleys.'[48] These tarinnen are broad valleys, with either a horizontal floor or one sloping gently in the form of a trough, over which the ice is spread in the form of a sheet. The Tungusses assert that the ice in some of these troughs never wholly melts away, although it lessens in quantity from the beginning of May till the end of August, after which it once more increases." On pages 166 and 167 Balch mentions the "Subsoil Ice in Alaska,"[49] citing I. C. Russell, and "Subsoil Ice in the Klondike Region,"[50] "Ice Cliffs on the Kowak River, Alaska,"[51] and "Subterranean Ice Sheet on Kotzebue Sound."[52]

5. SNOW-DRIFT ICE

The only ice whose origin can be wholly and positively assigned to drifts of *wind blown* snow are the accumulations found under sea cliffs and other escarpments, in cañons, gullies, and ravines.

[48] Bulletin de la classe physico-mathematique de l'Academie Imperiale des Sciences de St. Petersbourg, 1853, Vol. XI, pp. 305-316.

[49] A Journey up the Yukon River, p. 149, and Second Expedition to Mount Saint Elias, p. 19.

[50] Philadelphia Ledger, December 30, 1897.

[51] Lieut. J. C. Cantwell, National Geog. Magazine, October, 1896.

[52] Otto von Kotzebue, Entdeckungsreise in die Südsee, etc. Weimar, 1821, Vol. IV, p. 140.

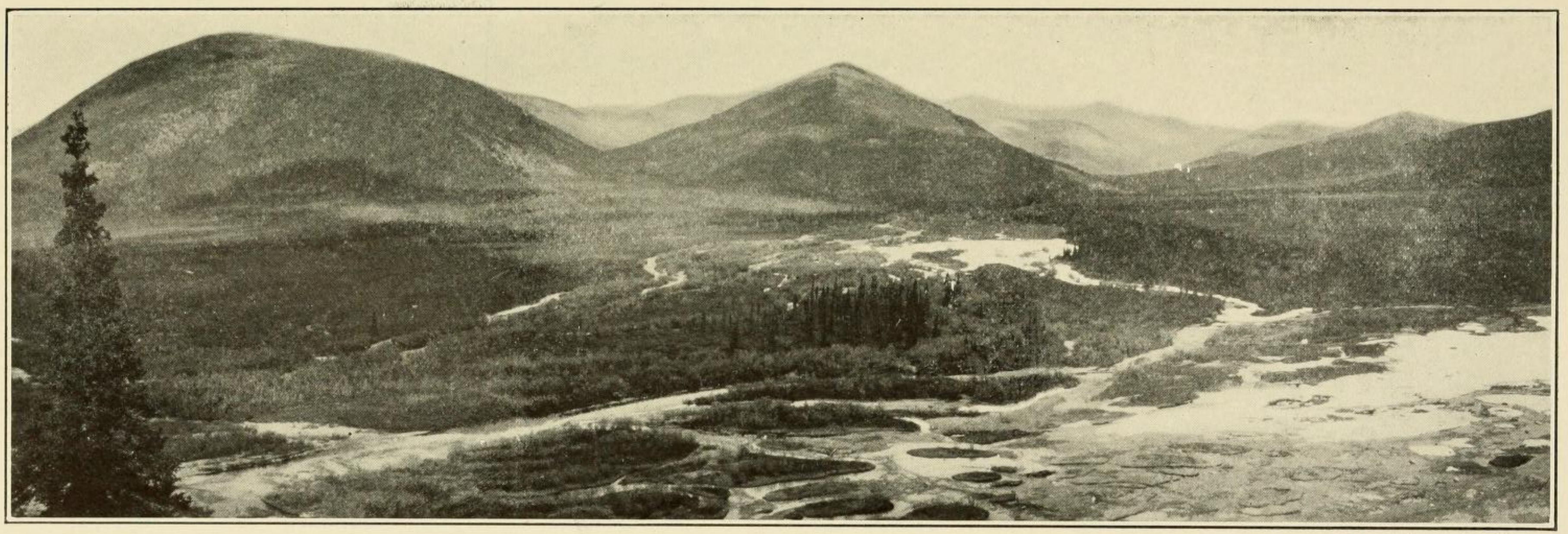


Photo. by Hess.

Panorama of the valley of the Goodpaster River looking north, showing accumulations of winter overflow flood-plain snow ice.

Their general character is shown in fig. 1, plate VII. This sketch from Captain Beechey's Narrative of the Voyage of the Blossom illustrates a deposit of snowdrift ice as typically developed on the Arctic coasts. They are of an entirely recent and transitory nature, not to be confused with beds of ice in any way. They lie banked solidly against the escarpments at intervals along the Arctic coast and sometimes along the larger rivers. Sometimes they persist for a number of years, but all are eventually undermined by the waves or undercutting of the banks against which they hang and disappear to be repeated elsewhere under more favorable conditions.

Sir John Richardson[53] remarks: "Elsewhere on the coast, cliffs equally vertical, but having a different exposure, were seen masked by a talus of snow, over which a coating of soil had been thrown by land floods of melting snow pouring down from the inland slopes. The duration of these glacier-like snow banks varies with circumstances. When the cliffs rise out of deep water, the ice on which the *talus* rests is broken up almost every summer, and the superincumbent mass, previously consolidated by the percolation and freezing of water, floats away in form of an iceberg. In other situations the snow cliffs remain for a series of years, with occasional augmentations marked by corresponding dirt bands, and disappear only towards the close of a cycle of warm summers. In valleys having a northern exposure and sheltered by high hills from the sun's rays, the age of the snow may be very considerable; but it is proper to say that though aged glaciers of this description do exist on the shores of Spitzbergen and Greenland, they are of very rare occurrence indeed on the continental coast of America."

Such snowdrift ice deposits also form in cañons, gullies, and ravines, but most generally are carried away each summer. They occur at all levels from present river banks and bottoms to places favoring their formation high upon mountain sides. The writer has seen occurrences of snow ice of drift origin banked solidly against the escarpment faces of the old dead elevated ice beds where it was intimately associated and almost incorporated with the face of the older ice.

One who has not seen its mode of occurrence, examining samples from it in the laboratory, upon classifying the ice merely upon its physical appearances and comparing such results with those of other experiments not having the same bearing, might assert that it possessed all the characters of drift snow ice as to air and dirt content,

[53] Zoology of the Voyage of the Herald, 1854, p. 6.

and contend, on the basis of these variable facts, that the bed of ice it may be confused with is also a deposit of snow drift origin.

6. LAND ICE IN SIBERIA

The real significance of land ice in Siberia with explanations to account for its origin appear to be as confused as the opinions concerning analogous phenomena in Alaska.

According to Toll's opinion [54] the ground ice deposits are nothing else than fossil glaciers, but he admits for certain cases the same origin Tolmatschow [55] accepts for the Beresowka ice. "If we observe," Toll says,[56] "the map, we see that masses of *stone ice* apparently of the type of a fossil glacier are to be found at the mouths of rivers. And if admitted, as I shall show later on, that the islands of New Siberia and the continent were still united in the Quaternary period it will be easy to reconstruct the courses of the rivers between the islands and the continent. In this case it may be thought that the masses of snow ice belong to the river terraces. i. e., that they are the remains of snow fallen during the winter, which have been covered by the spring overflow of the rivers and then fossilized. I admit that some isolated cases like this do happen. But observation of the conditions I have learned to know, as on the Ljachow islands, will hardly permit me to think that such an exceptional formation has given rise to those imposing accumulations and others like them."

The observations of Toll, who reported having seen on the southern coast of Ljachow Island an uninterrupted sheet of ice, with an earth layer on it, nearly ten versts long, have been criticised by Bunge.[57] Bunge thinks that when Toll visited the island the whole coast was covered with deep snow, and this snow has been taken by Toll to be an ice sheet. Toll was there in the spring. Bunge in the summer.

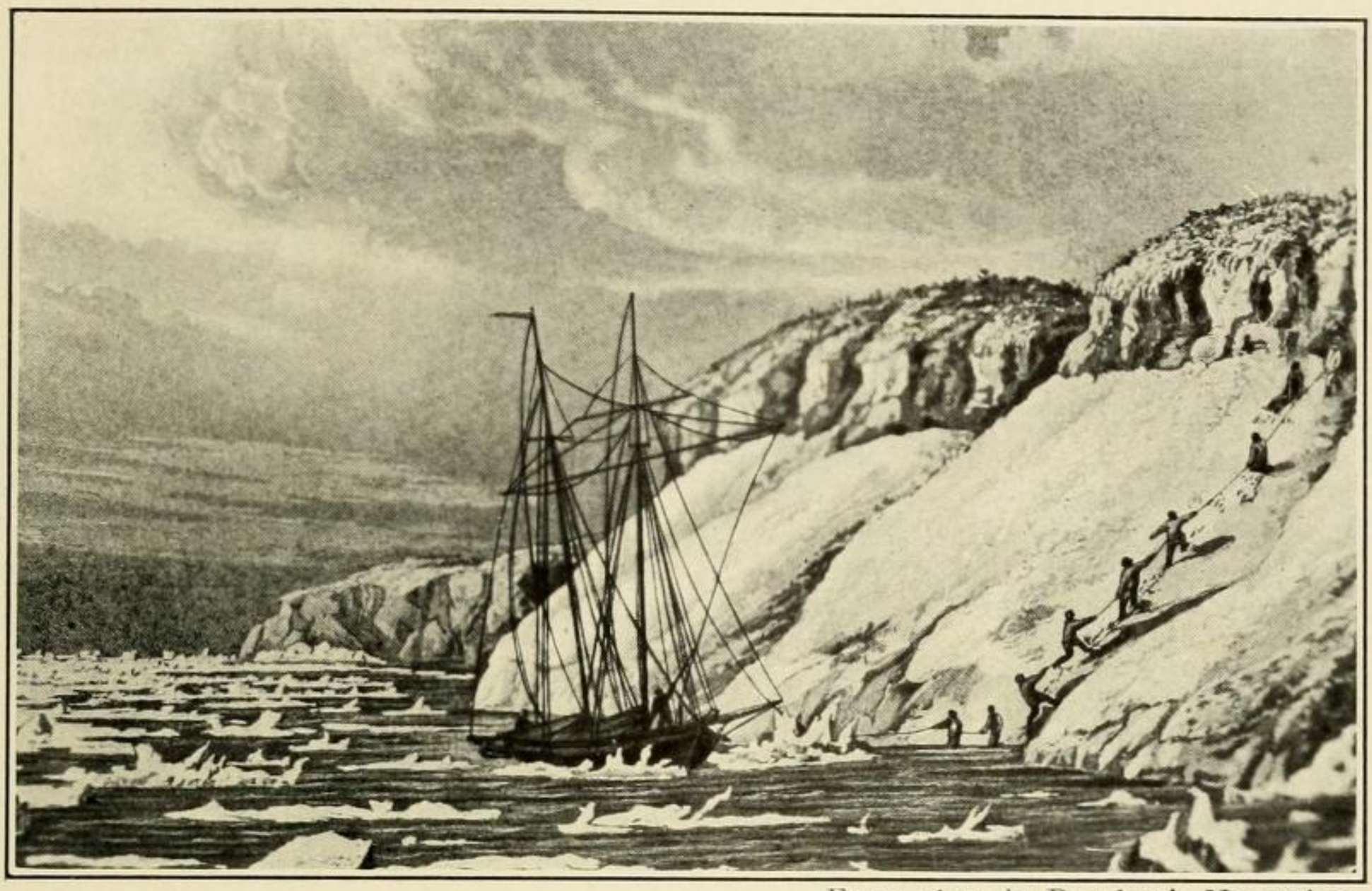
Toll supposes such deposits of ice represent the remains of glaciers, basing such contention primarily upon its physical characteristics, that it can only be snow ice, and resembles white glacier ice, or even névé, because rich in air. Tolmatschow supports Toll as far as favoring the view that the deposits are of snow origin:

[54] Die fossilien Eislager und ihre Beziehungen zu den Mammuthleichen. Mem. d. l'Acad. Imp. d. Sci., VII Ser., T. XLII, No. 13.

[55] Bodeneis vom Fluss Beresowka. Verhandl. d. K. Min. Geo., 2 Ser., Bd. XL, pp. 415-452.

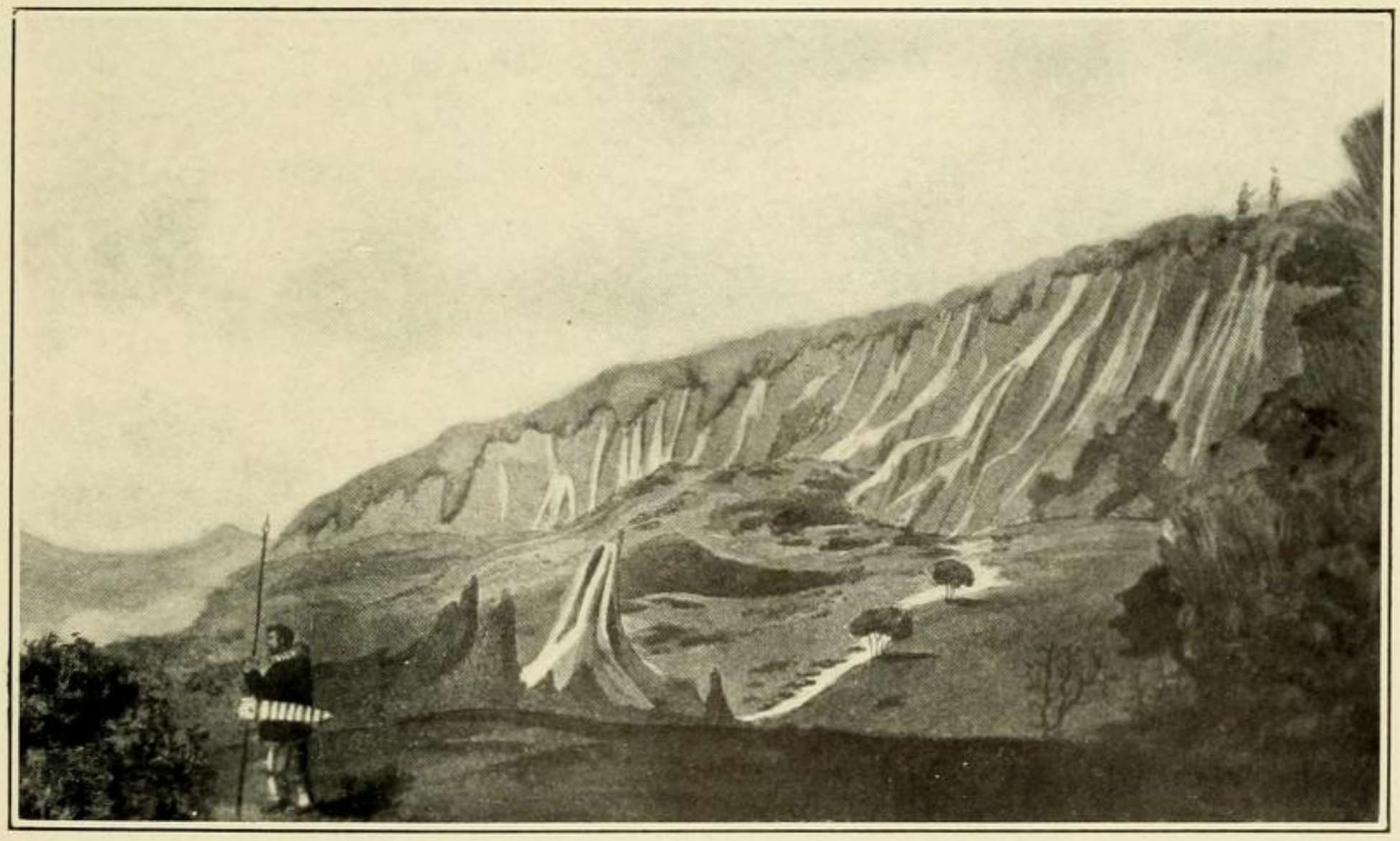
[56] Op. cit., p. 79.

[57] Einige Worte zur Bodeneisfrage. Verh. d. R. K. Min. Geo., St. Pb., II Ser., Bd. 40, p. 205.



From plate in Beechey's Narrative.

1. Cape Smyth, Arctic Coast of Alaska, showing a deposit of snowdrift ice.



2. Reproduction of Kotzebue's Plate illustrating the Ice Formation on Eschscholtz Bay.

"Dr. Bunge, who was with Toll on the New Siberia Islands, studied the ground ice formation carefully, but he came, in explaining the origin of the same formation, to conclusions quite different from those of his companion. According to Bunge's opinion the ground ice is a vein or strata-like formation: 'The contraction of the tundra ground caused by the cold, has given rise to many crevasses, which must have been large and deep. In spring and summer a heavy rainfall, coming in contact, in those crevasses, with frozen earth, freezes. This goes on a long time, sometimes many years, and in this way large veins of ice are formed in the tundra ground. The water not frozen can expand horizontally and so form horizontal sheets of ice. Through the wasting away of the tundra by the sea or a river the vein of ice may be laid bare and so expose an ice wall.'"

Tolmatschow comments: "It may be remarked the formation of the ice in such a way cannot be deduced from its structure. Water forming from snow is very rich in air, but from it ice so rich in air as snow ice cannot form. It is possible that, from the water that first comes into contact with the frozen soil, a thin sheet of ice comparatively rich in air, might be formed. But when the direct action of the very cold ground on the flowing water is excluded by this sheet of ice, we have conditions very similar to those which lead to the formation of the so-called blue ice of the present time glaciers. The color and name of this (blue) ice comes from the very small number of air-bubbles or from their complete absence, though the water coming from the melting of the surface of the glacier is by no means so poor in air as that of the tundra." Bunge says explicitly that the ice he has seen "has always small cracks and bubbles." Toll also points to the richness of the ice in air bubbles, and this proves once more that the land ice comes from snow. (Toll also gives photographs showing the granular appearance of the surface of the ice upon melting to support the contention of its snow origin.) If two learned men collect a large amount of data in the same district from the same formations in order to solve one question, and afterwards come to two conclusions contradicting and excluding each other, we must say that the question is not clear, even as it appears on the spot, and more close observation is to be desired. There is no doubt that vein ice is much spread in the tundra, but according to the structure of the ground ice, as it has been described by Bunge and Toll, it cannot have come from water, but from snow. "It seems to me (Tolmatschow) that some of the examples given by Bunge correspond exactly to this (snow) way of formation."

"In the case of the Beresowka the supposition of Bunge is untenable. The ice wall there presents a concavity of great radius, corresponding to the curvature of the bank of the river, i. e., to the direction of the washing away by the Beresowka, but not of a crevasse. Neither can his supposition explain how the ice is to be found at the upper edge of the terrace.

"The presence of ice on a terrace gives us an occasion to say a few words about the supposition accepted by many American scientists about the formation of land ice from lakes. We can very well imagine such a way of formation of the ice and accept it for certain cases, but then the ice must have the structure of water ice, and this is not the case with the Beresowka ice."

As will be discussed later the classification of ice by its gas content presents a very wide range of possibilities, for in nature many extraneous conditions must be considered that do not present themselves in laboratory examinations. Apparently nothing is to be gained toward demonstrating the snow origin of ice-beds by a microscopic study of its crystalline structure, for the ice no matter of what origin, but especially if from water, may undergo such modifications in crystalline form by recrystallization and regelation, especially near exposed surfaces, as to obscure all tracing of its original structure or origin. The presence of air or gas bubbles of various shapes and in varying quantity to the cubic unit of ice lead to nothing upon which to base even conjectures, for this phenomenon of enclosed gas is a variable occurrence in both snow and water ice, especially in nature.

"According to Toll's observations of 'stone ice' in the islands of New Siberia there is not any stratification to be found.[58] In other cases, as for instance in the ice deposits of the Ljachow Island, and also in quite new ice exposures on the Siberian continent on the lower Yana, he saw the stratification quite distinctly. When Bunge speaks of the ground ice of northern Siberia, he says explicitly: 'if the mass of ice were stratified, we should consider it as coming from accumulated masses of snow. These, of course, would have shown horizontal stratification, similar to those that we find in new deposits of snow; but nowhere are horizontal stripes to be found.'

"We must therefore admit that this ice is really not stratified, for it is not possible to admit that the stratification has been overlooked by the observers."

[58] Die fossilien Eislager, p. 72.

Tolmatschow's Views on the Ice of the Beresowka River

An abridged translation from the report (in Russian) of O. F. Herz, chief of an expedition sent out by the St. Petersburg Academy of Sciences to investigate the finding and excavating of remains of a mammoth, partly in the flesh, in a frozen state, on the banks of the Beresowka River, a tributary of the Kolyma, in northeastern Siberia, is published in the Smithsonian Report for 1903, pp. 611-625, pls. I-IX. Herz gathered some pieces of ice, along with other specimens from the formations associated with the mammoth. These materials were taken back to St. Petersburg, where he placed them together with his field notes and sketches in the hands of I. P. Tolmatschow to report upon from a geological standpoint.[59]

These accounts of Herz and Tolmatschow are of particular interest because they throw much light on the circumstances surrounding the occurrence of such remains. Unfortunately the position in which the carcass was found, was secondary to its place of original interment, and leaves doubt about one important point—whether the mammoth died and became entombed before or after the thick bed of ice, forming the terrace feature along the bank of the river at this place, was formed; or while it was forming. There appears to be no evidence at hand to settle this question and place the time at which this particular animal died and thus give us an authentic record of the occurrence of the mammoth in its true geological (stratigraphical) horizon.

