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SOME FROZEN DEPOSITS IN THE GOLDFIELDS OF INTERIOR ALASKA

A STUDY OF THE PLEISTOCENE DEPOSITS OF ALASKA

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ABSTRACT

A description of the frozen deposits in the vicinity of Fairbanks, Alaska, is given. The deposits consist of muck, sand, gravel, peat, volcanic ash and pure ice. The materials, other than the ash and ice, are shown to be of slope-wash and fluviatile origin. A large percentage of the ice is of glacial origin. The volcanic ash is the first to have been found in the region, and its probable source is discussed. The deposits contain large quantities of bones of Pleistocene vertebrates.

INTRODUCTION

During the spring of 1929, an agreement was made between Mr. Childs Frick of The American Museum of Natural History and President Bunnell of the Alaska Agricultural College and School of Mines to place a party in the field during the summer months to collect vertebrate fossils in the vicinity of Fairbanks, Alaska. During the seasons of 1929 and 1930, the field work was in charge of Mr. Peter Kaisen, who has been for many years a member of the American Museum's department of vertebrate palæontology. The writer was in charge of the field work during the 1931 season.

Vast gold-placer deposits are being worked in the vicinity of Fairbanks by the Fairbanks Exploration Company, a subsidiary of the U. S. Smelting, Refining, and Mining Company. Huge dredges are maintained at Goldstream, Wagner, Gilmore, Cleary and Chatanika—mining camps situated on the Steese Highway nine to thirty miles northeast of the town of Fairbanks. The collecting of fossils during the three seasons and the geologic work of the 1931 season were carried on at these mining camps. Geologic work was carried on also at Fox, a Company holding between Goldstream and Wagner, and at Fairbanks Creek, a few miles southeast of Cleary.

Placer mining in interior Alaska involves problems not encountered in most places. The difficulties arise because there is usually a thick

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overburden of frozen muck upon the frozen gold-bearing gravels. The frozen muck overburden is hydraulicked off—in the camps mentioned, by water brought 90 miles in a huge ditch. The frozen gold-bearing gravels are then thawed so that the dredges can dig into them. The thawing of the gravels is accomplished by what is known as the 'Cold Water Thawing Method.' Ditch water and natural drainage water are forced through vertical pipes, of ¾ inch diameter, which are driven to bedrock. These pipes are placed at 16 feet to 32 feet centers.

Besides collecting numerous vertebrate remains found in the frozen muck overburden, the writer had the opportunity of studying the peculiar frozen deposits as they daily were being hydraulicked. This article presents a description of these frozen deposits and attempts to explain their origin.

ACKNOWLEDGMENTS

The writer acknowledges, with much appreciation, the assistance of President Bunnell and Mr. Childs Frick, and the courtesies afforded by the Fairbanks Exploration Company. The officers and employees of the latter, a subsidiary of the U. S. Smelting, Refining, and Mining Company, facilitated in many ways the collecting of fossil remains uncovered by their dredges and the study of the stratification of the deposits on their properties. Information relative to similar deposits was received from Mr. E. Austin, manager of the Fairbanks Gold Dredging Company. Data received from Dean E. N. Patty, dean of the Alaska College, and from Mr. Paul Hopkins, associate chemist with the U. S. Bureau of Mines, are acknowledged. Last, but not least, the writer acknowledges the helpful suggestions from his assistant, Mr. Wilson W. Walton, graduate student in the Alaska College.

DESCRIPTION OF DEPOSITS

General Considerations

Frozen deposits are found in numerous valleys in interior and northern Alaska. In the Fairbanks district, frozen deposits are quite noteworthy because they contain gold and cover many of the gold-placers. Very little work of a geologic nature has been done on the frozen deposits in the vicinity of Fairbanks, and it has seemed strange to the writer that this should be so, because the deposits are different and, therefore, all the more interesting.