Tolmatschow says: "The difficult task of the expedition, i. e., the taking of the mammoth carcass to St. Petersburg in the best possible condition, the short time at its disposal, and the cold winter with much snow, did not permit of the pursuit of geological researches as completely as would have been desirable. Besides this the chief of the expedition, O. F. Herz, is not a geologist, but an old zoologist, and was not at all prepared to make geological observations because there was a geologist, Herr Sevastianoff, among the members of the expedition. (For some unstated reason this member did not accompany Herz to the mammoth remains on the Beresowka, but after reaching Mysova, within eighty-five miles of the mammoth, returned to Sredne-Kolymsk.)"

Tolmatschow devotes most of his article to a discussion of the properties of ice as a mineral, its crystallographic forms and the

[59] Bodeneis vom Fluss Beresowka. Verhandl. d. K. Min. Geo., 2d Ser., Bd. XL, pp. 415-452, pl. V-VIII.

varying amount of gas or air content in different kinds of ice, for he considers ice the most important geological feature of the place where the mammoth was found. He made a microscopical examination of the ice from the Beresowka River and considered the specimens of rock and soil only in order to understand the way of formation of the layers of clay, loam, and Quaternary detritus of the district.

"The samples of ice from the Beresowka were taken by Herz from two different places. Two small pieces (*A*) come from a little ditch excavated under the mammoth, 1.9 meters deep; the third piece, a larger one, (*B*) was taken from the lower part of the ice wall which is situated on the upper edge of the terrace on the bank of the river 55 meters above its level. As the two kinds of samples show some differences in their properties they are described separately.

"*A*. Comparatively pure transparent ice of a yellow color, a little dirty with a great quantity of cylindrical or oval bubbles of air (more properly of gas) disposed in parallel lines in a very regular way.[60] The bubbles are 1.5 mm. broad and 3-5-6 mm. long. The clayish parts which make the ice dirty, sometimes form layers as thin as paper. The action of heat breaks the ice into an agglomeration of rounded-off polyhedral grains from 5 to 7 mm. in diameter. The same grains, or better speaking their sections, are obtained at the surface of the ice, if it is rubbed on a hot plate of iron. Under the microscope we see in these specimens (especially when obliquely illuminated) thin scratches at the extremities of the single grains, and between crossed Nicols we notice also, that each grain is an independent crystal of ice, which lies amongst other crystals without any common crystallographic orientation. When one grain appears colored, the next remains dark when the specimen is turned, and under convergent light we see the cross of a mineral with one axis. . . . .

"By endo-metrical calculation I have found that one kilo of ice contains 180 cu. cm. of air. . . . . When the ice melts a small quantity of clay is obtained, which has been highly calcined and weighed. One kilo of ice contains up to 3 grams of clay, i. e., 0.3%. The specific weight is calculated 0.795.

"*B*. This ice is apparently dirtier than the first (*A*) probably because the particles of clay do not form as in (*A*) thin layers, but instead are uniformly distributed within the whole piece. The

[60] Op. cit. pl. v. f. 1.

bubbles of air are not so many, they are round or egg-shaped, and they are irregularly distributed. Upon melting, this ice also divides into rounded polyhedral grains of an average diameter of 5 mm., and altogether they are smaller than those of the first samples (*A*). Under the microscope we see the same images as before. The air contained was 50 cu. cm. per kilo of ice, the remains of clay 0.24%, i. e., 2.5 grams per kilo. The specific weight was 0.878.

"The first conclusion we may arrive at from these observations is that the ice just described cannot have been formed directly from water. Ice coming from the surface of water, for instance from a pond, shows a parallel increase of long-stalked crystals, whose optical axes are perpendicular to the freezing surface. A section taken from such ice shows under the microscope all the properties of a crystal. When melting, such ice divides into a series of irregular prisms some decimeters long. . . . . The freezing of water is much more complex than might appear when we observe an already formed piece of ice. But this relates only to the first phase of the formation of ice. Later on the freezing goes on in a much simpler and more regular way, so an ice is formed which in its principal mass is characterized by its prismatic structure and thereby can be easily distinguished from snow ice, as has been known for a long time, and recently once more clearly shown by Prof. E. Drygalski[61] in his study of the materials of the Greenland expedition. The large quantity of air of the ice coming from the Beresowka differentiates it also from ice coming from ordinary freezing of water, and confirms its snowy nature, as is shown by the great number of observations carried on chiefly on ice of glaciers.

"The well-known works of Agassiz and Nicolet have shown that one kilo of snow on changing into névé contains 64 cu. cm. of air; one kilo of white glacier ice 15 cu. cm. and one kilo of blue ice 1 cu. cm. . . . .

"It is easy to see that the quantity of air contained in the ice of the Beresowka approaches that of white glacier ice and even to névé ice, especially for the first sample (*A*).

"Its structure, which we have described above, resembles that of glacier ice, though in comparison to the ice of the Alpine glaciers, the grains are very minute. But in comparing it with the ice of the interior of Greenland, we do not notice this difference so much."

"The characteristic structure of névé ice—a conglomerate of ice grains kept together by an ice cement formed of very small grains—

[61] Grönland-Expedition, B. I, XVIII Kapitel. Die Structur des Eises.

has completely disappeared from the samples we have described. Herz does not say anything about the sheets of the principle mass of ice, he mentions only thin sheets of ice which appear in the layer of earth which covers the main body of ice. We can therefore say that the division of the main ice mass into layers either does not exist at all, or has been obscured by the secondary process of melting and erosion, and this last is the most likely thing to have happened."

The writer cannot agree that "the secondary process of melting" has obscured any stratified appearance of the principal ice mass on the Beresowka. Herz more probably failed to note such structure because it did not exist. However, he suggests that a more or less secondary and superficial process of melting partly accounts for the ice with large gas content such as Tolmatschow's samples exhibit and also for its granular structure. Granting all the theoretical considerations of ice Tolmatschow asks for, and granting without hesitation that his samples are snow ice, we are no nearer an explanation of the true origin of the fundamental bed of ice on the Beresowka. The characters of his samples fail to prove that the bed of ice in the terrace of the Beresowka has an origin from consolidated beds of drifted snow.

There appears to be two distinct kinds of ice associated with the mammoth on the bank of the Beresowka. One of fundamental, the other of superficial position and arrangement; one of stable and the other of transitory aspect. The writer considers the samples gathered by Herz and examined by Tolmatschow were from that kind of ice which is superficial in position and more or less transitory in its origin and occurrence; that therefore it is of no weight whatever in demonstrating that the fundamental ice feature of the Beresowka is of snow origin.

To explain: Tolmatschow's samples (*A*), two small pieces, came from a little ditch excavated under the mammoth 1.9 meters deep; (*B*) a large piece came from the lower part of the ice wall which is situated on the upper edge of the terrace on the bank of the river 55 meters above its level.

In brief, samples (*A*) came from the sliding talus slope and may well be of snow origin as the winter snows accumulate, pack down in crevices, and together with thaw water percolating through the interstices of the frozen talus blocks, become consolidated into ice. This appears to account for all the ice immediately associated with the mammoth's carcass as described and figured by Tolmatschow.

Sample (*B*) may also be of snow origin for snow accumulates

and solidifies against ice escarpments as readily as elsewhere. Tolmatschow's results and conclusions in regard to the ice of sample (*B*) may have been different if the sample had come from higher up on the ice face, or better still, if it had been taken more from the interior of the mass. As it is, the sample coming from the *lower part* of the *surface* may, even if not admitted to be of snow origin, readily have been modified "*by the secondary process of melting and erosion*" of water ice and must be admitted to be of a superficial nature and not a criterion by which to judge the origin of the mass of the ice bed.

It must also be borne in mind that those who think some ice deposits are of water origin, i. e., are frozen from water and not

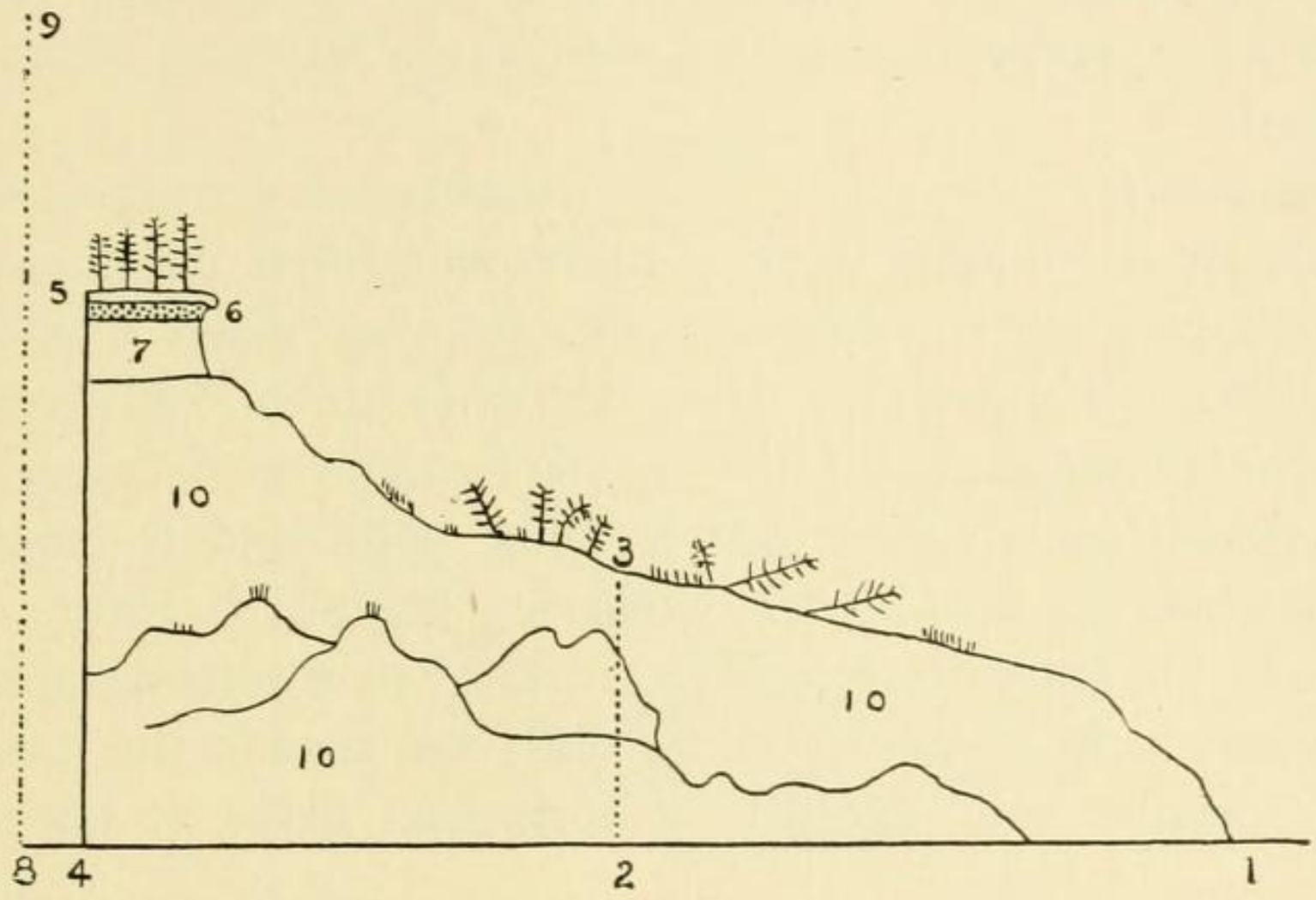


FIGURE 1.—Section of the bank of the Beresowka River with gliding talus at the place where the mammoth carcass was found.

[After Tolmatschow, op. cit., fig. 4, p. 430.]

1-2-4. Water level of the Beresowka.
2-3. 35 meters.
3. Place where carcass was found.
4-5. 55 meters.
5. Layer of soil.
6. Alluvial layer with shingle and lamellar ice.
7. Ice bed (fundamental position).
8-9. 120 meters, height of porphyry ridge ¼ mile back of terrace.
10. Pleistocene silts (lacustrine).

snow, do not claim that the process by which it transpires is the same as that of the freezing of an open, unobstructed expanse, like a lake or pond, that when once frozen it is suddenly covered over its whole area and preserved so that the normal crystallographic structure of the ice will be retained. The process is far different from this. True the pond or lake freezes over every winter, but

only such parts of the ice around the margins are preserved through each year as become protected by the mantle of moss whose growth gradually encroaches over the water from the shore margins each season. Where the lakes on the tundra have grown comparatively small and shallow, we almost invariably find on and near their banks a layer of semi-buoyant turf or peat under which in many places ice persists the year round. In this way conditions are presented that permit of the water acquiring a considerable gas content and also considerable dirt from decomposing vegetable matter, for quantities of vegetable organisms (diatoms) accumulate on the bottoms of even these Arctic ponds and lakelets there to decompose and evolve gases that may form bubble cavities in ice. By partial thawing and freezing such ice may also undergo rearrangements of its crystallographic structure as do salt and borax occurring in beds.

Before classifying ice as of snow or water origin upon the percentage of air it contains there is to be considered the phenomenon called anchor, frazil, or specular ice, forming when temperatures are very low. For instance, when the wind blows cold over a lake surface, the temperature of the upper two, three or more feet is reduced considerably below the freezing point and is colder than a surface sheet of *still water* when ice begins to form. In the former case the water is full of ice needles to a considerable depth and forms a granular ice very different from that in the latter case, when the needles congregate in a horizontal plane at the surface.

Features of the Beresowka Locality

"There are two very characteristic points about the Beresowka, one of the large affluents of the Kolyma, (1) its large valley and (2) a very winding course. This is particularly true of the part where the mammoth has been found; of this part Herz sketched a plan on the scale of 1:84,000.

"The remains of the mammoth lay on the left bank of the Beresowka which is being more and more washed away by the river. The Beresowka makes here a great winding by which a low alluvial peninsula (an island when the water is high) is formed, covered with willows and other shrubs. On the left of the Beresowka there is a steep bank 55 meters high above the water, then there is a terrace half a kilometer (about ¼ mile) wide extending for several kilometers (about 3 miles) along the river. The terrace is limited by a mountain range 120 meters high, which is separated from a second range 180 meters high by a small depression

of the surface. The formation of the bank is well shown by Herz's photographs. He did not go to the opposite side of the valley but noticed there, as on the left side, a 'Taiga' (wooded terrace) which runs along the river as a broad strip of land, and which he distinguishes from the lowlands or bottoms of the newest alluvial deposits of the Beresowka.

"From this point, up and down, the valley of the Beresowka becomes narrower, the mountains east and west get nearer to each other and they bound a large expansion of the valley similar to a

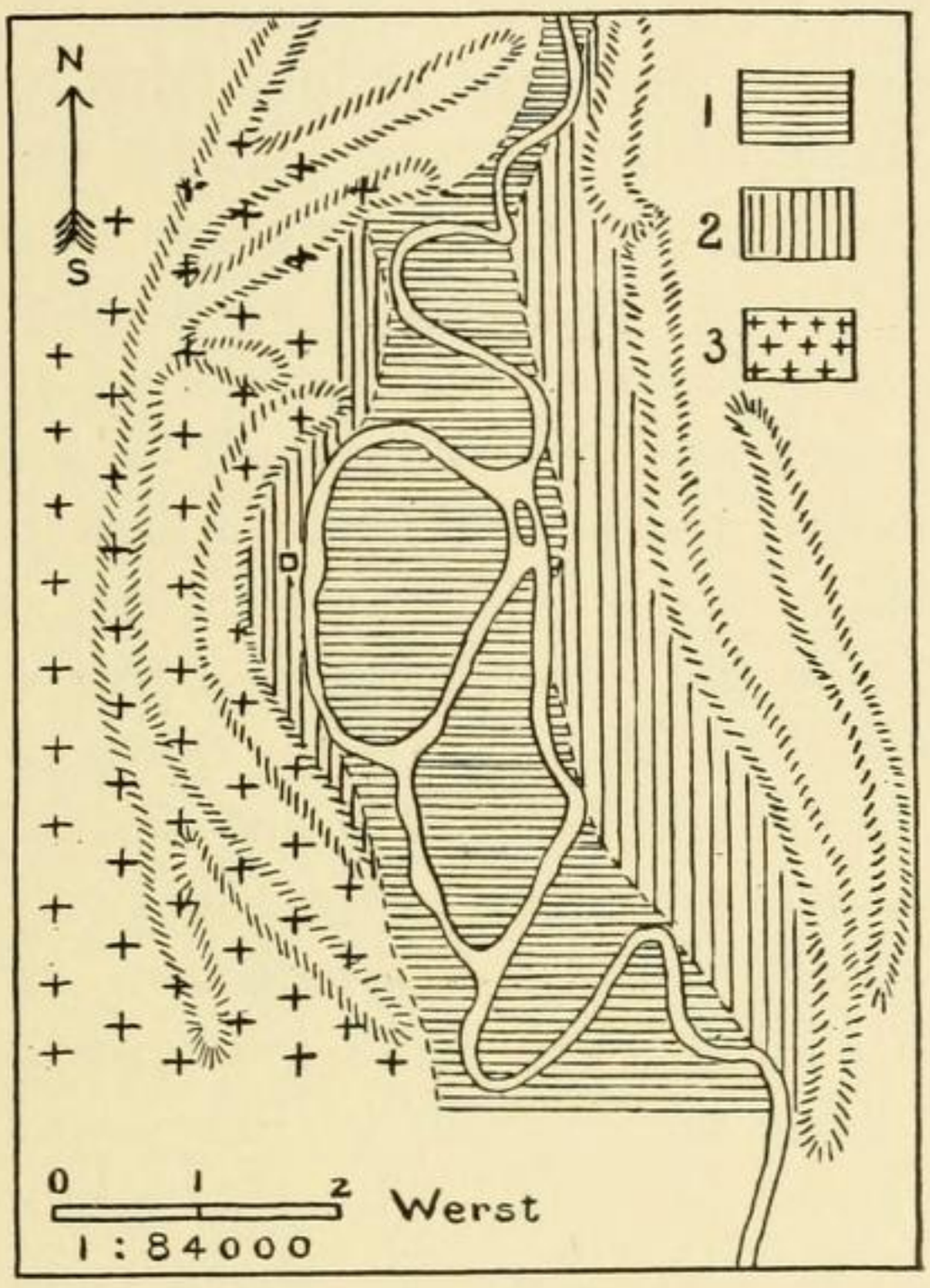


FIGURE 2.—Geologic map of the Beresowka valley about place where the mammoth was found. Small square indicates the position the carcass was in.
[After Tolmatschow, op. cit., fig. 1, p. 425.]

1. Recent alluvial deposits of the Beresowka.
2. Older terrace deposits "Taiga."
3. Porphyry of nearby hills.

lake. The older formation of the left terrace is what remains of a deposit that once filled the whole lake-like expanse of the valley of the Beresowka. According to Herz's opinion the deposits of the left bank originally filled the whole valley, but have been swept away by the Beresowka, so that only small portions remain and these will soon disappear. Although the right side of the valley was not examined its 'Taiga' terrace corresponds, orographically, to the left terrace.

"Now to consider the geological structure of the terrace more closely. (1) Above is to be found an earthy layer, covered with moss, 30-52 centimeters (12-20 inches) thick. (2) Under this a layer from 2-4 meters thick composed of layers of clay with coarse shingle corresponding, petrographically, to the rocks of the nearby mountains. With the shingle in this layer was also found pieces of wood, bones, etc. Through this clayey and loamy deposit besides the stones, roots, and pieces of wood, were lamellar layers of ice up to 15-18 centimeters thick, stretching through the mass. (3) Underneath this alluvial layer there is a vertical wall of ice five and even seven meters thick. With this ice wall the section closes, because below it comes the sliding talus to be found everywhere along the slope of the terrace. Under the place where the mammoth lay Herz dug to the depth of 2.25 meters. At first the excavation passed through deposits of earth alternating with thin layers of ice, but at a depth of 1.90 meters a compact mass of ice was found, which was not passed through at 2.25 meters depth."

Tolmatschow reviews the several suppositions that may be drawn about the thickness of the fundamental ice bed, for it appears in the Beresowka section the lower surface of this ice was hidden by talus. He does not think that it extends down to the level of the Beresowka as Herz thought,[62] and it is not represented that way in the profiles given, because in this case the structure of the bank would be quite different. . . . . Tolmatschow says: "The large dimensions of the sliding mass make me suppose that under the ice wall and high above the level of the Beresowka are to be found other deposits of clay and loam. The photographs (pl. VIII) and the sketches made by Herz give the sharp contrast between the vertical ice wall and the slope of the bank. If the thickness of the ice was greater there could not be such a contrast."

The writer can state that in apparently analogous cases observed in Alaska the ice rests on top of considerable thicknesses of homogeneous Pleistocene clays such as appear to form the body of the terrace on the Beresowka.

"By the washing away of these deposits the ice sheet above is undermined, the layers become loosened so that they fall and slide little by little with all that is to be found on them. Only in this way it seems to me, can be explained the singular fact that the mammoth, which lay in a sliding place, therefore in a secondary deposit, was found nevertheless in such a way, that there can be no doubt left about the place and position from which it has fallen."

[62] See translation, Smithsonian Rep., 1903, pp. 616, 618.

XI.—LAND ICE AND THE MAMMOTH

I. ASSOCIATION OF PLEISTOCENE MAMMAL REMAINS WITH ICE

The writer considers Tolmatschow's conclusions as to the horizon of the mammoth to be unestablished by the facts surrounding the finding of the Beresowka carcass, but beyond pointing out that it is not proved that this carcass came from above the ice bed there appear to be no suggestions to offer. Unfortunately there is every possible doubt about the true original position of this carcass, there being three horizons as far as position is concerned in which it may have been originally entombed. They are in descending order: (1) The clay and shingle layers intermingled with lamellar sheets of ice above; (2) the thicker, homogeneous and more fundamental (from a stratigraphic standpoint) ice-bed that forms the conspicuous part of the escarpment of the terrace wall; (3) from the Pleistocene clays underlying this thicker bed of ice.

As the writer's experience has been confined to Alaska, where as before stated no authentic instance of the occurrence of Pleistocene mammal remains is known in primary stratigraphic position, it is impossible to state whether the mammoth was confined to any particular one of the three horizons enumerated above or may not be found in all three of them.

Tolmatschow says: "As until now the bones and carcasses of mammoths have been found only in the earth layers on the ice, Toll thinks that the ice sheet represents a deposit stratigraphically independent from the upper one containing the bones of the mammoth. The Beresowka occurrence seems to confirm this supposition. But by the observations of Herz's expedition so many new things have been learned about the way mammoths lived, that we may imagine another reason for finding the mammoth in the earth layers on the ice.

"The remains of reeds and other grasses found in the mouth (partly on the tongue) and in the stomach of the mammoth show us, that at least in this case (and, it better be modified, at that particular moment), the animal was graminivorous, an inhabitant of the meadows, and these meadows were found by the animals on the river terraces, which in spring were likely to be under water and in summer, in spite of the layer of ice under them, were covered with a magnificent vegetation. In such meadows, perhaps where swampy, mammoths occasionally became engulfed and disappeared without having swallowed their food. It is likely such occurrences happened often on the terraces. Along with the animals fallen on

the spot, those floated down by the water during spring floods, were also buried in the terrace. Herz found under the mammoth carcass a distinct cervine antelope skull, which could have been brought there only by water. (It no doubt dropped from the alluvial layers above the thick ice, where fragments of bones were noted, and in this way became mixed in the talus.) Every place where the upper layers of earth are thick enough, i. e., where they have been forming long enough, fossil animal remains have been able to accumulate in large quantity. On the other hand where the alluvial layers are thin, such remains are rarely found, firstly, because they had not much attraction for living animals, and secondly, because bones carried there could be easily washed away.

"The finding of the mammoth in the earth layers, situated on the ice, is not a reason for considering the ice and earth layers as two geologically distinct strata and therefore belonging to different ages. Of course the upper layers of earth have been deposited after the formation of the ice, but the mammoth is a sure proof of the previous formation of the ice on which its carcass has been found. About this I will repeat the words of Tscherski.[63] Without entering into a discussion about the formation of the ice, and simply accepting the explanation of Toll, Tscherski in his works says: 'The old glacier which did not extend to the limits of the continent, but which in our opinion existed in the same region as the carcasses of the rhinoceros and mammoth, would not necessarily displace these coeval animals. Instead, the facts observed have persuaded us on the contrary, that these characteristic representatives of the Siberian post-pliocene fauna have not hesitated from treading, at the first occasion, on the mass of ice, which temporarily deprived them of part of their meadows.'"

Tolmatschow remarks: "As a consequence of what I have said I cannot consider the ice layers and a northern glacial transgression in the 'Yenissei Tundra' as having occurred at the same time. The only reasons for such a consideration are the 'marine clays with glacial detritus' in the Yenissei (delta) Tundra, the 'Stone ice' in the Anabara 'Tundra,' and the remains of mammoth in the earth layers of the New Siberia Islands. Above we have already discussed the relations between the ice and earth layers.

"We must not deny, of course, that the conditions, by which the ice age was brought about in the northern hemisphere, have passed

[63] Beschreibung der Sammlung posttertiärer Säugethiere. Mem. de l'Acad. Imp. Sc., St. Pb., VII Ser., T. XL, No. 1, p. 473.

away for Siberia, without any action, but there are only some local traces remaining. If the humidity of northern Siberia, which now has a very dry climate, were to increase slightly, the rainfall would certainly increase. It is quite possible that the formation of lake deposits of ice would occur during a period with heavy rainfall. But even if we call these older deposits of ice 'fossil ice' it does not follow that it is either the remains of a glacier or of continental ice, because, for such occurrence many different conditions and characteristic features are necessary, which are not yet known to exist in northern Siberia.

"As appears from the description of the Beresowka valley, deposits corresponding to the horizon of the mammoth are very common in this part of Siberia. All the older ground-ice deposits most likely belong to the same horizon."

In brief, Tolmatschow appears to be aware, without being conscious of the significance thereof, of the existence of an older ice on top of elevated Pleistocene silts. No doubt if he had viewed the phenomena personally he would have fully recognized this apparent fact.

Wrangell[64] says: "The best mammoth bones as well as the greatest number are found at a certain depth below the surface, usually in clay hills, more rarely in black earth. The more solid the clay, the better the bones are preserved. Experience has always shown that more are found in elevations situated near higher hills than along the low coast or on the flat tundra."

The one point that appears to be a matter of unanimous agreement among those who have described the Elephant Point locality on Kotzebue Sound, Alaska, is that the remains never occur in the ice-bed nor the peaty or earthy layers overlying it. It has been generally conceded they were derived from the clay beneath the ice. Hooper's suggestion is worthy of serious notice in accounting for some of the remains at Elephant Point. He says:[65] "Kotzebue was undobutedly in error in supposing that the fossil remains of animals found in the vicinity were embedded in the cliff, I examined them carefully each season and saw no signs of animal remains of any kind; while on the shore (beach) below high-water mark, we found them in abundance. They were not confined to the locality of the cliff, but extended each way as far as our investigations reached. They evidently came from the Buckland River, and were

[64] Wrangell's Voyages, p. 286, note.
[65] See Appendix.

brought down by drifting ice in the spring." Floating ice from the Buckland River also undoubtedly explains the presence on this beach of blocks of sandstone and basalt noticed by Beechey.[66]

The writer can attest to the transporting of bones considerable distances by rivers. In the summer of 1904 he ascended the Old Crow River, a tributary of the Porcupine, by its meandering course about one hundred and seventy miles, and along the upper one hundred miles of this distance found strong evidence in the shape of scattered bones of the former existence of mammoth, bison, and horse. On the bars also were accumulations of the broken and comminuted fragments of their bones. These remains were without exception all found below the high-water level of the flood stages of the river and were without question brought down from some primary source or sources of deposition, by the great transporting agent in those regions, floating ice. Yet the formation of the river banks along which the remains occur is a continuous deposit of Pleistocene lacustrine silts rising about 150 feet above the river level and frequently exposing, where the river is cutting laterally into them, terraced escarpments of ice. The ice deposits do not form a continuous sheet over the whole lacustrine area, nor do they rise as solid walls from the water level. They occur in the undulations of the surface on top of the silts as beds 10 to 30 feet thick, as already explained, and are elevated 100 feet or more above the river. In no case were individual beds of ice exposed for more than one mile and in most cases the exposures are not so extensive as this. In no case was anything seen above the ice but peat and humus. This is explained, however, by the fact that the deposits as exposed by the sections examined comprise the central area of what has been an extensive Pleistocene lake. Only near the former lake shores are to be expected the conditions of abruptly rising land slopes to afford detritus and alluvium for deposits on top of the ice such as exist at the Beresowka locality and at Elephant Point. It also appears from these cases that the surfaces of the drained lake bottoms where extensive were too treacherous or uninviting for the mammals of that time to wander out over them, so experience thus far points towards the immediate shores of the Pleistocene lakes as the places to search for mammal remains in their primary position.

In reviewing the facts as they appear the writer is satisfied that the statements to the effect that the ice-beds associated with the

[66] See Appendix.

mammoth are of snow origin or occur interstratified with the Pleistocene silts are based on misinterpretations of the facts as they exist. The erroneous conclusions drawn have passed down in literature and become so firmly fixed in the minds of some that it will no doubt take time to shake their belief. The evidence afforded by the exposures on Eschscholtz Bay is insufficient to support a claim that any of the ice-beds we know of in Alaska, excluding glaciers, are of Pleistocene age or existed before the mammoth became extinct.

The latest supporter of the snow-ice supposition—Tolmatschow—gives what he calls a "schematic representation" of the formation of the Beresowka ice from snow as follows: "The large lake through which the Beresowka flowed was filled with silt through which the river now cuts its bed. In winter the whole basin was covered with a thick bed of snow, which in summer disappeared except in those parts which are protected by a layer of loam. For the thinnest layer of such deposits, whether coming from the overflow of the river, or from the water melting from the mountains, affords a good protection from the summer sun. In our climate (Russia) the snow remains under such conditions up to the middle of summer, it will therefore remain more easily in northern Siberia. In certain cases the snow can remain until winter without any protection, i. e., when it accumulates in great quantities, and this can happen easily in such basins, where not only the fallen snow accumulates but also that blown from the nearby mountains. After short summers long winters come again and again.

"These beds increase, come into contact, melt together, and in a long series of years form a thick cover of snow. . . . . For this explanation we need not make any supposition about oscillation of climate, the age of ice, etc., and we may very well suppose that the process is also going on in Siberia now.[67] There is no doubt, that under the present day conditions of the climate of northern Siberia ice as it has been found on the Beresowka can remain undisturbed for thousands of years if we only exclude the action of its being washed away by the river."

From his various suppositions about the formation of the Beresowka ice Tolmatschow draws the same conclusions as before, i. e.,

[67] One of the weak points of the snow origin of ice is just this: Why do we not find the process transpiring today? Also, why is the elevated ice only found associated with the Pleistocene lacustrine silts? Why not at varying levels, and resting upon surfaces of different geological formations, etc. The snow ice phenomena we do find today are altogether different from those ice deposits associated with the elevated Pleistocene silts.

that the deposits represent large accumulations of snow in the river valley, but not the remains of a glacier. Geikie,[68] Penck,[69] Dawson,[70] and Dall [71] have expressed the same opinion for the ground ice of Alaska, i. e., that they are accumulations of snow protected by layers of earth.

However, Tolmatschow says, "I take the liberty here of saying that I would not extend this conclusion to all the deposits of ice of Siberia and North America as considered by Toll in his work. I say only, that the properties of the ice from many places, described by this and other scientists, corresponds entirely to the Beresowka ice."

In attempting to follow the progressive steps by which ice-beds formed from either snow or water might become covered by a thickness of fifty feet of structureless clay sediment, the process seems entirely too rapid to be comprehended by present day experience and to be entirely incompatible with the facts. The deposition of clay required a body of comparatively quiet water and in the deposition of fifty feet of sediment it appears necessary to imply at least that depth of water over any bed of ice that might have existed before the clays were laid down. Also a considerable period of time for such clay sedimentation to transpire. The formation and continued existence of a bed of ice under water in this manner has been weli remarked by Buckland to impose conditions such as to exclude the reasonable possibility of its occurrence. Such a condition as outlined above, however, appears to be called for if we accept Dall's supposition that the ice beds at Elephant Point are interstratified. That the arrangement presented at this locality in 1880-81 was simply due to a vertical displacement of fifty feet, more or less, by which a portion of the upper ice-bed appeared at a lower level is evident from Mr. Nelson's observation and section.[72]

The peculiar pungent odor that has been noticed by various observers in localities where mammoth and other mammal remains have been found associated with Pleistocene clays and Recent ice and peat beds, has been by some writers erroneously assigned to decaying animal matter. This odor is nothing more than gaseous emanations from decomposing vegetable matter. It is noticeable wherever exposures occur that favor the rapid thawing and oxi-

[68] Great Ice Age, p. 665.
[69] Deutsche geographische Blätter. Bd. IV, p. 174.
[70] Quart. Jour. Geol. Soc. Lond., Vol. L, pp. 1-9.
[71] Seventeenth Ann. Rep. U. S. Geol. Survey, 1896, p. 860.
[72] See Appendix, p. 111.

dizing of peat and humus and is more often found in situations where there are no traces whatever of animal remains. It is clearly and solely referable to decaying vegetable matter and in no case to animal matter in the Pleistocene clays.

It appears safe to assert that even when found intimately associated with mammal remains on talus slopes all occurrences of ice are to be considered more as an afterthought in studying the Pleistocene deposits of Alaska (and Siberia) with their fossil remains. The phenomena of Pleistocene and Recent are confused only superficially as is to be expected. The land ice bears no relation to the mammoth and its contemporary fauna beyond that the conditions of gradually increasing cold that have brought about the occurrence and preservation of the ice phenomena as exhibited today in Arctic and sub-Arctic regions was apparently also the primary cause of the extinction of the mammoth. The mammoth has become associated with ice because its remains have been found intermingled with ice on talus slopes. This is to be expected in clay bluffs overlain by beds of ice which in turn are covered by layers of peat or alluvium. In undergoing a vertical displacement due to the undermining of the sea or rivers, the ice may be fractured into large blocks by uneven stresses during its descent, the peaty covering become torn so fragments of it mixed with clay are washed down and over the new surface to fill up the cracks between the frozen blocks. Thus any mammoth or other remains that may be imbedded in the clays may become mixed heterogeneously with the re-sorted material among the ice blocks or lie exposed. Thus a frozen carcass may readily fall intact to find a secondary resting place in a crevasse between ice blocks and there be refrigerated.

XII.—SUMMARY OF CONCLUSIONS

I. That while remnants of the large Pleistocene mammal herds may have survived down to the Recent period and in some cases their direct descendants, as the musk-ox, to the present, most of them became extinct in Alaska with the close of Pleistocene.

II. The most rational way of explaining this extinction of animal life is by a gradual changing of the climate from more temperate conditions permitting of a forest vegetation much farther north than now, to the more severe climate of today, which subduing the vegetation and thus reducing the food supply besides directly discomforting the animals themselves, has left only those forms capable of adapting themselves to the Recent conditions surviving in these regions to the present.

III. There are no facts to support the contention that the climate of the Arctic and sub-Arctic regions ever has been colder than it is at present. There are no phenomena presented in those regions that require a more severe climate than that now existing to account for them. There are no ice deposits in Alaska, except those of large glaciers, that may be considered of Pleistocene age. There are no ice-beds interstratified with the Pleistocene deposits of Alaska.

IV. That the various forms of land ice, together with the deposits of peat, now existing throughout the Arctic and sub-Arctic regions of Alaska belong to the Recent period and these deposits may be most conveniently and logically classified by their *position* with reference to the Pleistocene and Recent formations and the ice deposits cannot be differentiated satisfactorily into deposits of snow or of water origin by their physical structure and character alone.

XIII.—APPENDIX

LITERATURE OF THE ELEPHANT POINT ICE-BEDS OF ESCHSCHOLTZ BAY IN KOTZEBUE SOUND, AND THOSE ON THE KOBUK RIVER

Kotzebue's Description

1821. Vol. I, p. 219.

Beechey's Description

1831. Vol. I. Part I. Narrative.
Part II. Appendix by Buckland.
1839. Vol. II. Zoology of Beechey's Voyage. Geology by Buckland, with map of Eschscholtz Bay colored by Belcher.

Descriptions by Seemann, Hooper, Dall, and others

1852. Botany of Voyage of the "Herald." Seemann.
Vol. I. Plate I. Picture of Ice-cliffs.
1853. Narrative of Voyage of the "Herald." Seemann.
Vol. II. Description of Ice-cliffs.
1854. Zoology Voyage of the "Herald." Richardson.
Description of Pleistocene mammal remains.
1881. Captain Hooper's description. July, 1880.
1881. W. H. Dall's description. September, 1880.
1883. Muir's remarks on soil and vegetation.
1884. Captain Hooper's observations in 1881. Nelson's photographs in Hooper's Rept. Nelson's MS. notes and drawings.
1887. Healy's Report on Cruise of Corwin in 1885. Lieut. Cantwell's Narrative of an Exploration of the Kowak (Kobuk) River. C. H. Townsend's notes.
1890. Lieut. Cantwell's letter to I. C. Russell. Lieut. Cantwell's Abstract in Science. Lieut. Cantwell's Account in National Geographic Magazine.

I. THE ICE-BEDS ON ESCHSCHOLTZ BAY IN KOTZEBUE SOUND

A discussion of the ice-beds of this so-called classic locality is reopened with some reluctance from the fact that the writer has never viewed the phenomena there presented. However, such a gross misconception of the significance of these ice-beds has become so generally accepted by repeated publication in what otherwise appear to be accepted authorities on the subjects they treat, that a thorough, careful, review of the testimony to date seems to be in order. To

present this impartially it appears necessary even if charged with much repetition and tediousness to reprint in accessible form all of the several descriptions of this locality, from that by its discoverer, Kotzebue, to the oft repeated and much quoted account by Dall, etc. Besides it seems desirable at this opportunity to bring together in chronological order all the scattered observations about this ice on the shores of Eschscholtz Bay that they may be available as a handy reference to future observers who may have the opportunity of visiting the locality and studying the facts.

[A VOYAGE OF DISCOVERY INTO THE SOUTH SEA AND BEERING'S STRAITS IN THE YEARS 1815-18. By Otto von Kotzebue. English translation in 3 vols. 8vo. London, 1821, Volume I.]

On the 7th of August, 1816, speaking of the native inhabitants about Eschscholtz Bay he says, page 218: "They perhaps also keep reindeer; as we saw many horns of these useful animals lying on the shore."

August 8, 1816, page 219. "We had passed a very unpleasant night, for it was stormy and rainy; and as the morning promised no better weather, I resolved to sail back to the ship; but scarcely had we gone half way, when we were overtaken by a violent storm from the southeast; the long-boat drew much water, and we were obliged to return to the landing-place we had just quitted. Being wet through, I had a fire made of driftwood, which we found everywhere in plenty; we dried our clothes, and prepared a refreshing soup. It seemed as if fortune had sent this storm, to enable us to make a very remarkable discovery, which we owe to Dr. Eschscholtz. We had climbed much about during our stay, without discovering that we were on real ice-bergs. The doctor, who had extended his excursions, found part of the bank broken down, and saw, to his astonishment, that the interior of the mountain, consisted of pure ice. At this news, we all went, provided with shovels and crows, to examine this phenomenon more closely, and soon arrived at a place where the bank rises almost perpendicularly out of the sea, to the height of a hundred feet; and then runs off, rising still higher. We saw masses of the purest ice, of the height of a hundred feet, which are under a cover of moss and grass; and could not have been produced, but by some terrible revolution. The place which, by some accident, had fallen in, and is now exposed to the sun and air [p. 220], melts away, and a good deal of water flows into the sea. An indisputable proof that what we saw was real ice, is the quantity of mammoths' teeth and bones, which were exposed to view by the melting, and among

which I myself found a very fine tooth. We could not assign any reason for a strong smell, like that of burnt horn, which we perceived in this place. The covering of these mountains, on which the most luxuriant grass grows to a certain height, is only half a foot thick, and consists of a mixture of clay, sand, and earth; below which the ice gradually melts away, the green cover sinks with it, and continues to grow; and thus it may be foreseen, that in a long series of years, the mountain will vanish, and a green valley be formed in its stead."

[NARRATIVE OF A VOYAGE TO THE PACIFIC AND BEERING'S STRAIT. By Captain F. W. Beechey, R. N. Vol. I. 4to, in two parts. London, 1831. Part I.]

July 29, 1826, page 257. "While the duties of the ships were being forwarded under my first lieutenant, Mr. Peard, I took the opportunity to visit the extraordinary ice-formation in Eschscholtz Bay mentioned by Kotzebue as being 'covered with a soil half a foot thick, producing the most luxuriant grass,' and containing an abundance of mammoth bones. We sailed up the bay, which was extremely shallow, and landed at a deserted village on a low sandy point, where Kotzebue bivouacked when he visited the place, and to which I afterwards gave the name of Elephant Point, from the bones of that animal being found near it.