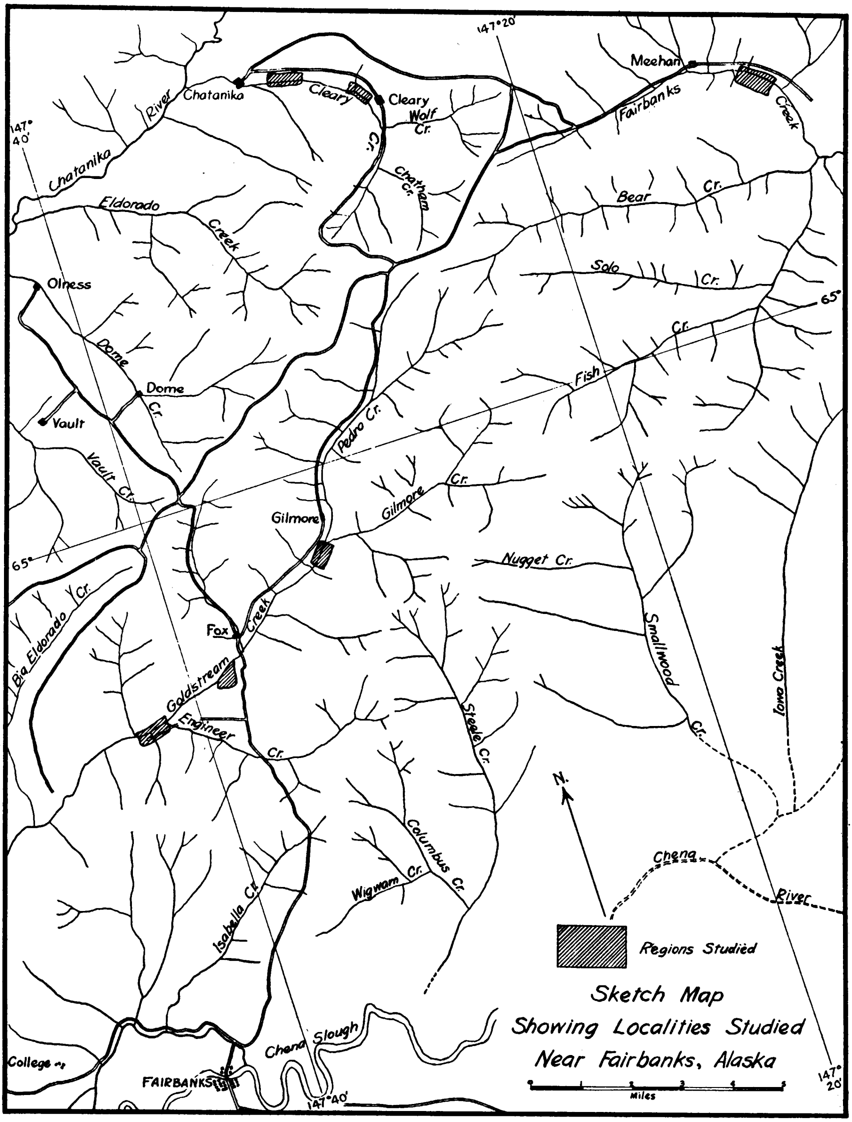

Fig. 1. Sketch map of frozen Pleistocene deposits to the northeast of Fairbanks, Alaska. The deposits consist of fossiliferous gold-bearing gravels, sand, peat, muck and masses of ice.

The frozen deposits consist of muck, gravels, sands, peat and other vegetation, volcanic ash and ice. The muck is prolific in fossil remains, containing especially super-bison, mammoth, horse, occasional moose, caribou and carnivores and numerous rodents of Pleistocene age[1]. The term muck usually is applied to the frozen muds, but it is sometimes used locally to designate any or all parts of the frozen materials over the gold-gravels. In this paper, the term muck is used in the first sense.

Except for thickness, the gold-bearing gravels and their overburden of ice and frozen muck, gravels, sands, peat and volcanic ash are more or less alike. A generalized description of one placer camp in the Fairbanks region would do for most of the others. A detailed vertical section from one locality, however, cannot be duplicated at any other place. In general, the deposits have the following sequence: bedrock usually of Birch Creek schist of pre-Cambrian age; on this are the frozen gold-gravels; then frozen muck containing beds of gravel, sand, peat and ash. Interspersed throughout the deposits are beds, irregular masses and 'dikes' of ice. In some localities there are beds of ice of considerable thickness and of great areal extent lying beneath a large percentage of the muck. The materials above the gold-gravels, taken as a whole, are stratified, though poorly so. The muck itself, for the most part, is unstratified. The various beds have various attitudes ranging from horizontal to vertical. Areally, the deposits change suddenly, the muck giving way to any of the phases mentioned. Few of the beds have any great areal extent.

Gold Gravels

The gravels underlying the muck are generally separated from it rather sharply, though at places there seems to be a gradation of the two. The gravels vary in thickness from a few feet to over a hundred feet, an average thickness being about 30 feet. The gravels are not exceedingly coarse, there being little material greater than 15 inches in diameter. The gravels are composed of the bedrock of the region—mica schists, quartz-mica schists, quartzite schists, garnetiferous schists, vein quartz, and other phases of the Birch Creek schist. Bones, skulls, teeth and tusks of Pleistocene vertebrates are also found in the gravels.[2] Nearly all of the gravel is in somewhat flattened, subangular pieces, and is not excessively water-worn. Fine materials in the gravels are composed of

[1]Frick, C., 1930, Natural History, XXX, No. 1.

[2]Practically all the fossil specimens from these gravels were recovered by the men on the dredges. The bones came from all parts of the gravels, as nearly as can be told. No special type of animal is found alone in these gravels—all the various specimens collected were represented in these gold-bearing gravels.

Fig. 2. Superbison skeleton, approximately one-twentieth natural size. Assembled from bones of different individuals found scattered in the frozen muck deposits of the Fairbanks area.

the same materials as the coarse, with the addition of some of the weathered products of the schists. The gold, except for a few colors, is found close to, or on, bedrock. The gravels are usually tightly frozen.

MUCK

The term muck here applies to the fine mud materials, usually tightly frozen, which normally overlie the frozen gold-gravels. Except for being frozen, the muck is unconsolidated. The muck is mostly unstratified. It varies greatly in thickness, being over 100 feet at Fairbanks Creek, over 70 feet at Chatanika, and about 30 feet at Goldstream. At any one camp the thickness varies greatly. It is always thicker on the slip-off slope[1] of the valley than it is on the other side. The muck deposits are always steeper on the slip-off side of a valley than on the "undercut" side of a valley—see cross-section. The "slip-off" side varies from place to place—on one limb of a valley we have a slip-off portion, then an undercut portion, then another slip-off portion. The muck extends up the hillsides, in some instances as much as 200 feet to 300 feet above the valley floor. On such hillsides the muck gradually thins out and becomes mixed with the coarser disintegration products.

The muck always contains a large percentage of muscovite mica. A mineral analysis shows the muck to consist of the resistant minerals of the bedrock schists. A few boulders 3 feet in diameter are found in the muck, but where coarse materials are found they seldom are greater than 2 inches in diameter.

Some vegetable matter is found throughout the muck. Peter Kaisen reports the occurrence at variable depths in the muck of layers of green moss, the moss going to pieces on thawing. The decay of this vegetable matter and dried flesh on the bones of some of the animal remains give the muck a putrid stench that at times is quite nauseating.[2]

The muck varies in color according to its moisture and vegetable content, being darker in color when the moisture and vegetable content are large. The prevalent color of the muck is dark gray to black, but it

[1]Under certain conditions that are well known, a river not only cuts downward but cuts in a lateral direction against its banks. Moreover, this side-cutting is greatest against those sides of the curves which front up against the course of the river. These sides tend to be undercut. The opposite side of the banks (opposite to those undercut) descend to the river with more or less gentle and gradual slopes. These gradual slopes are called "slip-off" slopes since the stream tries to slip away from them without eroding—in a large number of cases depositing materials because of a slack in the stream's velocity.