"The cliffs in which this singular formation was discovered begin near this point, and extend westward in a nearly straight line to a rocky cliff of primitive formation at the entrance of the bay, whence the coast takes an abrupt turn to the southward. The cliffs are from twenty to eighty feet in height; and rise inland to a rounded range of hills between four and five hundred feet above the sea. In some places they present a perpendicular front to the northward, in others a slightly inclined surface; and are occasionally intersected by valleys and water-courses generally overgrown with low bushes. Opposite each of these valleys there is a projecting flat piece of ground, consisting of the materials that have been washed down the ravine, where the only good landing for boats is afforded. The soil of the cliffs is a bluish-coloured mud, for the most part covered with moss and long grass, full of deep furrows, generally filled with water or frozen snow. Mud in a frozen state forms the surface of the cliff in some parts; in others the rock appears [p. 258], with the mud above it, or sometimes with a bank half way up it, as if the superstratum had gradually slid down and accumulated against the cliff. By the large rents near the edges of the mud cliffs, they

appear to be breaking away, and contributing daily to diminish the depth of water in the bay.

"Such is the general conformation of this line of coast. That particular formation, which, when first discovered by Captain Kotzebue, excited so much curiosity, and bore so near a resemblance to an iceberg, as to deceive himself and his officers, when they approached the spot to examine it, remains to be described, as we rowed along the shore, the shining surface of small portions of the cliffs attracted our attention and directed us where to search for this curious phenomenon, which we should otherwise have had difficulty in finding, notwithstanding its locality had been particularly described; for so large a portion of the ice-cliff has thawed since it was visited by Captain Kotzebue and his naturalists, that only a few insignificant patches of the frozen surface now remain. The largest of these, situated about a mile to the westward of Elephant Point, was particularly examined by Mr. Collie, who on cutting through the ice in a horizontal direction, found that it formed only a casing to the cliff, which was composed of mud and gravel in a frozen state. On removing the earth above, it was also evident, by a decided line of separation between the ice and the cliff, that the Russians had been deceived by appearances. By cutting into the upper surface of the cliff three feet from the edge, frozen earth, similar to that which formed the face of the cliff, was found at eleven inches depth; and four yards further back the same substance occurred at twenty-two inches depth.

"This glacial facing we afterwards noticed in several parts of the sound; and it appears to me to be occasioned either by the snow being banked up against the cliff or collected in its hollows in the winter, and converted into ice in the summer by partial thawings and freezings—or by the constant flow of water during the summer over the edges of the cliffs, on which the sun's rays operate less forcibly than on other parts, in consequence of their aspect. The streams thus become converted into ice, either while trickling down the still frozen surface of the cliffs, or after [p. 259] they reach the earth at their base, in which case the ice rises like a stalagmite, and in time reaches the surface. But before this is completed, the upper soil, loosened by the thaw, is itself projected over the cliff, and falls in a heap below, whence it is ultimately carried away by the tide. We visited this spot a month later in the season, and found a considerable alteration in its appearance, manifesting more clearly than before the deception under which Kotzebue laboured."

July 30, 1826, Chapter XI, page 260. "On the 30th of July we

weighed from Chamisso Island attended by the barge, and steered out of the sound. The day was very fine; and as we sailed along the northern shore, the sun was reflected from several parts of the cliff, which our telescopes discovered to be cased with a frozen surface similar to that just described in Eschscholtz Bay."

In Narrative of the Proceedings of the Barge of the Blossom to explore the coast N. E. of Icy Cape:

"On the 21st of August arrived off Sea Horse Islands. Thence to Cape Franklin —" and "Having run twenty-nine miles along the coast to the northeast they again landed.—The coast here assumed a different aspect, and consisted of clay cliffs about fifty feet high, and presented an ice formation resembling that which has been described in Eschscholtz Bay. Their latitude was 70° 58′ 63″ N."

Monday, Sept. 11, 1826, page 322. "Having now the assistance of the barge, I embarked in her to examine narrowly the shores of Kotzebue Sound. Proceeding to survey the head of Eschscholtz Bay, shallow water obliged the boat to anchor off Elephant Point, where I left Mr. Collie with a party to examine again the cliffs in which the fossils and ice formation had been seen by Kotzebue, and proceeded to the head of the bay in a small boat. We landed upon a flat muddy beach, and were obliged to wade a quarter of a mile before we could reach a cliff for the purpose of having a view of the surrounding country. * * *

"The shore around us was flat, broken by several lakes, in which there was a great many waterfowl. The cliff we had ascended was composed of a bluish mud and clay, and was full of deep chasms lying in a direction parallel with the front of the cliff. In appearance the cliff was similar to that at Elephant Point, which was said to contain fossils; but there were none seen in this one, though the earth, in parts, had a disagreeable smell, similar to that which was supposed to proceed from the decayed animal substances in the cliff near Elephant Point. * * * "

Page 323. "I found Mr. Collie had been successful in his search among the cliffs at Elephant Point, and had discovered several bones and grinders of elephants and other animals in a fossil state of which a full description and drawings from the remains will be found in the appendix. Associating these two discoveries, I bestowed the name of Elephant upon the point, to mark its vicinity to the place where the fossils were found; and upon the river that of Buckland, in compliment to Dr. Buckland, the professor of geology at Oxford, to whom I am much indebted for the above mentioned description of the fossils, and for the arrangement of the geological memoranda attached to this work.

"The cliff in which these fossils appear to have been imbedded is part of the range in which the ice formation was seen in July. During our absence (a space of five weeks) we found that the edge of the cliff in one place had broken away four feet, and in another two feet and a half, and a further portion of it was on the eve of being precipitated upon the beach. In some places where the icy shields had adhered to the cliff nothing now remained, and frozen earth formed the front of the cliff. By cutting through those parts of the ice which were still attached, the mud in a frozen state presented itself as before, and confirmed our previous opinion of the nature of the cliff. Without putting to this test, appearances might well have led to the conclusion come to by Kotzebue and M. Eschscholtz; more especially if it happened to be visited early in the summer, and in a season less favorable than that in which we viewed it. The earth, which is fast falling away from the cliffs—not in this place only, but in all parts of the bay—is carried away by the tide. * * *

"In consequence of this shallow water there was much difficulty in embarking the fossils, the tusks in particular, the largest of which weighed 160 lbs."

September 25, 1826, page 329. "In another excursion which I made along the north side of the sound, I landed at a cape which had been named after the ship (Blossom), and had the satisfaction of examining an ice formation of a similar nature to that in Eschscholtz Bay, only more extensive and having a contrary aspect. The ice here, instead of merely forming a shield to the cliff, was imbedded in the indentations along its edge, filling them up nearly even with the front. A quantity of fallen earth was accumulated at the base of the cliff, which uniting with the earthy spaces intervening between the beds of ice, might lead a person to imagine the ice formed the cliff, and supported a soil two or three feet thick, part of which appeared to have been precipitated over the brow. But on examining it above, the ice was found to be detached from the cliff at the back of it; and in a few instances so much so, that there were deep chasms between the two. These chasms are no doubt widened by the tendency the ice must have towards the edge of the cliff; and I have no doubt the beds of ice are occasionally loosened and fall upon the beach, where, if they are not carried away by the sea, they become covered with the earthly materials from above, and perhaps remain sometime immured. In some places the cliff was undermined, and the surface in general was very rugged; but it was evident in this, as in the former instance, that the ice was lodged in the hollow places in the cliff."

October 7, 1826, page 333. "Mr. Elson went up Eschscholtz Bay with two boats for [p. 334] the purpose of sounding and obtaining further information of Buckland River. * * * The barge brought us down a valuable addition to our collection of fossils, the cliff having broken away considerably since the first specimens were obtained."

Part II, page 560, September 18, 1827. "On the 18th a party of the officers landed in Eschscholtz Bay to search for fossils, but they were unsuccessful, in consequence of an irregularity of the tide, which was on that occasion unaccountably high, and scarcely fell during the day. The cliffs had broken away considerably since the preceding year; and the frozen surface of the cliff appeared in smaller quantities than before, but the earth was found congealed at a less depth from the top. This examination tended to confirm more steadfastly the opinion that the ice forms only a coating to the cliff, and is occasioned by small streams of water oozing out, which either become congealed themselves in their descent, or convert into ice the snow which rests in the hollows."

[CAPTAIN F. W. BEECHEY. NARRATIVE OF A VOYAGE TO THE PACIFIC AND BEERING'S STRAIT. Part II, 1831, pp. 593-612. 3 plates. Appendix.—On the Occurrence of the remains of Elephants, and other Quadrupeds, in the cliffs of frozen mud, in Eschscholtz Bay, within Beering's Strait, and in other distant parts of the shores of the Arctic seas. By the Rev. Wm. Buckland, D. D., F. L. S., F. G. S., and professor of geology and mineralogy in the University of Oxford.]

"Having been requested, at the time of Captain Beechey's return to England, 1828, to examine the collection of animal remains which he brought home from the shores of Eschscholtz Bay, and to prepare a description of them for the present publication, I attended at the Admiralty to assist at the opening and distribution of these specimens. The most perfect series, including all the specimens, engraved in plates 1, 2, 3 (fossils), was selected for the British Museum; another series, including some of the largest tusks of elephants, was sent to the Museum of the College of Edinburg, and other tusks to the Museum of the Geological Society of London. To the plates of these fossils, I have added a map of the bay in which they were collected,[1] on the same spot where similar remains were first discovered by Lieutenant Kotzebue and Dr. Eschscholtz, on the 8th of August,

[1] This map was not published until 1839 when it appeared along with other geological notes at the end of the volume on the Zoology of Captain Beechey's Voyage.

1816. Captain Beechey, in the course of his narrative (pp. 257, 323, and 560), has given a general description of the circumstances attending the examination of the locality in which the existence of these bones had been indicated by Lieutenant Kotzebue, and before I proceed to offer any observations of my own on these remarkable organic remains, or on the causes that may have collected them in such abundance on the spots where they are now found, I shall extract a further and more detailed account of the place and circumstances in which they were discovered, from the journals of Mr. Collie (surgeon to the English Expedition), by whom the bones were principally collected, and the chief observations and experiments made, on which Captain Beechey has founded his opinion, in which his officers, Lieutenant Belcher and Mr. Collie, entirely coincide with him, that the cliffs containing bones, which have been described by Kotzebue and Eschscholtz as icebergs covered with moss and grass, are not composed of pure ice, but are merely one of the ordinary deposits of mud and gravel, that occur on many parts of the shores of the Polar Sea, being identical in age and character with diluvial deposits of the same kind which are known to be dispersed over the whole of Europe, and over a large part of northern Asia and North America; and presenting no other peculiarities in the frozen regions of the north, than that which results from the present temperature of these regions, causing the water which percolates this mud and gravel to be congealed into ice.

"The question of fact, whether the cliffs containing these bones of elephants, and other land quadrupeds, are composed of 'masses of the purest ice, a hundred feet high, and covered on their surface with vegetation,' as stated in the voyage of Lieutenant Kotzebue (p. 219, English translation), or are simply composed, as Captain Beechey thinks them to be, of ordinary diluvium, having its interstices filled up with frozen waters, is important, as it affects materially the consideration of the further question, as to what was the state of the climate of the arctic regions at the time when they were thickly inhabited by genera of the largest quadrupeds, such as at present exist only in our warmest latitudes; this being a point of much interest and curiosity, in relation to the history of the physical revolutions that have affected our planet, and on which there still exists a difference of opinion among those individuals who have paid the greatest attention to the subject.

"Before I proceed to Mr. Collie's observations on the spot in which they were found, I shall extract from his journal a list of the total number of animal remains collected during the short time

he was with Captain Beechey in Eschscholtz Bay, and add my own list and description of the most perfect of these specimens, which I have selected to be engraved.

"List, showing the total number of animal remains collected in Eschscholtz Bay, taken from the journal of Mr. Collie:

"*Elephant*:—1 lower jaw, nearly complete; 7 molar teeth; 9 tusks. Five of them large, and weighing from one hundred to one hundred and sixty pounds each. Four small; one of these was found in the debris of the cliff half way up; the circumference of the largest tusk at its root is twenty inches, and at three feet above the root twenty-one inches and a half; another tusk, in which part of the tip is wanting, measures nine feet two inches along the curve from the root to the tip, and five feet two inches across the chord of its curve; 4 fragments of tusks; 3 dorsal vertebræ, five inches and a half in diameter; 1 atlas; 1 os innominatum, nearly perfect; 1 ilium, imperfect; 1 os pubis, imperfect; 4 fragments of scapulæ, one of them tolerably complete; 1 portion of humerus; 5 femora, one of them almost complete; 4 fragments of femora; 2 tibiæ, one of them nearly complete; 1 tarsal bone; 1 os calcis, entire, taken out of the cliff; 1 cuboides, nearly entire; 1 cuneiform; 1 phalangal bone.

"*Urus*:—1 skull, incomplete; 3 fragments of horns; 1 femur; 3 tibiæ; 1 dorsal vertebra; 1 sacrum.

"*Musk-ox*:—1 skull, with horns attached, incomplete and very modern.

"*Deer*:—1 fragment of antler; 4 tibiæ entire; 3 metatarsal bones; 1 os calcis. Some of these are probably casual and modern, and derived from reindeer that now frequent this part of America.

"*Horse*:—1 astragalus; 1 metacarpus; 1 metatarsus."

[BUCKLAND'S APPENDIX. Notes extracted from the Journal of Mr. Collie.]

[598] "The attention of the world has been called to the remarkable cliff in which fossil bones were found by Dr. Eschscholtz in August, 1816. On my first visit to it in the month of July, 1826, time did not permit me to do more than take a view of the most eastern part, and examine the nature of the icy fronting which is presented. At that time I saw no traces of fossils; this cliff faces to the north, and extends in nearly a right line, with few interruptions, for two miles and a half, and is in general about ninety feet high. It is composed of clay and very fine quartzy and micaceous sand, assuming a grayish appearance when dry. The land behind rises gradually to an additional height of one hundred feet, and is covered with a black, boggy soil, nourishing a brown and gray lichen, moss, several species of

ericæ, graminiæ, and other herbaceous plants, and is intersected with a few valleys containing small streams, and having their more protected declivities adorned with shrubs of willow and dwarf betula (*Betula incana*).

"A continued waste of the cliff is produced at the upper part by its falling down in considerable lumps to the bottom, where the debris remains for a longer or shorter time, and covers the front to a greater or less height, in some places, almost to the very top. Large masses are sometimes seen rent off and standing out from the body of the cliff ready to have their last slight hold washed away by the next shower, or by a little more thawing and separation of the frozen earth that serves them for attachment. The lumps of soil that fall are still covered with the herbaceous and shrubby verdure that grew upon them. The perpendicular front of the cliff of frozen mud and sand is every summer gradually decreasing by the melting of the ice between its particles into water, which trickles down and carries with it loose particles of earth. In some portions of the cliff the earthy surface is protected with ice, partly the effect of snow driven into the hollows and fissures, and partly from the congealation of water, which may have collected in chinks or cavities: these masses of ice dissolve in summer, and the water running from them carries with it any earth that lies in its way, and mixes itself with, and moves forward, the mass of debris below. By this gradual thawing and falling of the cliff, the black boggy soil at the surface becomes undermined, and assumes the projecting and overhanging appearance which is so remarkable. At the base of the greater part of the cliff the debris is washed by the sea at full tide, and being gradually carried away by the retiring waters, is spread out into an extensive shoal along the coast. It was in this shoal, where it is left dry by the ebbing tide, to the distance of fifty or a hundred yards from the cliff, that the greater number of the fossil bones and teeth were discovered, many of them so concealed as only to [599] leave a small end or knob sticking up; they were dispersed very irregularly. Remains of the musk-ox were found on this shoal, along with those of elephants.

"The few specimens taken out of the cliff, or more properly from the debris, on the front of it (for none, I believe, were taken out of the very cliff), were in a better state of preservation than those which had been alternately covered and left exposed by the flux and reflux of the tide, or imbedded in the mud and clay of the shoal.

"A very strong odour, like that of heated bones, was exhaled wherever the fossils abounded. Quantities of rolled stones, mostly

of a brownish sandstone, lay upon the shoal, left dry by the receding sea. With these were also porphyritic pebbles.

"Parts of some of the tusks, where they had been imbedded in the clay and sand, were coloured blue by phosphate of iron, and many of the teeth were stained in the same manner. The circular layers of the tusks in the more decayed specimens were distinctly separated by a thin vein of fibrous gypsum.

"In those parts of the bay where there are no cliffs, the waves are kept at a distance from the land by a gravelly beach, which they have thrown up for a considerable extent round the entrance of the streams which come down the valleys. These beaches have formed rounded flats containing marshes or lakes: not unfrequently a rather luxuriant herbage covers their surface. The land behind them rises in a gentle slope. Great part of the shore of Kotzebue Sound is made up of a diluvial formation, similar to that on the south shore of Eschscholtz Bay. From Hut Peak to Hotham Inlet it exhibits many cliffs similar to those just described, and also others with a uniform and steep slope, partly covered with verdure, and partly exposing the dry sand and clay which compose them. The most elevated cliffs form the projecting headland of Cape Blossom, and *abound in ice, notwithstanding their southern aspect,* particularly at Mosquito station and Cape Blossom. In their neighborhood I observed the natives had recently formed coarse ivory spoons from the external layer of a fossil elephant's tusk. The ice here in the end of September showed itself more abundantly than it did in the middle of the same month on the cliffs in Eschscholtz Bay which have a northern aspect.

"Mr. Collie then proceeds to explain still further his ideas of the manner in which masses and sheets of pure ice may have been collected in hollows and fissures on and near the front of the cliff in Eschscholtz Bay.

"'1st. By the accumulation of snow drifted into hollows subjacent to the overhanging stratum of black boggy soil that forms the brink of the cliff, and subsequently converted into ice by successive thawing and freezing in spring and summer.

[600] "'2dly. They may have been formed from water collected in deep fissures and cavities that intersect the falling cliff near its margin. The inclined position of the land immediately above this margin of peat, and the annual undermining which is produced by the thawing of the frozen mud beneath it, produce occasional land slips and movements of the edge of the cliff towards the sea; these cause cracks and fissures of the soil in various directions, but chiefly

parallel to the external face of the cliff. When these fissures descend through the black boggy soil of the surface into the frozen mud below, they become receptacles for the formation of ice, since the water that oozes into them is congealed upon their sides until it entirely fills them with a wall or dyke of solid ice. The fall of a mass of mud from the outer side of one of these walls would expose this ice, forming a case over the inner side of the fissure in which it was accumulated.

"'3dly. The manner in which an extensive facing of pure ice may be formed on these cliffs, by water during the summer trickling down their frozen surface from the soil above, and becoming converted to ice in the course of its descent, has been described by Captain Beechey [pages 258 and 330].'

"Lieutenant Belcher, in his notes, proposes another theory to explain the occurrence of masses of pure ice immediately below the margin of the peat on the top of the cliff on the southern shore of Eschscholtz Bay. He concieves that between the superficial bed of spongy peat, and the mass of frozen mud which forms the body and substance of this cliff, the water oozing downwards through the peat, during the thaw of each successive summer, is stopped at the point where it comes into contact with the perpetually frozen earth below, and there accumulates into a thick horizontal sheet of pure transparent ice, and that it is the broken edge of this icy stratum which becomes exposed in the margin of the cliff during the process of slow and gradual destruction which it is continually undergoing.

"This opinion, however, is, I believe, peculiar to Lieutenant Belcher. The experiment made by Mr. Collie in boring horizontally into the cliff, through a vertical face of ice, until he penetrated the frozen mud behind it, shows, that in this case the ice was merely a superficial facing of frozen water, consolidated as it descended the front of the cliff; and his further experiments in digging vertically downwards, in two places, through the peat into frozen mud, and finding no traces of any intermediate bed of ice appear unfavorable to any hypothesis as to the formation of a stratum of pure ice between the superficial peat and subjacent mud.

"It has just been stated that Captain Beechey and Mr. Collie propose three different solutions to explain the origin of these hanging masses of ice near the upper margin of vertical cliffs: 1st, That they may have been formed from snow drifted into hollows of the cliffs, and subsequently converted into ice; 2dly, From [601] water consolidatetd into ice within fissures and cavities, caused by the subsidence and falling forwards of the frozen mud; 3dly, From water

trickling down the external surface of the cliff, and freezing as it descended. To these the theory of Lieutenant Belcher would add a fourth process, by which a horizontal bed of ice is formed between a superficial bed of peat and the subjacent mud. These hanging masses of ice, whatever may be their origin, appear to have been so abundant at the time of the Russian expedition to this coast, as to have made Kotzebue and Eschscholtz imagine the entire cliff behind them to be an iceberg; an opinion in which all the English officers agree in considering to be erroneous, since the view and descriptions of the cliff on the south shore of Eschscholtz Bay, given on page 219 of the English translation of Kotzebue's Voyage, do not correspond with the state of this coast when it was subsequently visited by the crew of the Blossom.