[2]I believe that the decided stench of the muck is due to both decaying flesh and to decaying vegetation. To what degree the stench is due to the air reacting on the flesh is uncertain. I found several bones with flesh adhering to them, the exact number I cannot recall. These specimens are in the collection sent to the Museum. I see no reason to believe that these bones are of more recent date than any of the other bones—every find of such bones was such as to indicate that the bones are of the same age.

is also found as light gray, tan and brown. The colors usually blend and give a mottled effect.

Beds, 'dikes' and irregularly shaped masses of ice are found interspersed throughout the muck. The intimate association of the muck and ice will be discussed later. Distributed as thin layers throughout the muck are beds of sand and gravel and peat. Many of these beds within the muck lie horizontally; others dip at low angles in the direction of the present stream drainage; others dip more steeply from the sides of the valleys toward the centers of the valleys; others are vertical or nearly so. In some localities the muck is as much as 30 feet thick

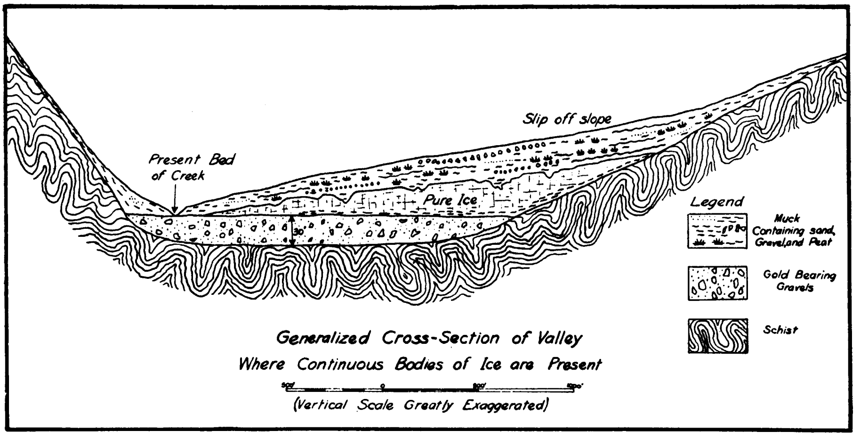

Fig. 3. Generalized cross-section of the Pleistocene deposits where continuous bodies of ice are present.

without having a bed of sand or other material contained in it, while at still other places not far distant there are ten or more beds of gravel or sand or peat within the muck in a vertical distance of a few feet. Here and there are found small forests which had been covered and thus preserved. The trees have a maximum diameter of 28 inches, the average diameter being 6 to 8 inches. Numerous stumps and roots of such trees are to be seen covering thousands of square feet.[1] Muck is found both beneath and above such occurrences. At some places within the muck, and on gravel beds within the muck, are found branches and logs disposed in haphazard manner, the long dimensions of such vegetation usually being horizontal.

[1]Prof. Gasser, professor of agriculture at the College, states that the trees "to all appearances" are spruce, the exact kind not being known to him. Prof. Gasser saw a few specimens which I collected several years ago. I am not acquainted with any occurrence of rerooted tree stumps. I saw none that I recognized as such.

ICE

Five per cent. is an estimated percentage of ice in the overburden. This percentage does not include the extremely large amount of frozen moisture in the muck which acts as a binding material. At some localities, as at Lower Fox and Upper Cleary, ice makes up as much as 60 to 65 per cent. of large areas. In some localities, as parts of Fairbanks Creek, ice is practically missing.

The ice varies in thickness from a fraction of an inch, as found in some beds, to over 30 feet.

The ice assumes various shapes—is found in beds, 'dikes' and irregular masses. The lower portions of a large percentage of the masses of the ice are connected.

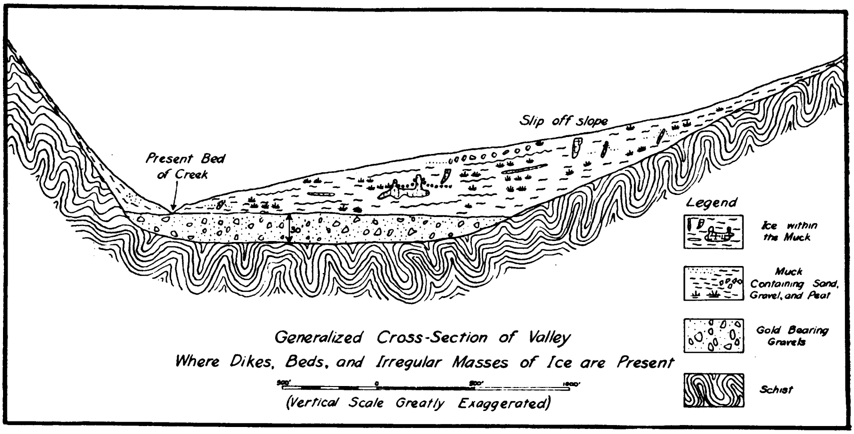

Fig. 4. Generalized cross-section of the Pleistocene deposits where dikes, beds and irregular masses of ice are present.

Generally the ice is very clear, but sometimes it contains small amounts of muck, giving it a dull appearance. Sometimes pebbles of bedrock are visible in the ice. The ice usually has very distinct crystals that have an average diameter of about ⅛ inch. The ice generally contains air bubbles up to an estimated amount of 5 per cent. of the ice. These air bubbles usually occur haphazardly, but at times are found in vertical rows, in horizontal rows, or in rows that are inclined in various directions and at various degrees of inclination. One large piece of ice may show two or more types of rows of air bubbles. Some of the bubbles are seen to be flattened at any angle inclined to the horizontal. The vertical rows do not necessarily contain the vertically flattened bubbles nor the horizontal rows the horizontally flattened bubbles.