[Dr. Buckland here gives Captain Kotzebue's observations quoted on preceding page which are not here repeated.]

"Mr. Collie's experiments, which I have before alluded to, in digging both horizontally and vertically through the ice and peat into frozen mud, show that, at the points where they were made, the cliff formed no part of any iceberg. Still more decisive is the important fact, that on the two occasions when it was [602] visited by the English expedition, the patches of ice upon the cliff in question were very few in number, and variable from one year to another; that the 'masses of the purest ice to the height of a hundred feet, which were seen by the Russian officers, had entirely vanished; and that nearly the whole front of the cliff, from the sea at its base to the peat that grew on its summit, presented a continuous mass of indurated mud and sand, or of under-cliffs formed by the subsidence of these materials.

"It seems quite certain, therefore, that there must have been a material change in the quantity of ice on the cliff in Eschscholtz Bay in the interval between the visits of Lieutenant Kotzebue and Captain Beechey; and if we suppose that, during this interval, there was an extensive thawing of the icy front that was seen by Kotzebue, but which existed not at the time of Beechey's visit, we find in this hypothesis a solution of the discrepancy between these officers; since what to the first would appear a solid iceberg, when it was glazed over with a case of ice, would, after the melting of that ice, exhibit to the latter a continuous cliff of frozen diluvial mud. Whilst the ice prevailed all over the front of the cliff, any bones that had fallen from it before the formation of this ice, and which lay on the under-cliffs or upon the shore, must, by an error almost inevitable, have been presumed to fall from the imaginary iceberg.

"This circumstance seems to suggest to us that it is worthy of consideration whether or not there may have existed any similar cause of error in the case of the celebrated carcass of an elephant in Siberia, which is said to have fallen entire from an iceberg in the cliffs near the Lena. The Tungusian who discovered this carcass suspended in what he called an iceberg may possibly have made no very accurate distinction between a pure iceberg and a cliff of frozen mud.

"It is stated by Lieutenant Belcher, that at a spot he visited on the southeast shore of Eschscholtz Bay, on ascending what appeared at first to be a solid hillock, he found a heap of loose materials, unsafe to walk on, and having streams of liquid mud oozing from it on all sides through coarse grass; that as the melting subsoil of the hillock sinks gradually down, the incumbent peat subsides with it; so that at no very distant period the entire hillock will disappear. In other mud cliffs, also, he observed similar streams of liquid mud, accompanied by a depression of the surface immediately above them. Thus, from the month of June to October these cliffs are constantly thawing, and throwing down small avalanches of mud, which between Cape Blossom and Cape Kruzenstern, are so numerous that you can scarce stand there an hour without witnessing the downfall of some portion of the thawing cliffs. Hence originates a succession of ravines and gullies, which do not run far inland, and afford no sections, being covered with the debris of the [603] superficial peat that falls into them. Small streams of muddy water, of the consistency of cream, ooze from the sides of these ravines, the water being supplied by the melting of the particles of ice which pervade the substance of the frozen mud and peat.

"There remain, then, three important points, on which all the English officers concur in the same opinion: 1st, That the bones and tusks of elephants at Eschscholtz Bay are not derived from the superficial peat; 2dly, That they are not derived from any masses of pure ice; 3dly, That, although collected chiefly on the shore at the base of the falling cliff, they are derived only from the mud and sand of which this cliff is composed.

"The occurrence of cliffs composed of diluvial mud is by no means peculiar to the south shore of Eschscholtz Bay. It will be seen by reference to the map (Plate I, Geology), that they are more extensive, but at a less elevation along the north shore of the same bay, and also on the southwest of it, at Shallow Inlet, in Spafarief Bay. Indeed, in following the line of coast north-eastwards, from the Arctic Circle, near Beering's Strait, to lat. 71° N., wherever the

coast is low, there is a long succession of cliffs of mud, in the following order: 1. Schischmareff Inlet. 2. Bay of Good Hope, on the south of Kotzebue Sound. 3. Spafarief Bay, at the southeast extremity of Kotzebue's Sound. 4. Elephant Point, in Eschscholtz Bay. 5. At the mouth of the Buckland River, at the head of Eschscholtz Bay. 6. The north coast of Eschscholtz Bay. 7. Cape Blossom. 8. Point Hope. 9. From Cape Beaufort to twenty miles east of Icy Cape. 10. Lunar Station, near lat. 71°. At the base of the mud cliff, fifteen feet high, in the Bay of Good Hope, a small piece of a tusk of an elephant was found upon the shore. At Shallow Inlet, the mud cliff was fifteen feet high, without any facings of ice, or appearance of bones; yet there was the same smell at low water as in the cliffs near Elephant Point, that abound so much in bones. At Icy Cape, the cliffs of mud behind the islands were about twenty feet high, but were not examined. Patches of pure ice were observed hanging on the mud cliffs in many places along this coast, but only where there was peat at the top; hence it may be inferred, that the ice, in such cases, is formed by water oozing from the peat. At High Cape, near Hotham Inlet, is a cliff of mud, a hundred feet high, covered at the top with peat, and having patches of ice upon its surface; but no bones were found here. In those parts of the coast where the cliffs are rocky there were no facings of ice.

"Having thus far stated the evidence we possess respecting the facts connected with the discovery of these bones in Eschscholtz Bay, I will proceed to offer a few remarks in illustration and explanation of them, and to consider how far they tend [604] to throw light on the curious and perplexing question, as to what was the climate of this portion of the world at the time when it was inhabited by animals now so foreign to it as the elephant and rhinoceros, and as to the manner in which, not only their teeth and tusks and dislocated portions of their skeletons, but in some remarkable instances, the entire carcasses of these beasts, with their flesh and skin still perfect, became entombed in ice, or in frozen mud and gravel, over such extensive and distant regions of the northern hemisphere.

"The bones from Eschscholtz Bay, like most of those we find in diluvial deposits, are no way mineralized; they are much altered in colour, being almost black, and are to a certain degree decomposed and weakened; yet they retain so much animal matter, that not only a strong odour like that of burnt horn is emitted from them on the application of heated iron, but a musty and slightly ammoniacal smell is perceptible on gently rubbing their surface.

"It must not, however, be inferred that this high state of preser-

vation can exist only in bones that have been imbedded in frozen mud or frozen gravel, since dense clay impermeable to water has been equally effective in preserving the remains of the same extinct species of animals in the milder climate of England. There are in the Oxford Museum bones of elephant and rhinoceros from diluvial clay, in Warwickshire and Norfolk, that are scarcely at all more decomposed than those brought by Captain Beechey from Eschscholtz Bay, and are nearly of the same color and consistence with them. I have also a fragment of the tusk of an elephant from the coast of Yorkshire, near Bridlington, of which great part had been made into boxes by a turner of ivory before the remainder came into my possession; and on comparing the state of the residuary portion of this tusk from Yorkshire with that of the scoop made of a fossil tusk by the Esquimaux in Eschscholtz Bay, I find the difference scarcely appreciable.

"It is mentioned, both by the Russian and English officers, that a strong odour like that of burnt bones is emitted from the mud of the cliffs in which they discovered these animal remains in Eschscholtz Bay; other observers have stated the same thing of the mud cliffs in Siberia, near the mouth of the Lena, which contain similar organic remains. But it is also stated by Mr. Collie that a like odour was perceived at the base of another mud cliff in Shallow Inlet, near Eschscholtz Bay, where there were no bones; and as in this latter case we must attribute it to some cause unconnected with the bones, and probably to gaseous exhaltations from the mud itself, we may, I think, draw the same inference as to the origin of the odour in all the other cases also; thus in Eschscholtz Bay, where nearly all the bones were collected at the base of the cliff on the beach below high water, how can the presence of two or three bones only, lying half way up the cliff, account for the odour which is emitted over a distance of more than a mile along this shore? How inadequate is a cause so partial to so general an effect! since, however numerous may be the animal remains that are buried in the interior of the cliff, no exhalations from them can escape through their impenetrable matrix of frozen mud; and even if that fallen portion of mud which constitutes the under-cliff be ever so abundantly loaded with fossil bones, it is scarcely possible that these should undergo such rapid decomposition as to transmit strong exhalations to the surface through so dense a substance as saturated clay; in fact, their high degree of preservation shows that no such rapid decomposition has taken place.

"With respect to the matrix of frozen mud, from which these

remains are said to be derived, it appears, from specimens of it adhering to the bones, that it consists of micaceous sand and quartzose sand, intermixed with fine blue clay. In a hollow of one of the tusks I found a quantity of this compound, and some fragments of mica slate. All these ingredients may have been derived from the detritus of primitive micaceous slates, such as constitute a large part of the fundamental rocks of the neighborhood of Eschscholtz Bay.

"Pebbles of porphyry also are said to occur in the cliff, and also on the beach below it, mixed, in the latter case, with pebbles of basalt and sandstone, and a few large blocks of basalt. No rock was noticed in this district from which these rolled stones could have been derived; some of those upon the beach may possibly have been drifted thither on floating icebergs. The tranquil state and retired position of the bay render it improbable that these pebbles have been brought to their present place by the influence of any existing submarine currents.

"It is important to clear from confusion two facts mentioned by Captain Beechey, viz., the occurrence of remains of the reindeer and of the musk-ox along with bones of the elephant in Eschscholtz Bay. Had the bones of either of these arctic animals been found unequivocally mixed with the bones of elephants in any undisturbed part of the high cliff, it would have followed that the reindeer and the musk-ox must have been co-eval with the fossil elephant; and this fact would have been nearly decisive of the question as to the climate of this region at the time when it was inhabited by these three species of animals. But as all the fossil remains collected in Eschscholtz Bay, with the exception of a very few bones and the tusk of an elephant that lay high up in the under cliff, were collected on the beach between high and low-water mark, nothing is more probable than that the bones of modern animals should become mixed with those of fossils after they had fallen upon the beach in the recesses of a quiet bay.

"Kotzebue (vol. 1, p. 218) says he saw many horns of reindeer lying on the shore in Eschscholtz Bay, and conjectures that the Americans, who frequent these [p. 606] coasts occasionally in the hunting season, may have brought with them the reindeer from which these horns had been derived. This hypothesis may explain the presence of such horns in a spot which no wild reindeer are known to frequent at present; but as Kotzebue [p. 219] mentions also the abundance of drift-wood upon the shores of this bay, it is probable that the same currents which brought the wood may have

also brought the carcasses of reindeer, and have stranded them on the shores where their horns were found.

"The agency of the same currents to which I have referred the drifting of the carcasses of reindeer into Eschscholtz Bay will also equally explain the presence of recent bones of the musk-ox in this bay on the same shoal with the bones of elephants that had fallen from the cliff. I have already stated that the condition of the skull and horns of a musk-ox, which were brought home with the fossil bones, is so very recent, and differs so essentially from the condition of all the bones of elephants from this place, that it is impossible it can have been buried in the same matrix with them; for, in such case, all would have been nearly in the same state, either of preservation or decay.

"It is stated by Cuvier,[2] that a similar doubt is attached to the heads of musk-oxen described by Pallas and Ozeretzkovsky, as found near the mouth of the Ob, and at the embouchure of the Yana, and that there is yet no sufficient proof of the existence of any fossil species of musk-ox that may be considered of the same age with the fossil elephant, or which can be brought in evidence as to the question of the climate of the polar regions when these elephants were living. Of the very few remains of musk-oxen which have yet been found, it does not appear that any have been buried at a great depth.

"There is nothing peculiar to Eschscholtz Bay in the occurrence of bones of horses with those of elephants; from the number of localities in which their teeth and bones have been found together, in diluvial deposits, it appears that more than one species of horse was co-extensive with the fossil elephant in its occupation of the ancient surface of the earth. Wild horses are at present almost unknown, except in warm or temperate latitudes.

"We may now consider how far the facts we have collected respecting the bones in Eschscholtz Bay are in accordance with similar occurrences, either in the adjoining regions to the north, or in other still more distant parts of the earth, and in different latitudes.

"It is stated by Pallas in the 17th volume of the New Commentaries of the Academy of Petersburg, 1772, that throughout the whole of northern Asia, from the Don to the extreme point nearest America, there is scarce any great [607] river in whose banks they do not find the bones of elephants and other large animals which cannot now endure the climate of this district, and that all the fossil

[2] Ossemens Fossiles, second edition, Vol. IV, p .165.

ivory which is collected for sale throughout Siberia is extracted from the lofty, precipitous, and sandy banks of the rivers of that country; that in every climate and latitude, from the zone of the mountains in central Asia to the frozen coasts of the Arctic Ocean, all Siberia abounds in these bones, but that the best fossil ivory is found in the frozen lands adjacent to the Arctic Circle; that the bones of large and small animals lie in some places piled together in great heaps, but, in general, they are scattered separately, as if they had been agitated by waters, and buried in mud and gravel.

"The term mammoth has been applied indiscriminately to all the largest species of fossil animals, and is a word of Tartar origin, meaning simply 'animal of the earth.' It is now appropriated exclusively to the fossil elephant, of which one species only has been yet established, differing materially from the two existing species, which are limited, one to Asia, the other to Africa.

"Of all the fossil animals that have been ever discovered, the most remarkable is the entire carcass of a mammoth, with its flesh, skin, and hair still fresh and well preserved, which in the year 1803 fell from the frozen cliff of a peninsula in Siberia, near the mouth of the Lena.[3] Nearly five years elapsed between the period when this carcass was first observed by a Tungusian in the thawing cliff, in 1799, and the moment when it became entirely disengaged, and fell down upon the strand, between the shore and the base of the cliff. Here it lay two more years, till great part of the flesh was devoured by wolves and bears; the skeleton was then collected by Mr. Adams and sent to Petersburg. Many of the ligaments were perfect, and also the head, with its integuments, weighing four hundred and fourteen pounds without the tusks, whose weight together was three hundred and sixty pounds. Great part of the skin of the body was preserved, and was covered with reddish wool and black hairs; about thirty-six pounds of hair were collected from the sand, into which it had been trampled by the bears.

"The following description, by Mr. Adams, of the place in which this mammoth was found will form an interesting subject of comparison with Captain Beechey's account of the cliff in Eschscholtz Bay: 'The place where I found the mammoth is about sixty paces distant from the shore, and nearly a hundred paces from the escarpment of the ice from which it had fallen. This escarpment occupies

[3] The details of this case are published by Dr. Tilesius in the fifth volume of the Memoirs of the Academy of Petersburg, and also by Mr. Adams in the Journal du Nord, printed at Petersburg in 1807.

exactly the middle between the two points of the peninsula, and is two miles long; and in the place where the mammoth was found, this *rock* has a [608] perpendicular elevation of thirty or forty toises (from 180 to 240 feet). Its substance is a clear pure ice; it inclines towards the sea; its top is covered with a layer of moss and friable earth fourteen inches in thickness. During the heat of the month of July a part of this crust is melted, but the rest remains frozen. Curiosity induced me to ascend two other hills at some distance from the sea; they were of the same substance, and less covered with moss. In various places were seen enormous pieces of wood of all the kinds produced in Siberia; and also mammoths' horns, in great numbers, appeared between the hollows of the rocks; they all were of astonishing freshness. The escarpment of ice was from thirty-five to forty toises high; and according to the report of the Tungusians, the animal was, when they first saw it, seven toises below the surface of the ice. * * *'

"I have to observe in this passage, that it contains no decisive evidence to show that the ice seen by Mr. Adams on the front of the cliff from which the elephant had fallen was anything more than a superficial facing, similar to that found by Captain Beechey on parts of the front of the earthy cliff in Eschscholtz Bay; the same cliff which, a few years before, when visited by Kotzebue, seems to have been so completely incased with a false fronting of ice as to induce him to consider the entire hill to be a solid iceberg. One thing, however, is certain as to this mammoth, viz., that whether it was imbedded in a matrix of pure ice or of frozen earth, it must have been rapidly and totally enveloped in that matrix before its flesh had undergone decay, and that whatever may have been the climate of the coast of Siberia in antecedent periods, not only was it intensely cold within a few days after the mammoth perished, but it has also continued cold from that time to the present hour.

"Remains of the rhinoceros also appear to be nearly co-extensive with those of the elephant in these northern regions. Pallas mentions the head of a rhinoceros which was found near Lake Baikal, near Tshikoi, and four heads and five horns of this animal from various parts of Siberia on the Irtis, the Alei, the Obi, and the Lena. These horns in the frozen districts are so well preserved that splices of them are used by the natives to strengthen their bows.

"Pallas conceived that these remains are not derived from animals that ever inhabited Siberia, but from carcasses drifted northward from the southern regions by some violent aqueous

catastrophe, and that there is proof both of the violence and suddenness of this catastrophe in the phenomenon of an entire rhinoceros found with its skin, tendons, ligaments, and flesh preserved in the *frozen soil* of the coldest part of eastern Siberia. On the arrival of Pallas in Ircutia in March, 1772, the head of this animal was laid before him, together with two of its feet, having their skin and flesh hardened like a mummy; it had been found in December, 1771, in [609] the sand banks of the Wiluji, which runs in about 64° of north latitude into the Lena; the head and two feet only were taken care of, the rest of the carcass, though much decayed, was still enclosed in its skin, and was left to perish; the bones were yellow, the foot had on its skin many hairs and roots of hairs. On various parts of the skin were stiff hairs from one to three inches long.

"If we compare these phenomena of the arctic regions with those of other countries, and especially with England, we shall find it by no means peculiar to the northern extremities of the world to afford extensive deposits of diluvial mud and gravel, containing the remains of extinct species of the elephant and rhinoceros, together with those of horses, oxen, deer, and other land quadrupeds. A large portion of the east coast of England, particularly of Essex, Suffolk, Norfolk, Yorkshire, and Northumberland, is composed of similar deposits of argillaceous diluvium, loaded in many places with bones of the same species of quadrupeds; these deposits occur not only on the low grounds and lands of moderate elevation, but also on the summits of the highest hills, e. g., on the chalky cliff of Flamborough Head, four hundred and thirty feet above the sea. In the central parts of England, near Rugby, we have similar deposits, containing bones, tusks, and teeth of the same species of animals. In Scotland we have the same argillaceous diluvium on the east coast, near Peterhead, and near the western coast, at Kilmours, in Ayrshire, where it contains tusks of elephants and bones.

"The analogies which these deposits offer to those in the arctic regions are striking. In both cases the bones are of the same species of animals. In both cases they are imbedded in superficial deposits of mud and gravel of enormous extent and thickness. In both cases the deposits derive no accession from existing causes, and are suffering only continual loss and destruction by the action of the atmosphere, of rivers, and of the sea. Their chief peculiarity in the polar regions seems to consist in the congealation, to which the diluvium itself as well as the remains included in it are subject, from the influence of the present polar climate. Examples might

be quoted to show the occurrence of similar remains in diluvial deposits all over Europe, and largely in America. Having then such extensive accumulations of the bones of animals, and the detritus of rocks, all apparently resulting from the simultaneous action of water, but which the operation of existing seas and rivers in the districts occupied by this detritus can never have produced, and are only tending to destroy, we may surely be justified in referring them all to some adequate and common cause, such as the catastrophe of a violent and general inundation alone seems competent to have afforded.

"The facts we have been considering are obviously much connected with the still unsettled question respecting the former climate and temperature of that part [p. 610] of the earth in which they occur. Too much stress has, I think, been laid on the circumstances of the mammoth in Siberia being covered with hair. We have living examples of animals in warm latitudes which are not less abundantly covered with hair and wool in proportion to their size than the elephant at the mouth of the Lena. Such is the hyæna villosa lately noticed at the cape by Dr. Smith, and described[4] as having the hair on the neck and body very long and shaggy, measuring in many places, but particularly about the sides and back, at least six inches; again, the thick shaggy covering on the anterior part on the body of the male lion, and the hairy coat of the camel (both of them inhabitants of the warmest climates), present analogies which show that no conclusive argument in proof that the Siberian elephant was the inhabitant of a cold climate can be drawn from the fact of the skin of the frozen carcass at the mouth of the Lena having been covered with coarse hair and wool; but even if it were proved that the climate of the arctic regions was the same both before and after the extirpation of these animals, still must we refer to some great catastrophe to account for the fact of their universal extirpation, and from those who deny the occurrence of such catastrophe, it may fairly be demanded why these extinct animals have not continued to live on to the present hour. It is vain to contend that they have been subdued and extirpated by man, since whatever may be conceded as possible with respect to Europe, it is in the highest degree improbable that he could have exercised such influence over the vast wilderness of northern Asia, and almost impossible that he could have done so in the boundless forests of North America. The analogy of the non-

[4] Vol. XV, Plate 2, page 463, Linn. Trans.

extirpation of the elephant and the rhinoceros on the continent and islands of India, where man has long been at least as far advanced in civilization, and much more populous than he can ever have been in the frozen wilds of Siberia, shows that he does not extirpate the living species of these genera in places where they are his fellow-tenants of the present surface of the earth. The same non-extirpation of the elephant and rhinoceros occurs also in the less civilized regions of Africa; still further, it may be contended, that if man had invaded the territories of the mammoth and its associates until he became the instrument of their extirpation, we should have found, ere now, some of the usual indications which man, even in his wildest state, must leave behind him; some few traces of savage utensils, arrows, knives, and other instruments of stone and bone, and the rudest pottery; or, at all events, some bones of man himself would, ere this, have been discovered amongst the numberless remains of the lost species which he had extirpated. It follows, therefore, from the absence of human bones and of works of art in the same deposits with the remains of mammoths, that man did not exist in these northern regions of the earth at or before the time in which the [p. 611] mammoths were destroyed; and the enormous accumulation of the wreck of mountains that has been mixed up with their remains points to some great aqueous revolution as the cause by which their sudden and total extirpation was effected. It cannot be contended, that like small and feeble species, they may have been destroyed by wild animals more powerful than themselves. The bulk and strength of the mammoth and rhinoceros, the two largest quadrupeds in the creation, render such an hypothesis utterly untenable.

"The state of the argument then respecting the former climate of the polar regions is nearly as follows: It is probable that in remote periods, when the earliest strata were deposited, the temperature of a great part of the northern hemisphere equalled or exceeded that of our modern tropics, and that it has been reduced to its present state by a series of successive changes. The evidence of this high temperature and of these changes consists in the regular and successive variations in the character of extinct plants and animals which we find buried one above another in the successive strata that compose the crust of the globe. These have in modern times been investigated with sufficient care and knowledge of the subject to render it almost certain that successive changes, from extreme to moderate heat, have taken place in those parts of the northern hemisphere which constitute central and southern Europe;

and although we are not yet enough acquainted with the details of the geology of the arctic regions to apply this argument to them with the same precision and to the same extent as to lower latitudes, still we have detached examples of organic remains in high latitudes sufficient to show the former existence of heat in the regions where they are found—a few detached spots within the Arctic Circle that can be shown to have been once the site of extensive coral reefs are as decisive in proof that the climate in these spots was warm at the time when these corals lived and grew into a reef, as, on the other hand, the carcass of a single elephant preserved in ice is decisive of the existence of continual and intense cold ever since the period at which it perished. We have for some time known that in and near Melville Island, and it has been ascertained by Captain Beechey's expedition, that at Cape Thompson, near Beering's Strait, there occur within the Arctic Circle extensive rocks of limestone containing many of the same fossil shells and fossil corals that abound in the carboniferous limestone of Derbyshire: the remains of fossil marine turtles also (chelonia radiata) have been ascertained by Professor Fischer to exist in Siberia. These are enough to show that the climate could not have been cold at the time and place when they were deposited; and the analogy of adjacent European latitudes renders it probable that the same cooling processes that were going on in them extended their influence to the polar regions also, producing successive reductions of temperature, accompanied by corresponding changes in the animal [p. 612] and vegetable creation, until the period arrived in which the elephant and rhinoceros inhabited nearly the entire surface of what are now the temperate and frigid zones of the northern hemisphere.

"Assuming then on such evidence as I have alluded to, the former high temperature of the Arctic Circle, and knowing from the investment in ice and preservation of the carcass of the mammoth, that this region was intensely cold at the time immediately succeeding its death, and has so continued to the present hour; the point on which we are most in want of decisive evidence is the temperature of the climate in which the mammoth lived. It is a violation of existing analogies to suppose that any extinct elephant or rhinoceros was more tolerant of cold than extinct corallines or turtles; and as this northern region of the earth seems to have undergone successive changes from heat to cold, so it is probable that the last of these changes was coincident with the extirpation of the mammoth. That this last change was sudden is shown by

the preservation of the carcass in ice: had it been gradual, it might have caused the extinction of the mammoth in the polar regions, but would afford no reason for its equal extirpation in lower latitudes; but if sudden and violent, and attended by a general inundation, the temperature preceding this catastrophe may have been warm, and that immediately succeeding it intensely cold; and the cause producing this change of climate may also have produced an inundation, sufficient to destroy and bury in its ruins the animals which then inhabited the surface of the earth."

[ZOOLOGY OF CAPTAIN BEECHEY'S VOYAGE TO THE PACIFIC AND BEERING'S STRAIT. London, 1839. Geology by Buckland from the notes of Lieutenant Belcher and Mr. Collie, pp. 159-180. Plate I is a plan of Eschscholtz Bay showing the various geological formations in colors, by Lieutenant Belcher.]

Kotzebue Sound [p. 169].—"The bounding shores of Kotzebue Sound for the most part rise by perpendicular cliffs, either directly from the waters or from a shelving beach. In some places the land is remarkably low, and only so much raised as to render the idea probable, that it is an alluvial formation, the result of the accumulated mud and sand brought down by large rivers and thrown up by the sea. The cliffs are in part abrupt and rocky; others are made up of falling masses of mud, sand, and ice. The first, or rocky cliffs, predominate to the southward of a line drawn from the northwest side of Eschscholtz Bay to the southeastern part of the Bay of Good Hope. The second, or diluvial cliffs, complete the remaining northeast side of the sound, and take in part of the south side of Eschscholtz Bay. Low grounds chiefly border the Bay of Good Hope, and form the land of and around Cape Espenberg. The history of these mud cliffs, and of the remarkable organic remains contained in them, has been given in vol. 1, Appendix [p. 173]. Cape Beaufort, viz., about 300 feet above the level of the sea. This cape seems to constitute a boundary between the hilly ranges above described to the southwest, and the low plains, intersected with lagoons and lakes, which extend to the northeast of it as far as the eye can reach [p. 174]. These plains are the commencement of a country of diluvial formation, that extends from Cape Beaufort to Icy Cape, Reindeer Station, and Wainwright Inlet. Beyond that Mr. Elson has described the coast and country to be a continuation of the same formations, and at Cape Smyth, near his extreme point, in lat. 71° 13′ N., long. 156° 45′ W., he observed icy cliffs presenting their fronts under the like circumstances as at Cape Blossom and in Eschscholtz Bay."

[NARRATIVE OF THE VOYAGE OF THE H. M. S. HERALD DURING THE YEARS 1845-51, UNDER CAPTAIN HENRY KELLETT, R. N. By Berthold Seemann. In two volumes. London, 1853. Vol. II, p. 33. The Ice-cliffs of Eschscholtz Bay—Their Formation and Fossil Remains—Sir John Richardson's views on them.]

"The ice-cliffs[5] of Eschscholtz Bay, in Kotzebue Sound, well deserve attention. They extend along the southern side of the bay, east and west, from Elephant Point to Eschscholtz Point; they are from forty to ninety feet high, and consist of three distinct layers. The lower layer is ice, the central clay, containing fossils, and the uppermost peat. Partly from the action of the waves, partly the thawing of the ice, that side of the cliffs facing the sea is cut perpendicularly, and presents a clear view of the internal structure of the formation.

"The ice, or lower layer, as far as it can be seen above the ground, is from twenty to fifty feet thick, but is every year decreasing. In the months of July, August, and September a considerable quantity melts, which causes the downfall of the two upper layers, and gives [p. 34] the whole a very confused aspect, by mixing together peat, clay, plants, bones, and ice in a most disorderly manner. The ice was thought by some of the earlier visitors to be only a superficial coating; but this supposition was disproved in 1849, when enormous portions were found to have separated from the main body, testifying beyond a doubt that it formed part of a solid iceberg. Others, who comprehended the real nature of this lower layer, endeavored to explain its presence by assuming that the water of the surface penetrated through the peat and clay, gradually accumulated, changed into a mass of ice, and thus caused the rising of the cliffs. This hypothesis at first sight appears plausible, but if examined it falls to the ground. In temperate climates we often find moorlands rising, like a sponge, in consequence of the mass of water which has accumulated in them; in Kotzebue Sound, however, where the soil is always frozen at a depth of two or three feet from the surface, no water can possibly sink to the depth of several fathoms, and consequently no rising can take place.

"The second or central layer varies in thickness from two to twenty feet, and consists of alluvial clay intermingled with gravel, sand, and fossil bones, the whole emitting the peculiar smell common in burial-places. In one spot was found some long black hair, together with a quantity of light brown dust, evidently decomposed

[5] For a view of these cliffs see Plate I of the "Botany of the Voyage of H. M. S. Herald."

animal matter. The fossils are sometimes of great size. In 1848 we collected eight tusks of the antediluvian elephant, the largest of which, though broken at the point, was eleven feet six inches long, one foot nine [p. 35] inches in circumference at the base, and weighed 243 lbs. Molar teeth, thigh-bones, ribs, and other fragments of this gigantic animal, and a great number of horse and deer bones, were disinterred. The species found in these cliffs are the mammoth (*Elephas primigenius*), the fossil horse (*Equus fossilis*), the moose-deer (*Cervus Alces*), the rein-deer (*Cervus Tarandus*), fossil musk-ox (*Ovibos moschatus*), *Ovibos maximus*, fossil bison (*Bison priscus ?*), the heavy-horned fossil bison (*Bison crassicornis*), and the big-horn (*Ovis montana*).

"The uppermost layer, or surface, is from two to five feet thick. consisting of peat, entirely destitute of fossils. It bears the kind of vegetation to which it owes its existence—plants peculiar to moorlands. Among them many mosses, lichens, sedges, and several *Ericaceæ* and willows may be recognized, the occurrence of which demonstrates the possibility of the growth of plants in a soil frozen beneath, a fact formerly much disputed.

"As the ice could not have been formed by water percolating through the clay and afterwards becoming frozen, it is natural to conclude that it was in its present site previous to the arrival of the clay. This conclusion is strengthened by the evidence afforded by the clay itself, for the fossils are solely confined to that layer. If these were indiscriminately distributed, we might be led to suppose that the whole had undergone the same revolution; such not being the case, we are forced to believe that the clay with its fossils arrived after the ice had been firmly established, and, as these fossils belong to the antediluvian period, the ice must be very old.

"Dr. Richardson, with that accuracy for which he [p. 36] is so distinguished, has in the 'Zoology of the Voyage of H. M. S. Herald' described the bones collected by us, and prefaced his description by the following philosophical observations:

[THE ZOOLOGY OF THE VOYAGE OF H. M. S. HERALD, UNDER CAPTAIN HENRY KELLETT, DURING THE YEARS OF 1845-51. Fossil mammals. By Sir John Richardson. Printed in 1852, but not published until 1854. Observations on the Fossil Bone Deposit in Eschscholtz Bay, pp. 1-8.]

"The science of chemistry, as at present taught, justifies our belief that animal substances, when solidly frozen and kept steadily in a temperature below the freezing point, do not undergo putrefaction, and may be preserved without change for any conceivable

length of time. The depth to which, in northern countries, the summer thaw penetrates, varies with the nature of the soil, but, except in purely sandy and very porous beds, it nowhere exceeds two feet in American or Siberian lands lying within the Arctic Circle. The influence of the sun's rays is not perceptible at this depth until towards the close of summer, which occurs at a varying period of from five to ten weeks from the time that the surface of the earth was denuded of snow by the spring thaw. During the rest of the year, even in the forest lands, though not so long there as in the open barren grounds, or *tundras,* the soil is firmly and continuously bound up in frost. The thickness of the permanently frozen substratum is more or less influenced by its mineral structure, but is primarily dependent on the mean annual temperature of the air acting antagonistically to the interior heat of the earth. Unless the mean heat of the year in any given locality falls short of the freezing-point, there exists no perennial frozen substratum in that place. It is not necessary that we should here endeavor to trace the isothermal line of 32° Farh., as the reader may obtain a correct idea of its general course by consulting Baer's charts. It will suffice to say, that on the continent of America it passes some degrees to the southward of the sixtieth parallel of north latitude, and that while it undulates with the varying elevation of the interior, it has a general rise northwards in its course westerly.

"Where the permanently frozen subsoil exists it is a perfect ice-cellar, and preserves from destruction the bodies of animals completely enclosed in it. By its intervention entire carcasses of the extinct mammoth and tichorhine rhinoceros have been handed down in arctic Siberia from the drift period to our times, and, being exposed by land-slips, have revealed most interesting glimpses of the fauna of that remote epoch. Conjecture fails in assigning a chronological date to the time when the drift and bowlders were spread extensively over the northern hemisphere: the calculations that have been made of the ages occupied in the formation of subsequent alluvial deposits are founded on imperfect data; and we merely judge from the absence of works of art and of human bones, that the drift era must have been antecedent to the appearance of man upon earth, or at least to his multiplication within the geographical limits of the drift. Whatever may be our speculations concerning the mode in which the carcasses in question were enclosed in frozen gravel or mud, their preservation to present time in a fresh condition indicates that the climate was a rigorous one at the epoch of their entombment and has continued so ever since. Moreover, as

large carcasses could not, without decomposition, be conveyed from a distance by water, it is fair to conclude that the animals lived in the districts in which they are now found, or in their immediate neighborhood, and not, as some have supposed, in warmer and more distant regions.

"It seems also to us to be impossible that ice could have been the vehicle by which whole bodies or complete skeletons could have been brought from warmer parallels and deposited in the vast cemeteries of polar Siberia or in Eschscholtz Bay, for the simple reason that ice is not the product of these warmer countries. Nor does the difficulty seem less of explaining how such a group of pachyderms and ruminants could have been brought down by travelling glaciers from warmer southern valleys of mountain ranges no longer in existence, without admitting such extensive changes in the surface level of the district, as would confound all our ideas of the distribution of the drift, as we at present find it.

"It is easier to imagine that the animals whose osseous remains now engage our attention ranged while living on the shores of an icy sea, and that by some sudden deluge, or vast wave or succession of waves, they were swept from their pasture grounds. It is not necessary that we should here discuss the extent of this deluge, or inquire whether it covered simultaneously the north of Europe, Asia, and America; or operated by a succession of great waves or more local inundations. What more immediately concerns our subject is, to know that in the drift containing marine shells of existing species, and boulders borne far from their parent cliffs, we have evidence of diluvial action extending from the ultima Thule of the American polar sea to far southwards in the valley of the Mississippi.

"The identification of the fossil mammoth and rhinoceros of England and Europe with those of Siberia by the first of living comparative anatomists, might lead us to conclude that the same fauna inhabited the northern parts of the new and old world; but I think that we shall find evidence in the bones of bovine animals brought from Eschscholtz Bay, that an American type of ruminants was perceptible even in that early age.

"At the present time the moose-deer and mountain sheep inhabit districts of America suited to their habits up to the most northern limits of the continent; while the musk-ox and reindeer go beyond its shores to distant islands; and the arctic hare is a perennial resident of the most northern of these islands that have been visited, or up to the seventy-sixth parallel. Supposing the climate of North America, at a time just antecedent to the drift period, to have been

similar or nearly so to that which now exists, the habits and ranges of the ferine animals at the two dates, though the species differ, may have had a close analogy. The mammoth and other beasts that browsed on the twigs of willows or larger trees may have ranged as far north, at least in summer, as the moose-deer does now, or up to the seventieth parallel; and lichenivorous or herbivorous ruminants may have extended their spring migrations still further north: these journeys in quest of seclusion and more agreeable food being quite compatible with the co-existence of vast wandering herds of the same species in more southern lands, reaching even beyond the limits over which the drift has been traced, and where the final extinction of the entire race may be owing to causes operating in comparatively recent periods [p. 3].

"The St. Petersburg Transactions, and other works contain accounts of the circumstances attending the discovery of the entire carcases of a rhinoceros and of two mammoths in arctic Siberia; and one cannot avoid regretting that they were beyond the reach of competent naturalists, who might, by examining the contents of the stomach, the feet, external coverings, and other important parts, have revealed to us much of the habits of these ancient animals and of the nature of the country in which they lived. The inexhaustible deposits of organic remains in the Kotelnoi or New Siberian Archipelago lying off the Sviatoi Noss, may yet disclose some equally perfect carcases; and their exploration by a scientific expedition is a project that promises a rich return for the labour and expense of such an undertaking.

"In arctic America such remains have been discovered in a north-eastern corner alone, and as yet, bones, horns, and hair only have been obtained, without any fresh muscular fiber; but all the collectors describe the soil from which they were dug as exhaling a strong and disagreeable odour of decomposing animal matter, resembling that of a well-filled cemetery. In August, 1816, Kotzebue, Chamisso, and Eschscholtz discovered, in the bay which now bears the name of the last mentioned naturalist, some remarkable cliffs, situated a short way southwards of the Arctic Circle, and abounding, in the bones of mammoth, horses, oxen, and deer. The cliffs were described by their discoverers as pure icebergs one hundred feet high, and covered with soil on which ordinary arctic vegetation flourished. These novel circumstances excited strongly the attention of the scientific world; and when Captain Beechey and his accomplished surgeon Collie, ten years later, visited the same place, their best efforts were made to ascertain the true nature of the phenomenon. Dr. Buckland drew

up an account of the fossil remains then procured with illustrative plates, and Captain Beechey published a plan of the locality.[6]

"This plan comprises a nearly square section of country, having a width and length of about fourteen miles. The Buckland River, where it bends to the northward to fall into Eschscholtz Bay, flanks the district on its inland or eastern border. From the mouth of this river the coast-line trends nearly due west to Eschscholtz Bluff, and forms the south side of that bay; the shore for one-half of the way, or about seven miles, between the Bluff and Elephant Point, being composed of high icy cliffs, and for the remainder of the distance, or from Elephant Point to the river, the coast is low and slightly incurved. The west face of the land fronts Kotzebue Sound and is formed of slaty gneiss rocks, which terminate on the north at Eschscholtz Bluff, and ten or twelve miles to the southward the rocky eminences, taking an inland direction, are flanked by low marshy ground. A ridge of hills runs nearly parallel to the western shore at a distance of a mile and a quarter; and at their southern angle, where they bend inland, there stands still nearer the coast-line one of the loftiest bluffs, ascertained to be 640 feet high. From this corner the course of the range is south-easterly, the swampy country above mentioned running along its base. The banks of the Buckland are also represented as being high, if not hilly [p. 4], and they enclose, in conjunction with the range, a sloping valley or basin, drained by numerous rivulets, and opening to the north on the low coast eastward of Elephant Point. At the western entrance of the Buckland there is a minor display of frozen mud-cliffs; similar deposits exist also on its eastern bank as well as on the north shore of Eschscholtz Bay, likewise on various points of the coast between Bering's Strait and Point Barrow; but fossils have been detected only in Eschscholtz Bay, and on the banks of a few rivers that join Bering's Sea between it and Mount St. Elias.

[Richardson here gives extracts from the Narrative of Captain Beechey's voyage which I quote on a previous page and do not repeat here. Commenting upon the holes dug by Mr. Collie, three feet and five yards back from the edge of the cliff in which frozen earth was found at eleven and twenty inches depth, Richardson says in a footnote:] "Had the pits been sunk at a distance from the edge of the cliff to the depth of three or four yards, information of a more decided character would have been obtained; for the experiments do not of themselves prove satisfactorily that the frozen mud

[6] Zoology of Captain Beechey's Voyage, 1839.

which was reached so early in the summer as the end of July, at the depth of twenty-two inches, was not merely an unthawed layer of the superficial soil, reposing on pure ice at some distance below [p. 5].[7]

"The above description of these remarkable cliffs has been quoted at length, as it is not only perfectly clear but also concise. The opinions of Captain Beechey and his officers respecting the origin of the ice-cliffs are discussed at considerable length in Dr. Buckland's paper, printed as an appendix to the Narrative of the Voyage.

"After an interval of twenty-four years, the recent voyage of the 'Herald' to this interesting spot has given a third opportunity of collecting fossil bones and examining the structure of these now far-famed cliffs. Captain Kellett, Berthold Seemann, Esq., and Dr. Goodridge, with the works of Kotzebue and Beechey in their hands, and an earnest desire to ascertain which of the conflicting opinions enunciated by these officers was most consistent with the facts, came to the conclusion, after a rigid investigation of the cliffs, that Kotzebue was correct in considering them to be icebergs. I have been favored with papers on the subject from each of the Herald's officers named above, and shall quote as fully from them as my limits allow, after premising a few general observations on the frozen cliffs of other parts of the arctic coast that have come under my personal observation.