Beds, 'dikes' and irregularly shaped masses of ice are common at most of the camps. The beds range from a fraction of an inch in thickness to over a foot. The width of the beds of ice is generally but a few feet, sometimes but a few inches. 'Dikes' of ice vary from a few inches to ten or more feet in height, and from a fraction of an inch to two or three feet in width. The sides and upper and lower surfaces of these 'dikes' may be straight and smooth, or irregular. Almost without exception, irregularly shaped masses of ice are thicker at the top than at their lower portions. The top surface of the ice, as well as the sides of the

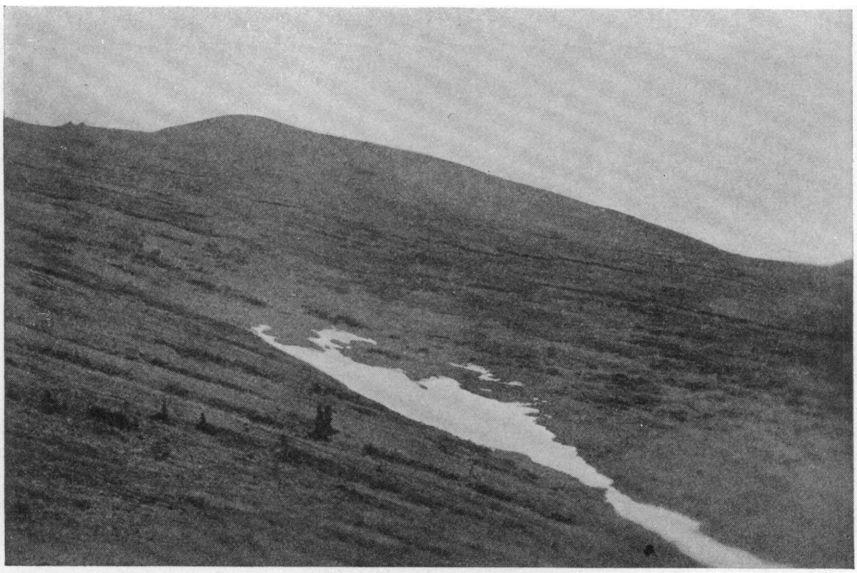

Fig. 5. Tongues of rock waste and vegetative cover creeping to lower levels. (Snapshot taken at 11:00 P.M. in June.)

block, are smooth in some cases and quite irregular in other instances. Beds and masses of ice are found separating the various phases of the deposits or may be contained in any one phase. 'Dikes' of ice are found in all phases of the deposits or may be cut through all of them.

A large percentage of the ice is seen to be continuous. This fact is not readily observed at most places and can be seen only by studying the deposits day by day as the hydraulicking advances. At Fox and Upper Cleary, however, the continuity of the ice can be seen at a glance, as at these places the hydraulicking has gone on in such a manner as to expose the ice and muck in deep cuts. In many localities, the muck, as it washes over the ice, obscures the ice and leaves the impression that little or no ice exists. Portions of Goldstream, Chatanika and Lower Cleary, as well as Fox and Upper Cleary, show large percentages of the ice to be continuous. At Gilmore, Wagner and Fairbanks Creek, existing conditions are such that continuity of the ice could not be determined.

At places where the ice is continuous, the ice sometimes rests on frozen gold-gravels and at other times upon a comparatively thin layer of frozen muck. The contour of the lower surface of the ice approxi-

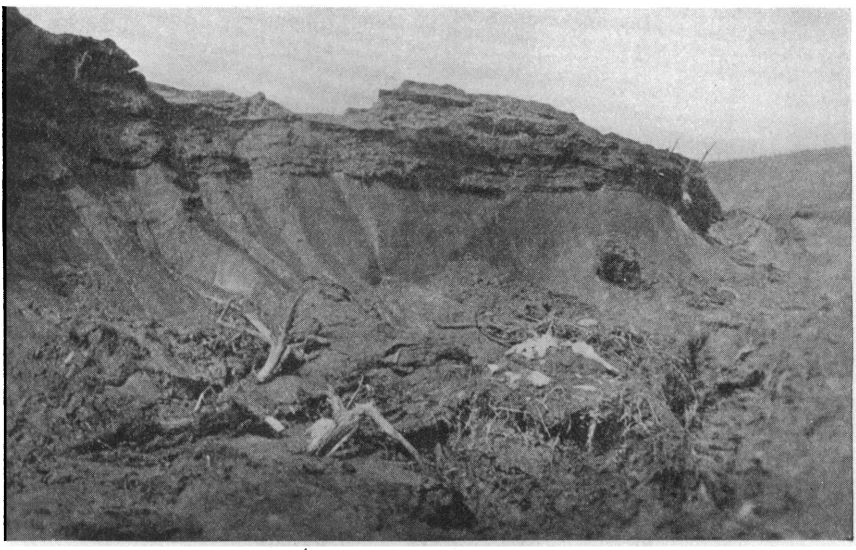

Fig. 6. Part of a glacier with overburden of frozen muck and peat.

mates the contour of that portion of the valley in which it happens to lie. The upper surface of the ice always slopes from the slip-off or more gentle side of the valley toward the center of the valley, the sloping surface varying from 3 to 15 degrees. Portions of the upper surface of the ice are extremely smooth, but the major portion is usually uneven, as if a sheet of ice on a sloping surface had undergone much erosion. At no place do any of the irregularities of the upper surface of the ice protrude higher than the smooth, sloping surface of the ice. At Fox the ice is seen to be continuous for at least 1000 feet in width and about the same number of feet in length, and has a maximum thickness of about 35 feet. With further hydraulicking the length and width will, without a doubt, prove to be very much greater. It is the writer's surmise that the portion seen is but a small fraction of the total amount of continuous ice present. The measurements given for Fox are also quite characteristic of the other camps where such ice is exposed.

Many, but not all, of the irregularly shaped masses and 'dikes' of ice rest on large beds of ice such as noted at Fox and other camps.

Fig. 7. The frozen deposits exposed by hydraulic 'giants.'

Beds, Other Than Ice, Contained in the Muck

Peat

Beds of peat are of very common occurrence wherever muck is found. The beds range from ½ inch to 3 feet in thickness, the average thickness being about 3 inches. In some localities as many as fifteen beds of peat can be seen in a vertical distance of five feet. A large percentage of the peat beds covers but small areas. Most occurrences show the peat to be of relatively pure vegetable matter, but at times it contains small amounts of sand. Practically all of the peat is frozen.

It is the usual thing for muck to underlie and overlie peat beds. At times peat is found to lie directly on ice, and at other times upon gravel or sand beds. At times it underlies gravels, sands, ice, or even volcanic ash.

Peat beds in the overburden have various attitudes, ranging from horizontal to vertical, the horizontal or gently inclined beds predominating.

Gravels and Sands

Frozen gravel beds and frozen sand beds occur frequently within the muck. The average thickness of such gravel beds is a few inches, with a maximum thickness of 30 inches. The average diameter of the

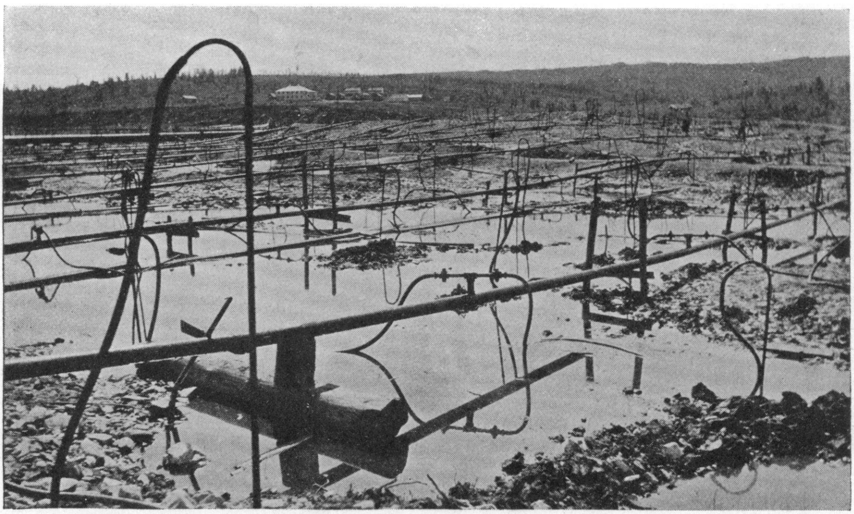

Fig. 8. Network of iron pipes through which ditch water is run to thaw the frozen gold-bearing gravels.

gravel is about ½ inch. The gravel is always very angular. The rock composition of the numerous beds is similar to that of the gold-gravels. It is the usual thing for muck to underlie and overlie the gravels. A few beds rest on ice. The position of the beds is similar to that of the beds of peat.

The average thickness of the sand beds within the muck is about 1 inch, with a maximum of about 8 inches. The sand ranges from medium- to very coarse-grained. The sand is composed of the more resistant minerals and rocks in the immediate vicinity. The sand beds usually underlie and overlie muck, but a few beds are seen to rest on ice. The position of the beds is similar to that of peat and gravel within the muck.

Many exposures show sand, gravel and peat beds turned up at their contacts with 'dikes' and irregularly shaped masses of ice. While the muck is largely unstratified, it, too, shows evidence of upturning at many contacts with the ice. For the most part, where any of the beds contact with the large masses of the continuous ice, this upturning is not noted.

Volcanic Ash

To the writer's knowledge, he is the first to discover a deposit of volcanic ash in the vicinity of Fairbanks. The ash is found as a thin whitish layer from 2 feet to 10 feet beneath the surface. It stands out quite

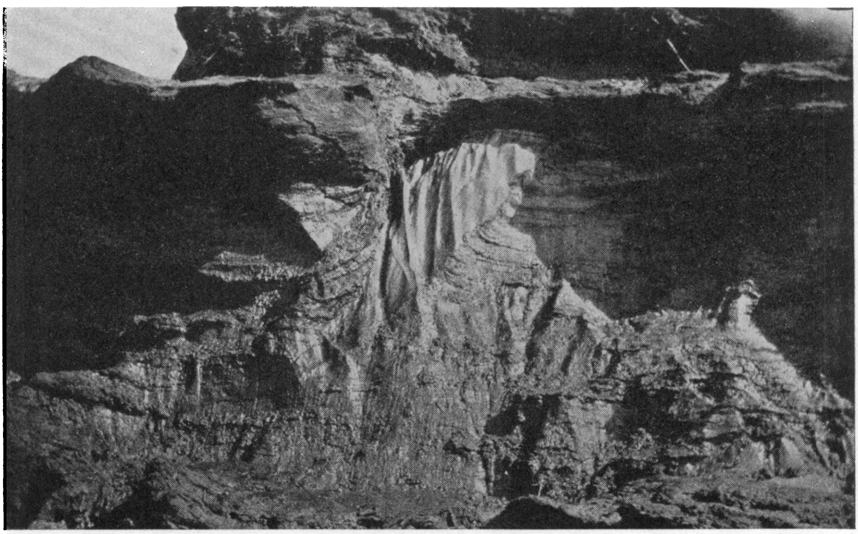

Fig. 9. Beds of muck, gravel, sand and peat are disturbed, when in contact with ice masses.

noticeably against the darker colors of the muck. It varies somewhat in thickness at any one camp, but has an average thickness of 1 inch.

A microscopic study shows the ash to consist practically entirely of glass. The index of refraction of the glass is 1.490, corresponding to an obsidian glass. A few crystals of hornblende and some crystallites are present in the ash.

The volcanic ash is usually found in the muck proper, but at times, as at Chatanika, it rests directly on peat. At no place is it seen to rest on gravel, sand or ice.

The attitude of the ash beds is variable. It generally is horizontal or gently inclined. Where inclined, the usual inclination is toward the center of the valley.

The surfaces on which the gravels, sands, peat and ash were formed are quite undulatory. Uneven contacts are the rule throughout the muck deposits. Uneven contacts are very noticeable at almost any place, but they are especially noticeable when the volcanic ash is present. This is true because the ash stands out in contrast to the rest of the deposits.