"At Cape Maitland in Liverpool Bay, which forms the estuary of the Beghula River, and lies near the seventieth parallel, there are precipitous cliffs from eighty to one hundred feet high, composed of layers of black clay or loam enclosing many small waterworn pebbles and a few large boulders, with the exception of about eighteen inches of soil on the summit, which thaw as the summer advances, these cliffs present to the sea a constantly frozen wall, that crumbles annually [p. 6] under the action of the rays of a summer sun, but the fragments being carried away by the waves and prevented from accumulating, the perpendicular form of the cliff is preserved. Elsewhere on the coast cliffs equally vertical, but having a different exposure, were seen masked by a talus of snow, over which a coating of soil had been thrown by land-floods of melting snow pouring down from the inland slopes. The duration of these glacier-like snow-banks varies with circumstances. When the cliffs rise out of deep water, the ice on which the *talus* rests is broken up almost every summer, and the superincumbent mass, previously

[7] Richardson's comments on Beechey in a foot note.

consolidated by the percolation and freezing of water, floats away in form of an iceberg. In other situations the snow-cliffs remain for a series of years, with occasional augmentation marked by corresponding dirt-bands, and disappear only towards the close of a cycle of warm summers. In valleys having a northern exposure and sheltered by high hills from the sun's rays, the age of the snow may be considerable; but it is proper to say that though aged glaciers of this description do exist on the shores of Spitzbergen and Greenland, they are of very rare occurrence indeed on the continental coast of America. The ice-cliff of Eschscholtz Bay may have had an origin similar to that of the Greenland icebergs, and have been coated with soil by a single or by successive operations. I find it difficult, however, to account for the introduction of the fossil remains in such quantity, and can offer to the reader no conjecture on that point that is satisfactory even to myself. The excellent state of preservation of many of the bones, the recent decay of animal matter shown by the existing odor, quantities of hair found in contact with a mammoth's skull, the occurrence of the outer sheaths of bison horns, and the finding of vertebræ of bovine animals lying in their proper order of sequence, render it probable that entire carcases were there deposited and that congealation followed close upon their entombment. A gradual improvement of climate in modern times would appear to be necessary to account for the decay of the cliffs now in progress and the exposure of the bones. The shallowness of the water in Eschscholtz Bay, its narrowness, and its shelter from seaward pressure by Choris Peninsula and Chamisso Island, preclude the notion of icebergs coming with their cargoes from a distance having been forced up on the beach at that place. Neither is it more likely that the bones and diluvial matters were deposited in the estuary of Buckland's River and subsequently elevated by one of the earth waves by which geologists solve many of their difficulties, for ice could not subsist long as a flooring of warmer water. In short, further observations are still needed to form the foundations of a plausible theory.

"Dr. Goodridge describes the several cliffs in succession with much detail, beginning with that next Elephant Point and proceeding to the westward. His paper, though interesting throughout, is too long for transcription entire, and I shall therefore merely abstract the most material parts. He commences by stating that the unusually mild season had produced great landslides and exposed the structure of the several eminences forming the cliffs more extensively than in the year in which Captain Beechey visited them. Elephant

Point, forming a high promontory in 1826, had now subsided to a mere hillock by the thawing of the icy substratum, as Kotzebue predicted would happen. A pit was dug to some depth in the loose loamy soil of this hillock, formed by the debris of the ruined cliff, at a point where the thighbone of a mammoth protruded above the surface, without any ice being found; but on the east of the hill next in succession, a wedge-shaped landslip had left a triangular chasm, whose floor, elevated twenty feet above the beach, was bounded by walls fifty feet high, of pure transparent ice, and its interior angle, reaching thirty feet backwards from the face of the cliff, exhibited an alluvium seemingly undisturbed since it was originally deposited, and consisting of regular layers of 'drift' and peat covered with thick beds of broken sticks and vegetable matter, over which lay a stratum of red river-gravel, then a bed of argillaceous earth, capped by dry friable mould [p. 7] and surface peat, nourishing its peculiar vegetation of coarse grass, moss, lichens, etc. The icy side walls showed bands or layers considerably inclined, and testifying to their origin in drift snow; and the size of the sticks imbedded in the back walls of the chasm was greater than that of the stems of any of the bushes now growing in the neighboring ravines. It is to be recollected, however, that a short way up Buckland River, groves of spruce-fir are to be met with. A rivulet separates this hill from Elephant Point, and Dr. Goodridge found some of its slopes to be formed of semi-fluid mud, over which a man could not pass. On the *second* hill or cliff the depth of the soil varied with the unevenness of the ice on which it rested, from twenty feet to less than four, the soil being everywhere dry. On digging in one spot to the latter depth the surface of the ice was found to incline upwards in the direction of the hill, and the soil thrown out by the spade was so pulverulent that it was readily blown away by the wind. The *third* hill, which projected more boldly than the others, contained as far as explored, neither fossils nor ice, but seemed to be entirely composed of thick beds of peat, *logs* of wood, sticks, and vegetable matter, lying generally, but not regularly, in a horizontal position, resting on dry clay, and a bed of river gravel two feet thick. The *fourth* hill presented a *higher* and more extensive ice-cliff than any of the others, the ice having melted further back towards the center of the hill, and forming an even wall upwards of eighty feet in height. The *fifth* cliff or marked projection, in proceeding to the eastwards, appeared to have sunk bodily from the hill, forming its background, but had left behind it a few icy pillars and detached walls standing twenty feet above the surrounding level surface, and

still covered with from seven to ten feet of soil. Water was flowing copiously from these walls of ice, and they were transparent, without admixture of earth, while the soil which capped them was dry and friable. In the slope of this ruined cliff most of the fossils obtained on this occasion were found, a few small fragments only having been gathered from the soft mud at its foot. Some were collected from the surface of the slope, others were dug out at places where the tips of the tusks protruded through the soil.

"A deep valley through which a stream of water flows divides the *sixth* hill from the preceding one. Portions of this hill had subsided from the melting of the icy foundation, but in one part a solitary block of ice about twenty feet square rose above the surface, retaining a thin layer of soil on its summit. From the vicinity of this block the hill rose abruptly on all sides; its declivity descended without break to the beach, and its soil, except in the section that had sunk, did not appear to have been ever disturbed. The beach at this place was not composed of muddy detritus, like that which skirted the bases of the other cliffs. A mammoth tusk, having been noticed protruding above the surface of the hill, was traced downwards by digging to the depth of eight feet, and the skull with a quantity of hair and wool were found lying on a thin bed of gravel, beneath which was solid transparent ice. Enveloping the bones there was a bed of stiff clay several feet in thickness, and mixed with them a small quantity of sticks and vegetable matter. The superficial soil was loose and dry. A strong, pungent, unpleasant odor, like that of a newly opened grave in one of the crowded burial places of London, was felt on digging out the bones, and the same kind of smell, in a less degree, was perceptible in various other places where the cliffs had fallen. From the same pit out of which the mammoth's skull was dug the bones of some smaller animals (scapula, tibia, etc.) were taken and were duly labelled at the time, but in the course of their transfer from one public department to another, after reaching London, the labels have been lost, together with the specimens of the buried wood, gravel, and other matters found associated with the bones. Dr. Goodridge says that this eminence was the last examined, the approach of night having prevented the party from exploring another [p. 8] hill lying between it and Eschscholtz Bluff. That hill, however, was covered with luxuriant vegetation and no icy cliffs showed themselves.

"'On Choris Peninsula,' says the same gentleman, 'frozen soil was found at the depth of four feet at the end of September, after an unusually warm summer, and a cask full of flour deposited by

Captain Beechey in 1826, on Chamisso Island, was perfectly sound and fit for food when disinterred in 1848. It was disengaged with much difficulty from the frozen subsoil, and even the iron hoops of the cask were not rusted.' Dr. Goodridge appends to his paper some remarks on the annual waste of the ice-cliffs, and says that the bay is gradually filling up with the clay and soil which are precipitated into the sea on the melting of the ice on which they are reposed.

"Mr. Seemann reports the heads of porpoises and antlers of reindeer were found on the beach, having been deposited there by the natives.

"Captain Kellett, in answer to some queries I addressed to him, informed me that the ice-cliffs were in many places as much as sixty feet high, and of pure ice. He did not think that the ice extended inland as far as the range of hills, though on digging at a distance of a quarter of a mile from the edge of the cliff he found pure ice under a covering of between three or four feet of soil. In no instance were the fossils imbedded in the ice, but they generally lay on its surface, the large tusks showing through the soil. Many were gathered from the mud at the base of the cliffs, where they were exposed to the wash of the tide. In digging within the Arctic Circle to erect marks he always found the soil frozen at a depth of two feet.—Such are the chief particulars that I collected from the three officers quoted above. The naturalist who wishes to study the subject more deeply will find several opinions discussed in Dr. Buckland's Appendix to Captain Beechey's Voyage, as already mentioned."

[REPORT OF THE CRUISE OF THE U. S. REVENUE STEAMER CORWIN IN THE ARCTIC OCEAN IN 1880. By Captain C. L. Hooper. Published in 1881, by Treasury Department.]

"Glacial Formations and Fossils at Elephant Point

"On the 16th (July, 1880), I visited Elephant Point, about fifteen miles distant, on Eschscholtz Bay, near the mouth of the Buckland River. This place is remarkable for a singular ice formation, which Kotzebue described as 'a glacier covered with soil six inches thick, producing the most luxuriant grass, and containing abundance of mammoth bones.' Captain Beechey, of the Royal Navy, while cruising in the Arctic in 1826-27, claims to have fully established the fact that Kotzebue was mistaken; that what he called a 'glacier' was occasioned either by the water from the thawing ice and snow trickling down the surface of the earthy cliff

from above, or by the snow being banked up against the cliff in winter, and afterwards converted into ice by alternate thawing and freezing, producing the appearance which deceived the Russians.

"The cliffs in which this singular formation is found begin half a mile from the eastern extremity of Elephant Point and extend westward, nearly in a direct line, about five miles. They are from forty to one hundred and fifty feet in height, and rise inland to rounded hills from two hundred to three hundred feet high.

"The eastern part, where the ice formation is found, is nearly perpendicular for about one mile; from thence to the western extremity, it is slightly inclined and intersected by small valleys and streams of water.

"I examined the ice, and, although not fully convinced that Beechey has given the true explanation of it, I do not think it is a glacial formation. In several places where water has run down over the face of the cliff, in small streams, from the melting snow above, I found holes melted at least thirty feet deep, showing solid walls of clear ice.

"I also ascended the cliff and dug down from the top in several places, and always came to solid ice, after digging through frozen earth for a few feet. I searched the face of the cliff for fossil remains, but found none, either in the ice or in the soil above it. I was more fortunate, however, on the beach below, after the tide fell. There I found a large number of mammoth bones and tusks, and some smaller bones belonging probably to the 'Aurock' (Bison) and musk-ox."

[EXTRACT FROM A REPORT TO C. P. PATTERSON, SUPT. COAST AND GEODETIC SURVEY. By W. H. Dall, Assistant in charge of schooner "Yukon," employed on the coast of Alaska. American Journal of Science, 1881, Vol. 21, p. 106.]

"On the 2d of September (1880), the weather being unsuitable for observations, I took the large boat and crew and crossed the bay toward Elephant Point, the site of the extraordinary ice formation, first observed by Kotzebue and afterward reported on by Beechey and Seemann.

"We landed on a small, low point near some old huts, and proceeded along the beach about a mile, the banks being chiefly composed of volcanic breccia or a slaty gneissoid rock. They rose fifteen to fifty feet in height above the sea, rising inland to hilly slopes, without peaks and probably not attaining more than three or four hundred feet anywhere in the vicinity.

"As we passed eastward along the beach, a change took place

in the character of the banks. They became lower and the rise inland was less. From reddish volcanic rock they changed to a grayish clay, containing much vegetable matter, which, in some places, was in strata in the clay, and in others indiscriminately mixed with it. Near the beginning of these clay banks, where they were quite low, not rising over twenty feet above the shore, we noticed one layer of sphagnum (bog moss) containing marl of fresh-water shells, belonging to the genera Pisidium, Valvata, etc. This layer was about six inches thick. The clay was of a very tough consistency, and, though wet, did not stick to or yield much under the feet. The sea breaks against the foot of these banks and undermines them, causing them to fall down, and the rough, irregular talus that results is mingled with turf and bushes from the surface above. A little farther on a perpendicular surface of ice was noticed in the face of the bank. It appeared to be solid and free from mixture of soil, except on the outside. The banks continued to increase slowly but regularly in height as we passed eastward. A little farther on another ice-face presented itself on a larger scale. This continues about two miles and a half to Elephant Point, where the high land turns abruptly to the south and west, and we followed it no farther. The point itself is boggy and low, and is continued from the foot of the high land, perhaps half a mile to the eastward, forming the northwest headland to a shallow bay of considerable extent.

"To return to the 'cliffs': these for a considerable distance were double; that is, there was an ice-face exposed near the beach with a small talus in front of it, and covered with a coating of soil two or three feet thick, on which luxuriant vegetation was growing. All this might be thirty feet in height. On climbing to the brow of this bank, the rise from that brow proved to be broken, hummocky and full of crevices and holes; in fact, a second talus on a larger scale, ascending to the foot of a second ice-face, above which was a layer of soil one to three feet thick covered with herbage.

"The brow of this second bluff we estimated at eighty feet or more above the sea. Thence the land rose slowly and gradually to a rounded ridge, reaching the height of three or four hundred feet only, at a distance of several miles from the sea, with its axis in a north-and-south direction, a low valley west from it, the shallow bay at Elephant Point east from it, and its northern end abutting in the cliffs above described on the southern shore of Eschscholtz Bay. There were no mountains or other high land about this ridge in any direction, all the surface around was lower than the ridge itself.

"About half a mile from the sea, on the highest part of the ridge, perhaps two hundred and fifty feet above high-water mark, at a depth of a foot, we came to a solidly frozen stratum, consisting chiefly of bog moss and vegetable mould, but containing good-sized lumps of clear ice. There seemed no reason to doubt that an extension of the digging would have brought us to solid, clear ice, such as was visible at the face of the bluff below. That is to say, it appeared that the ridge itself, two miles wide and two hundred and fifty feet high, was chiefly composed of solid ice overlaid with clay and vegetable mould. It was noticeable that there was much less clay over the top of the upper ice-face than was visible over the lower one, or over the single face when there was but one and the land and bluff were low near the beach. There also seemed to be less vegetable matter. Near the beach six or eight feet of clay were observed in some places, without counting what might be considered as talus matter from further up the hillside. In one place only did we notice a little fine, reddish gravel, and nowhere in the talus or strata any stones.

"The ice-face near the beach was not uniform. In many places it was covered with clay to the water's edge. In others, where the bank was less than ten feet high, the turf had bent without breaking after being undermined, and presented a mossy and herbaceous front, curving over quite to high-water mark.

"The ice in general had a semi-stratified appearance, as if it still retained the horizontal plane in which it originally congealed. The surface was always soiled by dirty water from the earth above. This dirt was, however, merely superficial. The outer inch or two of the ice seemed granular, like compacted hail, and was sometimes whitish. The inside was solid and transparent, or slightly yellow-tinged, like peat water, but never greenish or bluish like glacier ice. But in many places the ice presented the aspect of immense cakes or fragments, irregularly disposed, over which it appeared as if the clay, etc., had been deposited. Small pinnacles of ice ran up into the clay in some places, and, above, holes were seen in the face of the clay-bank, where it looked as if a detached fragment of ice had been and had been melted out, leaving its mold in the clay quite perfect.

"In other places the ice was penetrated with deep holes, into which the clay and vegetable matter had been deposited in layers, and which (the ice melting away from around them) appeared as clay and muck cylinders on the ice-face. Large rounded holes or excavations of irregular form had evidently existed on the top of

the ice before the clay, etc., had been deposited. These were usually filled with a finer-grained deposit of clay with less vegetable matter, and the layers were waved, as if the deposit had been affected by current action while going on.

"In these places was noticed, especially, the most unexpected fact connected with the whole formation, namely, a strong peculiar smell, as of rotting animal matter, burnt leather, and stable manure combined. This odor was not confined to the spots above mentioned, and was not quite the same at all places, but had the same general character wherever it was noticed. A large part of the clay had no particular smell. At the places where the odor was strongest, it was observed to emanate particularly from darker, pasty spots in the clay (though permeating elsewhere), leading to the supposition that these might be remains of the soft parts of the mammoth and other animals, whose bones are daily washed out by the sea from the clay talus.

"At or near these spots, where the odor was strongest, a rusty, red lichen, or lichen-like fungus, grew on the wet clay of the talus in extensive patches. Some of these, of the bad smelling deposit, and as many bones of the mammoth, fossil buffalo, etc., as we could carry were secured. These included a mammoth tusk, with both ends gone, but still five and a half feet long and six inches in diameter, which I shall forward to the office. Dwarf birches, alders, seven or eight feet high, with stems three inches in diameter, and a luxuriant growth of herbage, including numerous very toothsome berries, grew with the roots less than a foot from perpetual solid ice.

"The formation of the surrounding country shows no high land or rocky hills, from which a glacier might have been derived and then covered with debris from their sides. The continuity of the mossy surface showed that the ice must be quite destitute of motion, and the circumstances appeared to point to one conclusion, that there is here a ridge of solid ice, rising several hundred feet above the sea, and higher than any of the land about it, and older than the mammoth and fossil horse; this ice taking upon itself the functions of a regular stratified rock. The formation, though visited before, has not hitherto been intelligibly described from a geological standpoint. Though many facts may remain to be investigated, and whatever be the conclusions as to its origin and mode of preservation, it certainly remains one of the most wonderful and puzzling geological phenomena in existence.

"On the 3d of September we sailed from Chamisso Harbor for Bering Strait. * * *"

The above account has been reprinted by Mr. Dall in the following: Bulletin of the U. S. Geol. Survey No. 84, 1892, pp. 261-263, pl. III.

"Respecting the strong, peculiar odor it is remarked in a footnote on page 262. 'This phenomenon was observed by Kotzebue, Beechey, and the Herald party, and lends further probability to the view that the animals were mired in the clay and thus met their death. Since, if the clay contained merely the accumulated bones of animals which had died and decayed on the surface of the ground, it is unlikely that so much animal matter would have been hermetically sealed in the clay and kept on ice to offend the nostrils of later visitors. On the other hand, if the ice had not been present and the temperature not kept so low it is unlikely, even in the clay, if animal matter could have been preserved for such an enormous period of time in a condition to give out so ammoniacal a stench. All the circumstances point toward the view that the ice preceded and subsequently co-existed with animals whose remains are now in its vicinity.'"

On page 263 Dall continues: "From the character of some of the bad-smelling deposit which was brought home and appeared to be exclusively composed of vegetable fiber finely comminuted, no doubt is felt that it represents dung of the mammoth or some other herbivorous animal which had been preserved in pockets on the surface of the ice where it was probably dropped, and by its dark color attracting the rays of the sun had sunk in, as is usual with dark objects dropped on an exposed ice surface."

The above discussion is repeated in a Report on Coal and Lignite of Alaska, by W. H. Dall, 17th Ann. Rep. of U. S. Geol. Survey, 1896, pp. 850-860. It is also referred to by Geikie[8] and Wright.[9]

[CRUISE OF THE REVENUE STEAMER CORWIN IN THE ARCTIC OCEAN IN 1881. Treasury Department Document No. 429. Washington, 1883.]

Muir, page 50, under head of Kotzebue Sound, remarks:

"A striking result of the airing and draining of the boggy tundra soil is shown on the ice-bluffs around Eschscholtz Bay, where it has been undermined by the melting of the ice on which it rests. In falling down the face of the ice-wall it is well shaken and rolled before it again comes to rest on terraced or gently sloping portions of the wall. The original vegetation of the tundra is thus de-

[8] The Great Ice Age, p. 664.
[9] Ice Age in North America, p. 33.

stroyed and tall grasses spring up on the fresh mellow ground as it accumulates from time to time, growing lush and rank, though in many places that we noted these new soil-beds are not more than a foot in depth, and lie on the solid ice."

[CRUISE OF THE U. S. REVENUE STEAMER CORWIN IN THE ARCTIC OCEAN IN 1881. Notes and Observations. By Captain C. L. Hooper. Treasury Department Document No. 601. Washington, 1884, pp. 79-82. With a text figure and two photographs.]

"At meridian of the 7th (Sept., 1881) we steamed over to Elephant Point, and came to anchor off the remarkable ice formation for which that place is celebrated. During the afternoon, accompanied by Messrs. Muir and Nelson, I went on shore to make an examination of the ice-cliff. In my report of the cruise of the Corwin in 1880, I made mention of this phenomenon:

"We spent several days in the vicinity of Elephant Point examining this and smaller ice formations which were discovered by our exploring parties from day to day; and although it is not claimed that all doubt is set at rest on this subject, we can safely assert that the large quantity of ice known to be here precludes the possibility of Beechey's explanation being the true one. Several hundred feet back from the edge of the cliff, at a place where a cave had occurred, caused by a small stream of running water, we found ice clear and solid. Ice appears in the face of the cliff in several places, but that discovered by Kotzebue is much the larger. This is about half a mile in length, and although its exact width is not known, it may safely be assumed to be not less than 300 feet. At about 400 feet back from the edge of the cliff the ground rises quite abruptly for 80 or 100 feet, and changes from the springy, mossy covering to a solid mass of earth and stones, and in several places large bosses of lichen-covered granite are exposed to view. Although but two feet beneath the surface, in no place is ice exposed on the top. The layer of mossy turf covers it as evenly as if laid on by man to protect it from the sun's rays. That it owes its existence now to this covering of moss I have no doubt, but its origin is not so clear. The grass referred to by Kotzebue grows along the edge of the cliff, and on all irregularities on the face of the ice where the soil from above has been undermined by the melting and falling over, has lodged. Considering its cold foundation and the shortness of the season, the growth of this grass is almost phenomenal. Specimens collected by us, growing on a mere handful of soil on the very face of the ice cliff, were 4 feet long, and when dry emitted the fragrant odor of fresh, new hay.