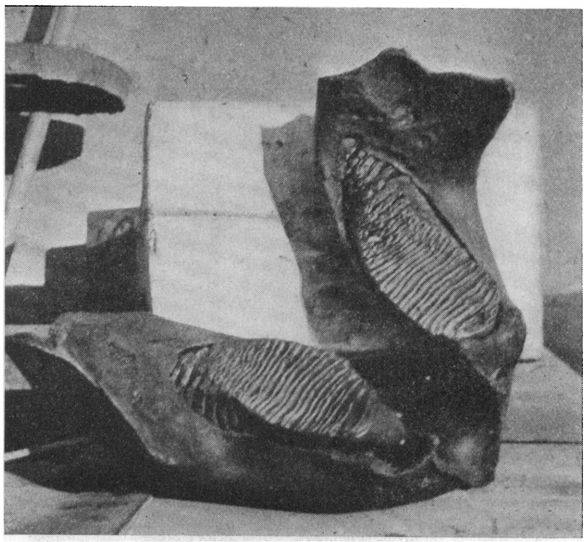

Fig. 10. Lower jaw and teeth of a mammoth.

Much of the ash has been displaced since its formation. Step-faulting on a very small scale has occurred. It is one of the outstanding physical features of the ash bed.

A FEW OBSERVATIONS IN THE VICINITY OF FAIRBANKS

The Mantle of To-day

Numerous outcrops of bedrock in the Fairbanks district are to be found, almost entirely, close to or at the summits of the ridges of the highlands and on the steeper slopes of the valleys. The gentle slopes and the valley floors are formed, almost without exception, of unconsolidated materials of varying degrees of coarseness.

There is usually a deep mantle of both residual and transported materials over a very large portion of the district. This unconsolidated material is composed of silts, sands and gravels which have been brought down the slopes of the valleys and have been stratified to some extent by running water. The material also includes much broken bedrock and rock slides.

Slope-waste forms an important percentage of the mantle upon bedrock. It continually slips down the slopes and unites with the materials of stream action. A thick blanket of moss and other vegeta-

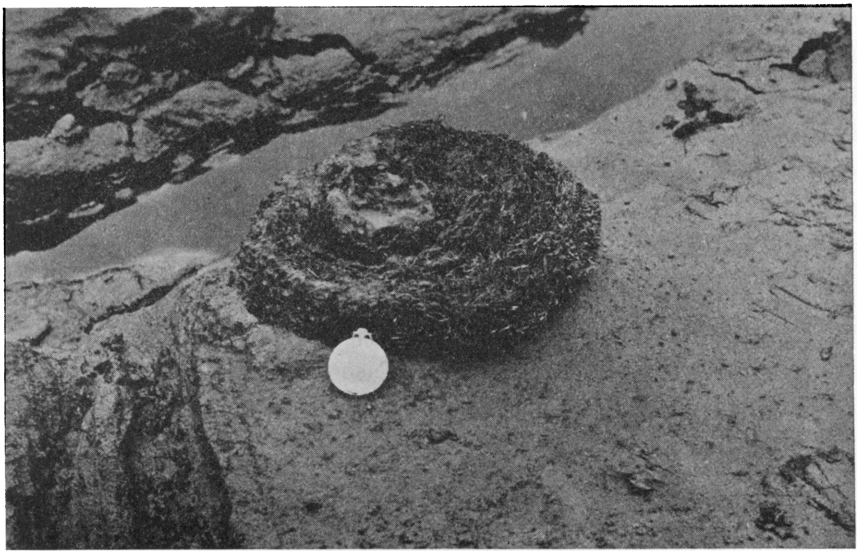

Fig. 11. An exposed, frozen nest of a rodent. Ice dike behind nest.

tion usually covers the hills and valley sides. To some extent this vegetative cover keeps the coarser materials from being transported to lower levels, and allows the freezing and thawing to continue for a greater length of time than it normally would do, at any one level; it also allows the coarser materials to be broken into finer and finer particles. Fine-grained materials make up a considerable fraction of the slope-wash.

Tongue-shaped ripples of waste and vegetation, largely moss, are common features throughout parts of the district, especially that part which is above timber line. The ripples are moss-covered—both the waste materials and the moss moving down hill. The lower limits of the ripples, as they advance down hill, have a very characteristic scalloped outline. It is generally believed that the process of formation of these tongue-shaped ripples of waste and moss has been aided by a decrease of friction, the decrease being due to a frozen surface above which there is saturated waste material, the saturation increasing the mobility.

The main weathering process going on to-day in this region is disintegration. Disintegration, which is almost continuously at work, tends to give us finer and finer particles not unlike the parent substances. These fine substances are moving down the slopes, both steep and gentle. While some coarse material is carried onto the valley floors and some fine products of disintegration are left at the higher levels, it is the general rule that the coarse products are left at the higher elevations and the finer materials are brought to the lower altitudes.

Peat

Just a word need be said about the peat in this vicinity. It is quite well understood that peat is usually a product of a mild or even cold climate. Peat is common in the Fairbanks district. Near College it is 18 feet in thickness. The moss and small vegetation from which the peat formed is believed by the writer not to have grown in water, but to have thrived in damp places which were slightly above the water level, in flat areas where the drainage is sluggish and, perhaps, around the margins of ponds. To-day peat is forming in such places. The writer is not acquainted with any locality in the district where there is a lake or pond containing floating vegetation or a floating fringe of vegetation. Many small ponds are fringed with vegetation, however, which is growing up from the bottom.

Ice

Almost without exception, there is, in interior Alaska, permanently frozen ground at some depth. Above this permanently frozen ground there is everywhere some thickness of material which is alternately frozen and thawed each year. Although dependent to a great degree upon the cold of winter and the warmth of summer, the thickness of this alternately frozen and thawed ground is also dependent upon the nature of the material lying above the frozen ground. Clays and like materials thaw much more slowly than sands or gravels. If the surface of the ground is covered by moss, peat or fine-grained disintegration products, the underlying materials will thaw during the summer much less than in regions which are covered with gravels or are not moss-covered. Most of the regions known to the writer alternately freeze and thaw to a depth of about 4 feet.

The formation of ice over the flood plains of rivers and creeks in interior Alaska is of yearly occurrence. Deposits of ice over flood plains, ice formed in valleys and at valley junctions, ice formed on hillsides—in fact, ice formed directly from flood waters and ice formed on a surface by ground-seepage are called 'glaciers' by the miners and some geologists of the Territory. The term glacier is so used here.

The formation of these glaciers is easily understood. Whenever, during the cold period of the year, the flow of a river is slackened by the formation of ice along the shores, ice forming in shallow places, or the formation of anchor ice, the waters coming from the headwater regions will be impeded and overflow. The overflow water soon freezes and within a short time an icy flood plain exists.

Small creeks build large deposits of ice where they leave gullies and tend to spread out into a valley. The formation of distributaries at the mouth of a gully offers greater surface per volume of water and thus tends to freeze quickly. Water from the head of a gully spreads out over the frozen mass and, in turn, itself freezes, building up a deposit of ice much after the manner of an alluvial fan.

Groundwater seepages along hillsides cause the formation of many glaciers. In most cases the glaciers are built largely during the early part of the winter before the flow of groundwater ceases. Some glaciers, perhaps, are built during the late winter or early spring. Glaciers of hillside origin are known to grow to great dimensions: glaciers about 1000 feet long, 1000 feet wide, and 10 feet to 25 feet thick are not unknown to form in favorable places to-day.

Glaciers forming during the winter are melted during the summer months. The writer has seen some glaciers, however, that have persisted until about the middle of summer. It is a question whether the climate in times past was such that all the ice might have existed without any sort of protective covering. It is not unlikely that this was so, because even to-day there is but little excess of melting over freezing. Ice can exist indefinitely, if there be protective material on it. This protective covering need not be thick, if it is fine-textured. Muck and moss form an almost perfect covering. A covering for the ice might be formed of material transported by gravity, by water, or, to a very small extent, by the wind.

THEORY OF FORMATION

It is the belief of the writer that the muck and the various beds of sand and gravel which it contains are a product of slope-wash and fluviatile conditions.

After the placer-forming period,[1] fine-grained products of long-continued disintegration predominated, and (as the products to-day are descending to lower and lower levels) glided down the slopes of the uplands and tended to fill the valleys. As practically all the valleys were unsymmetrical, the deposits grew more rapidly, and thus thicker, on the slip-off slopes. The slope-wash deposit had an initial dip characteristic of the slope of the surface upon which it happened to lie, the dip invariably being from the uplands toward the lower levels. Some of the products of the slope-wash joined the materials of stream action, giving stratified, more or less horizontal, beds of muck. Some coarse disintegration products were deposited with the fine products, as would be expected.

During wet seasons coarse materials would be a considerable percentage of the wash from the uplands, the gravels and sands being deposited in the valleys by the meandering streams. Many of the beds of sand and gravel have initial slopes dipping away from the uplands; other beds deposited by running water are horizontal. The angularity of the sands and gravels shows that there had been very little transportation of these materials.

The muds of the slope-wash contained, at various places, a considerable amount of small vegetation, the decay of which gives the decided stench to the deposits.

That a great percentage of the deposits, if not the whole amount, was formed slowly and at a comparatively quiescent time, is attested by the fact that there exist numerous thin beds of peat throughout the fine-grained muck. Moss and other small vegetation that grew in the flat areas of the valleys where the drainage was sluggish, and also perhaps around the margins of numerous ponds, were covered time after time by the wash from the hills and by the muds during flood stage of the streams. From time to time sands and gravels were deposited by streams upon the vegetation. Some of the vegetation forming the peat came, without a doubt, from the sides of the hills. Some of this peat forms short vertical dikes within the muck.

Portions of the valleys were forested by small trees, the stumps of many of these trees being covered in situ by muds and sands and gravels

[1]Prindle, L. M., and Katz, F. J., 1913, "A reconnaissance of the Fairbanks Quadrangle, Alaska," U. S. Geol. Survey Bull. 525, pp. 96–98.

of slope-wash and fluviatile origin. Log jams were quite common in the streams. These jams, plus the types of deposits formed, indicate that the streams were perhaps meandering and sluggish.

Different hypotheses have been presented as to the origin of deeply frozen ground in the far north regions. Russell[1] was of the belief that deposition and freezing were more or less simultaneous; Brooks[2] believed the frozen ground to have resulted from a colder Pleistocene climate and that to-day the ground is thawing in places. Some consider that the ground has been frozen under present climatic conditions.

The writer believes that mining operations in the vicinity of Fairbanks testify to the fact that that part of the ground which is frozen during any winter, thaws during the succeeding summer, and that under present climatic conditions it would be impossible for ground to be deeply frozen and remain so.

The writer believes that the gold-gravels and their overburden were frozen but a short time after deposition and that the upper portions were thawed each summer, the depth of thawing never quite equaling the depth of the freezing, so that the thickness of the frozen materials is the result of numerous additions of materials which were frozen shortly after deposition. The thickness of the deposits argues against the freezing having taken place after the whole of the deposits had been formed.

The estimate of the relative age of the pure ice within the muck will be different, according to the manner of the ice formation. Did the ice masses form after the muck and its enclosed beds? Did the ice masses form simultaneously with the muck deposits? Did the ice masses form prior to the muck deposits? Did some of the ice form simultaneously with the muck and some after its formation? A study of the air bubbles is of no help in studying the origin of the ice, as there is no regularity of the bubbles.

That the continuous beds of ice, up to 30 feet and 40 feet in thickness, formed after all the muck and its included beds were laid down, is out of the question. Such formation would have required a vertical pushing up of an average of about 20 feet of muck as the ice grew in thickness. It seems improbable that the continuous ice bodies formed later than the major portion of the muck. Large caves, filled with water which later froze, are not to be considered.