" Ice formations, in may respects similar to that at Elephant Point, occur in various parts of the northern regions, both in America and Siberia, wherever the frozen subsoil is found. This, according to Baer, is coincident with the isotherm of 32° Fahr., and its thickness increases in proportion as the mean temperature of the locality falls below that degree, its unlimited descent being checked by the interior heat of the earth. The extent and thickness of this frozen substratum, whether increasing or decreasing, and to what extent affected by local causes, are interesting subjects of inquiry. The thickness of the frozen mass has been measured in various parts of the north by boring. At Yakutz, Siberia, latitude about 62° and mean annual temperature 14°, the ground was found frozen to a depth of 382 feet. At Fort Simpson, on the Makenzie River, in nearly the same latitude as Yakutz, the mean annual temperature 25°, the frozen substratum was found to terminate at 17 feet from the surface; and at the close of the summer of 1837 the surface was found to be thawed to a depth of 11 feet, leaving only 6 feet of ground frozen. So far there appears nothing remarkable in the frozen substratum, it being controlled principally by the mean annual temperature of the locality and the internal heat of the earth. But why this frozen substratum should occur at certain places in the form of pure ice does not appear so clear. Whether these ice masses are fragments of the original ice sheet which overswept the polar regions, or are formed by the waters from the melting snow draining through the soft, light mosses which form the tundra, is a matter for scientific investigation. The presence of fossil remains of extinct species of animals in some of the Siberian ice masses points to the supposition that they have existed for many thousands of years, while some of the ice examined by us near Elephant Point showed unmistakable signs of having been formed by the melting snow filtering through the surface covering. The mass, though many feet in thickness, was composed of fine strata of ice, some pure and free from vegetable matter, and some so filled with decayed moss as to present more the appearance of frozen earth than ice. Upon being melted, however, it was found to contain but a small amount of vegetable matter, which had a rank, disagreeable taste and smell. This peculiarity was first attributed to the presence of animal matter, but, on examination with a microscope, revealed nothing but the remains of the same species of plants which formed the covering of the whole. A number of wedge-shaped pieces of ice found in the banks around Eschscholtz Bay were probably formed by a small crack in the ground filling with snow and ice, and continuing to enlarge under successive changes from freezing to thawing.

"While making investigations in the vicinity of Elephant Point, Mr. Nelson discovered the remains of a beaver dam at one end of the ice cliff, which gave rise to a great deal of speculation and discussion on board as to whether this particular body of ice was not originally a lake; and indeed, considering the habits of the beaver, it is difficult to account for the presence of this dam upon any other hypothesis. The dam was in a good state of preservation, the wood plainly showing the marks of the animals' teeth. It is readily seen how the land forming the north shore of the lake may have been washed away, and the ice exposed, by the water from the Buckland and other rivers, which discharge into Eschscholtz Bay. The shallowness of the bay, and the difference in the height of the cliff, on its opposite sides, show that a large amount of washing away has taken place. The moss and grass covering the surface of the ice are also easily accounted for. The germs are readily transported from the surrounding hills by small streams on the surface, snow-slides, high winds, etc. It is of a parasitic and very rapid growth, covering the most barren ground in a short time, even the dry hard surface of volcanic rock, and that it readily thrives on the ice is shown by the luxuriant growth found by us on every projecting point on the face of the ice-cliffs. Kotzebue was undoubtedly in error in supposing that the fossil remains of animals found in the vicinity were imbedded in the cliff. I examined them carefully each season and saw no signs of animal remains of any kind, while on shore; below high-water mark, we found them in abundance. They were not confined to the locality of the cliff, but extended each way as far as our investigation reached. They evidently came from the Buckland River, and were brought down by the drifting ice in the spring. The other rivers emptying into Kotzebue Sound contain large numbers of them, as also those emptying into Norton Sound. The natives assured us that large beds of these bones were to be found in the rivers but a few miles inland. Many of the tusks found in America up to the present time are very much decayed from exposure, but it is probable that by digging into the frozen earth they would be found in a perfect state. Our half-breed interpreter, Andrew, claimed to have seen large quantities in the bed of a stream which he discovered while on an overland trading voyage from Norton Sound to Kotzebue Sound the previous winter. He said he had taken a small piece on his sled and brought it down near the coast, but finding that it was overloading his dogs, he threw it off and left it. Some of our men accompanied him to the spot and found a portion of a small tusk in a perfect state of preservation.

The bones are found generally in the bed of rivers or in the alluvial deposits near their mouths. Many theories have been advanced to account for the accumulation of these bones, and by some writers it was supposed that the animals may have died in large numbers when in herds, but it is altogether likely that the remains were brought together by the action of the thousands of small streams of water formed by the melting snow, which everywhere flood the tundras in the spring. In this way they are carried to the larger rivers, and by them swept down, until by the widening of the river and the consequent decrease of the strength of the current they become stationary and are in time buried in the alluvium."

Hooper prolongs his text with a series of disconnected compiled remarks concerning the mammoth in general. Concerning Cape Blossom he remarks, pages 39: "It presents seaward a sheer cliff, which was described by Beechey as having an ice formation similar to that at Elephant Point. Although I visited this place several times during my two cruises, yet I saw no signs of ice against the face of the cliff like that at Elephant Point, which remains the same from year to year."

Fortunately this account may be materially supplemented from the personal notes of Mr. E. W. Nelson who has generously placed his private journal, with drawings, in the writer's hands.

September 7, 1881. "We steamed up opposite the bluff on Elephant Point. The water shoaled so we were forced to anchor in two and three quarters fathoms. The bluff was found to be one hundred and forty feet high and to be made up of ice and clay along its face for about three miles. The lower ice frequently presents a shelving projection under which the water at high tide (the rise and fall at the time of our visit being about three feet) had eaten fifteen to twenty feet. This exposure of ice slopes up and has its upper surface hidden by an inclined bank of sod and soil fallen from the terrace above. This sloping bank, covered with a luxuriant mass of vegetation, mainly grass two to four feet high interspersed with thrifty alder bushes, ends sharply against a more or less abruptly rising wall of ice five to twenty feet high forming the brow of the bluff. Over this upper ice is a layer from a foot to three or four feet of vegetable humus and peat upon which is a rank growth of grass. This surface ascends back and up gradually a few hundred yards or less to meet a slope rising at a much greater angle that extends up to the rounded summits of hills that continue into the interior.

"The accompanying sketch gives an idea of a section of the bluff.

"All along the shore in this locality a peculiar odor from the mass of decomposing vegetable matter exposed fills the air. This was more noticeable where the decaying vegetation in the clay was more abundant.

"Toward the eastern end of the face of the bluff on a slightly projecting point I found an old beaver house inbedded in the earth with two feet of vegetable humus on top of it. It was exposed in section by the crumbling of the bank.

"The base of the nest rested on an alder seven inches in diameter at the butt and the rest of the heap was composed of alder sticks one-half to three or four inches in diameter from six inches to five or six feet long. Nearly all of the smaller sticks had their bark eaten off and many still retained the marks of the teeth. All showed the

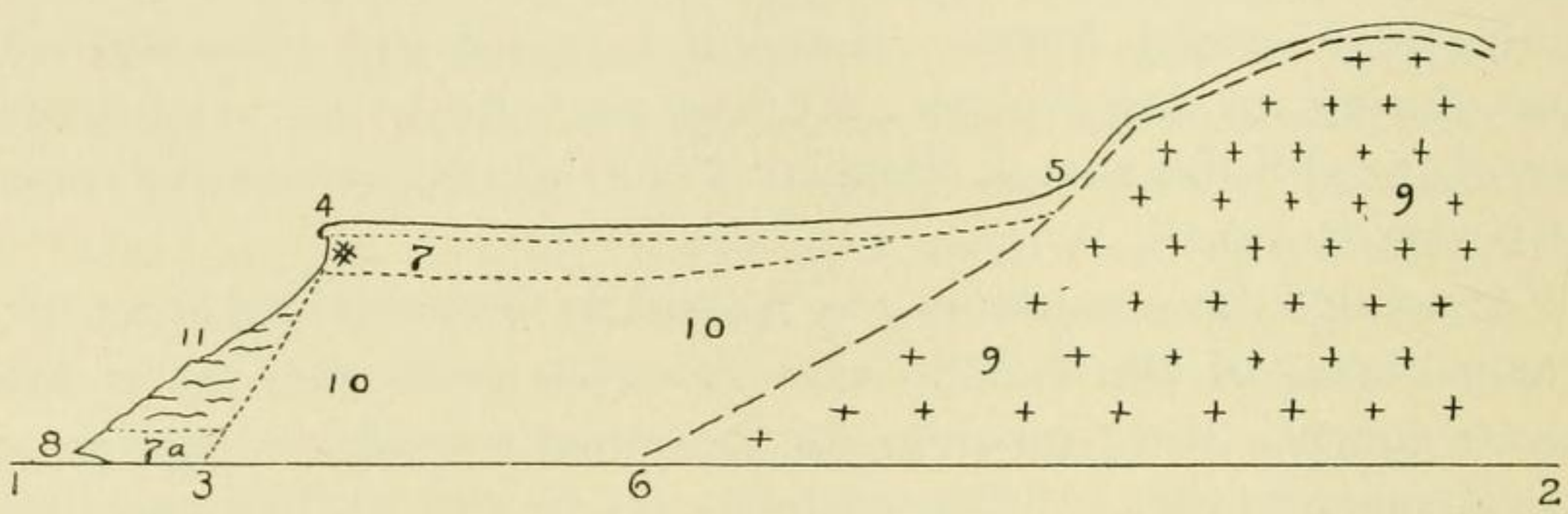


FIGURE 3.—Section of so-called "Ice-cliff" at Elephant Point, Kotzebue Sound, Alaska.

[After E. W. Nelson MS.]

1-2. Sea level.
3-4. Approximate surface of displacement along face of frozen silt bluffs.
4-5. Top of terrace 100-400 yards wide composed of about 4 feet of peat and humus overlying ice.
5-6. Approximate limit of Pleistocene basin.
7. Bed of dormant elevated ice with exposed front of 5-20 feet lying on top of silts (10) and overlaid by turf layer (4-5).
7a. Bed of ice that is probably derived from the upper bed (7). In its present position through displacement by the undermining of the sea.
8. Edge of ice (7a) being undermined in places by the sea.
9. Metamorphic rocks limiting the Pleistocene deposits and forming the interior ridges.
10. Frozen Pleistocene lacustrine silts 100 to 125 feet above sea level.
11. Loose talus slope along face of bluff, which being loosened up and aerated supports good growth of grass, etc.
Position of beaver nest.

teeth marks at each end. The entire mass was permanently frozen except for an inch or two along the exposed surface where it was slightly thawed. Only a few yards away on each side of the beaver nest, and apparently back of it, on about the same level, was ice apparently surrounding the mass of frozen earth upon which the nest

rested. I gathered some of the sticks from the nest. They were all alders, watersoaked, and soft enough to be easily picked to pieces with the finger nail."

2. ICE-CLIFFS ON THE KOBUK RIVER

[EXPLORATION OF THE KOWAK (KOBUK) RIVER. Science, Dec. 19, 1884, p. 551.]

Abstract of exploration on the Kowak or Kuak River of Alaska, made during the season of 1884 by a party under Lieut. Cantwell, U. S. steamer Corwin, Capt. Healy.

"July 12, 1884. At half past two p. m. a series of ice-cliffs, like those of Eschscholtz, was observed, composed of a solid mass of ice extending three-quarters of a mile along the left bank, covered by a thin layer of dark-colored earth, and rising to a height of a hundred and fifty feet. Trees were growing on the surface. Up to this point, and for some distance farther, not a single stone or pebble was to be seen, and the silence was frequently disturbed by the fall of large masses of the soft earthy banks undermined by the strong currents. * * * At half past four p. m. (July 24th) a remarkable clay bluff, three-quarters of a mile long and a hundred and fifty feet high, was reached on the left bank of the river. Quantities of mammoth tusks were observed in this clay and its debris where undermined by the stream."

[CRUISE OF THE REVENUE STEAMER CORWIN IN THE ARCTIC OCEAN IN THE YEAR 1885. Washington, 1887, p. 48. A Narrative Account of the Exploration of the Kowak River, Alaska. By Lieut. John C. Cantwell.]

"One of the most remarkable, in fact the only remarkable feature of the lower river, is the ice formation in the high black bluffs. The recent heavy rains had caused the river to rise to an unusual height, and I observed in many places where the erosion of the flood had exposed vast masses of ice, which had escaped my notice formerly. Change is the order of the day here, and it is no uncommon thing to see, soon after a flood or freshet in the river, masses of earth, upon which trees thirty or forty feet high have grown, suddenly break away and fall with a tremendous roar into the river. I obtained sketches and photographs of these broken bluffs, but no picture can adequately portray the feeling of utter desolation which this destructive work of the ever-rushing river conveys.

"The constant falling away of the soft earth, leaving the solid ice bare in many places, has given rise to many curious and fantastic formations.

"For miles along the river in this portion of its course these icy cliffs appear and disappear at regular intervals, so that it is observed that they recur in bends that are parallel with each other, which would seem to indicate that its existence is not due to deposits of ice by the river, else it would be in all of the bends, but that its presence is due to some other cause. If a straight line is drawn through the center of one of these ice-cliffs, and through the E.N.E. and W.S.W. points of the compass, it will not only touch all of the cliffs, but if extended to the sea will touch the coast at a point very near Elephant Point, on Eschscholtz Bay, where, it is well known, a peculiar ice formation in the bluffs has been observed and commented upon by numerous scientific men.

"Climbing to the top of one of these ice-cliffs, Mr. Townsend and I pushed our way through the dense thickets of willow and luxuriant growth of grass into the interior for about one mile, where we found a shallow lake about a mile in diameter, which I have no doubt had its origin in the mass of ice over which we had been travelling. It is almost inconceivable how such a rank vegetation can be sustained under such conditions. If we stood in one place any length of time the spongy moss became saturated, and soon a pool of dark-colored water made our position untenable.

"Besides the moss, berries, and stunted willows, clusters of spruce trees, some measuring six and eight inches in diameter, have taken root and grown in the thin strata of soil overlying the ice."

In the same report on pages 81-102 are Notes on the Natural History and Ethnology of Northern Alaska, by Charles H. Townsend, page 85. "Above the many-channeled delta the Kowak assumes a different character. High banks of old ice and clay appear, bearing a thin coat of surface soil, which supports the stunted arctic growth of white spruce. The banks, undermined by the melting of their ancient icy substratum, often slide in massive sections into the river, carrying a wide margin of forest with them. * * * Sometimes cavernous holes are excavated as the gritty ice disappears, and the overarching mass of earth hangs ready to fall when a few more hours exposure to the incessant arctic sunshine shall have set it free. These banks are too icy to be tunneled by kingfishers or bank swallows, consequently such birds are scarce along the lower river.

Page 89. "*Elephas.*—Tusks, teeth, and bones of the mammoth were seen in many of the villages on the Kowak River. The natives frequently carve ornaments and useful articles out of mammoths' tusks, and I saw some very large soup-ladles made out of this fossil ivory. At Cape Prince of Wales, where the Corwin anchored

a short time on her way north, several tusks and large bones of the mammoth were brought aboard for barter. * * * On August 28, 1885, at Schismareff Inlet, I found the front half of the skull of a mammoth lying on the open tundra, which was not fossilized in the least, being simply a mass of dry bone, firm and light. This is rather remarkable, considering the long extinction of the mammoth and the geologic and climatic changes which have since taken place in North America."

In the Amer. Geologist, Vol. VI, page 49, I. C. Russell publishes a letter from Lieut. J. C. Cantwell in answer to a request for further information regarding the ice-cliffs on Kowak River, Alaska.

"The river is navigable for a distance of 375 miles. At two points before reaching the headwaters, we encountered gorges where the width of the stream scarcely exceeds twenty yards and where the channel was filled with rough bowlders.

"Some seventy or eighty miles from the mouth is where we first observed the ice-cliffs mentioned in my official report. At this point the cliffs were from 125-150 feet high, gradually decreasing in height as we noted their recurrence on our way up stream, until they had entirely disappeared when we had reached the foot-hills of the first chain of mountains through which the river flows. The topography of the Kowak Valley in the vicinity of the ice-cliffs is characterized by undulating tundra plains, varied by patches of small spruce timber which, as a general rule, was most abundant along the banks of the stream. For about a mile there is exposed to view a solid mass of ice superposed by a layer of soft earth forming a uniform thickness of about six feet. In color the cliffs are dark brown. The ice is not clear and must have been formed from water holding in solution a large quantity of earthy matter. There is no apparent stratification. No gravel was seen. The shore line in front of the cliffs was marked by an accumulation of soft almost impalpable dust piled in heaps to a height of 15 or 20 feet. The dust piles were evidently the result of the melting of the ice during the summer, as the annual spring freshets sweeps everything before them.

"In the first place the ice is solid without fracture from top to bottom [10] and again there are numerous high sand and clay cliffs abutting on the river in situations exactly similar to those occupied by

[10] The writer does not believe Mr. Cantwell means to be understood that the cliffs are solid ice from the river level to a height of 150 feet, but that simply the ice deposit itself on top of the clays is solid, i. e., not stratified. His photographs support this interpretation.

the ice-cliffs, in which not a particle of ice is to be seen. All the ice-cliffs are located on the left or south bank of the river."

[NATIONAL GEOGRAPHIC MAGAZINE. Vol. VII, 1896, pp. 345-346. Ice-Cliffs on the Kowak River. By Lieut. J. C. Cantwell.]

"The Kowak River rises in the northwestern part of Alaska, and after a tortuous easterly course of about 550 miles, the greater portion of which is within the Arctic Circle, it flows into Hotham Inlet, a large body of fresh water opening into Kotzebue Sound. During the summer of 1884-85 it was my good fortune to visit this region and to make a reconnaissance of the stream from its mouth to its headwaters. Among the many novel and interesting features of the region, which had never previously been visited by white men, none were more striking than a remarkable series of ice-cliffs observed along the banks of the river about 80 miles from its mouth. These deposits of ice were first seen in some of the low silt banks of the delta, and it was supposed that they were the result of the spring freshets in the river forcing large masses of ice into the soft, yielding soil of the banks. But when on our emerging from the delta, and reaching the higher land of the interior we still found these ice deposits in the form of clifs, from 80 to 150 feet high, the theory of current formation had to be abandoned. The banks of the stream in the region where the ice-cliffs are found are not all filled with ice, and the water marks on those which are composed only of soil and rock show beyond question that the water has never reached a sufficiently high stage to have transported the ice to its present position.

"At two points the cliffs attain an altitude of over 150 feet, and one cliff measured by sextant angles showed 185 feet. The tops of all the cliffs were superposed by a layer of black, silt-like soil from 6 to 8 feet thick, and from this springs a luxuriant growth of mosses, grass, and the characteristic arctic shrubbery, consisting for the most part of willow, alder, and berry bushes, and a dense forest of spruce trees from 50 to 80 feet high and from 4 to 8 inches in diameter.

"Where the face of the cliffs was towards the south the upper portion of the formation would be found undergoing the process of destruction under the melting action of the sun's rays, while in other situations the erosion of the river current was constantly undermining the cliffs. Both of these destructive agents caused great masses of soil and tree-laden ice to become detached and fall into the stream. Where the retreating waters of spring had left these

masses of detached ice stranded on the adjacent beaches or bars, piles of soft dust almost entirely free from any gritty substance would be left as a monument to mark the spot where the ice had been melted by the summer sun. These small dust heaps are a characteristic feature of the region where the ice-cliffs are found and are entirely different in appearance from the gravel and sand heaps deposited in the same way by ice floated down from the upper river.

"An examination of the tops of the ice-cliffs was very difficult on account of the dense undergrowth and the thick carpet of moss, but on one we discovered a lake about a mile in diameter and situated some 500 yards from the face of the cliff. The water in this lake was fresh and clear, but upon being disturbed became exceedingly turbid, owing to the presence of a large quantity of fine, decayed vegetable matter on the bottom. A piece of the ice melted showed a residuum of fine, impalpable dust, which under a lens proved to be composed mainly of vegetable matter and, while fresh, emitted a very pungent, disagreeable odor.

"The country in this region is mostly rolling tundra plains, with innumerable small lakes, and streams, all of which are tributary to the larger river. There is no evidence of glacial action whatever, and it is not until the first mountain range is reached, a hundred miles further up-stream, that any rocks *in situ* are seen. Here and further inland more plainly are to be found beds of trap, which on examination shows to be a pronounced olivine diabase, with such minerals as hornblende, mica, feldspar, augite, etc., present. Other rock forms show unmistakable evidence of the eruptive agencies that have been at work in the formation of the upper river region. The formation of the remarkable ice-cliffs in the lower country is, however, a geological nut which the writer admits his inability to crack."