A detailed study of the physical relations of the continuous bodies of ice leads the writer to believe that this ice is of glacial origin, the glaciers

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[1]Russell, I. C., 1889, "Surface Geology of Alaska," Bull. Geol. Soc. America, I, pp. 129–130.
[2]Brooks, A. H., 1916, "Antimony deposits of Alaska," U. S. Geol. Survey Bull. 649, p. 27.

forming along hillsides as the groundwater escaped, building up glaciers which extended across the valleys. The ice was preserved by a protective mantle of muck, gravel, sand and peat brought down upon it by spring freshets and by slope-wash. Successive deposits of muck and carpets of arctic vegetation gradually spread over the original protective mantle and thus insured the ice permanent protection.

Small streams eroded much of the glacial ice and deposited thereon sands and gravels and muck. Some of the muck, gravel, sand, logs and isolated boulders within the ice are explained as successive outwash upon the growing glacier.

The numerous disconnected and variously shaped blocks of ice found within the muck were formed after much of the muck, and thus the glaciers, were formed. Various narrow 'dikes' of ice cutting across numerous peat beds show that the ice must have formed in cracks within the deposits, because the ice could not have stood up in the air during the length of time it took for the enclosing materials, including the peat, to form.

It is believed that the disjoined and variously shaped masses of ice were formed in cracks in the muck. The cracks, usually parallel to the length of the valley, were due to the slippage of masses of the muck to lower and lower levels. Many times the slippage of the muck occurred on the upper surface of the continuous beds of ice. Some of the cracks were formed by the freezing and thawing of the deposits, combined with the pull of gravity. Water drained into the cracks and gradually froze against the cold sides. With very cold weather the ice contracted, and in consequence a new crack was formed between the ice and the walls or within the ice itself. Water filling this crack and again contracting with very cold weather allowed the fissures to grow in width. Where an original crack started there would be a zone of weakness, and the fissure likewise continued to grow to higher elevations as subsequent materials were added from time to time. Since fissures formed in said manner taper downward, the ice masses are thinner at the bottom and wider at the top. The growth of the masses of ice went on from year to year, possibly failing during some mild winters when most of the cracks were open.

Due to the freezing of the water against the walls of the fissure and due to the expansion of the ice during the summer, the readjustment of the stresses caused strain in the immediate vicinity of the ice masses. The strained beds of muck, gravel, sand and peat were forced upward, toward the region of least resistance, at the contacts, and at times were pushed vertical or even beyond.

The presence of thawed ground at various localities appears to be the result of present-day circulation of underground water. Water at any temperature above the freezing point causes the ice and frozen muck to thaw and melt.

It is believed that the climatic conditions at the time of formation of the deposits were not essentially different from to-day.

The volcanic ash, found in the vicinity of Fairbanks, had its origin, perhaps, in some crater near the northern border of the St. Elias Mountains near the international boundary. The thickness of the ash, the fact that it occurs in only one stratum, the physical characteristics of the ash, and its depth beneath the surface lead one to believe that it is the same ash that Capps describes as being present over an area of more than 100,000 square miles in the vicinity of southwest Yukon Territory. Capps[1] reports: "It has long been known that a large area in Alaska and Yukon Territory is covered by a layer of volcanic ash. The ash lies near the surface, beneath a thin covering of soil and silt, and gives evidence of an explosive volcanic eruption that in terms of geologic history is very recent, though antedating historic record in this part of the world." He describes it as a "fine, white sandy material, with a harsh feeling when rubbed between the fingers. Microscopically it is found to consist chiefly of volcanic glass. In addition to the glass, fragments of sanidine feldspar occur, together with portions of minute crystals of hornblende and other minerals." . . . "The outermost observations (of the ash) recorded include, on the west, observations on the Nebesna, Tanana, and Yukon rivers, by Brooks and others; on the northeast and east, on Gravel, Macmillan, and Pelly rivers, by Keele, Dawson, and McConnell; on the southeast, on Teslin River and at Lake Marsh and Lake Bennett, by Schwatka, Dawson and others; and on the south and southwest, along the southeast flank of the St. Elias Range, by Hayes, Brooks, and Capps." The thickness of the deposits varies greatly according to the distance from its origin—at Carcross 1 inch, Eagle ¾ inch, Selkirk 8–12 inches, east of Kennecott and north of Mt. Logan from 2 to 300 feet. Capps goes on to say that "the ash usually appears along cut banks of the rivers as a thin white band near the top of the bank, covered only by a few inches or a foot or two of soil, silt, or vegetable humus." . . . "Over any given district of small area the ash tends to be rather uniform in thickness, although locally it thickens into lenses or thins out entirely. It occurs prevailingly in a single layer, was apparently ejected during one period of eruption, and fell as one con-

[1]Capps, Stephen R., 1915, "An Ancient Volcanic Eruption in the Upper Yukon Basin." U. S. Geol. Survey Prof. Paper 95d, pp. 59–64.

tinuous shower in which there were no time breaks of sufficient length to interrupt the vertical continuity of the deposit." . . . "All the evidence, so far obtained, . . . , both as to the areal distribution of the ash and as to its thickness, points to some crater near the northern border of the St. Elias Mountains near the international boundary as to the vent from which the ash came."

If the ash found in the Fairbanks district is the same as that reported by Capps, and there is every reason to believe that it is, the outer known limit of ash-fall, as given by Capps[1] must be extended westward about 150 miles.[2]

The muck and all, or practically all, of the ice are of Pleistocene to Recent age. Within the muck and its enclosed beds, as previously noted, are to be found remains of the superbison, muskox, moose, elk, caribou, horse, mammoth, lion, bear, wolf and various rodents. During the summer of 1931, the writer collected about two tons of bones which were sent to the American Museum of Natural History. Dried flesh adhered to a small percentage of the bones. In one instance a frozen fossil rodent's nest was found containing the greater portion of a mummified ground squirrel. The largest percentage of the collected bones were obtained from 'bone pits' in several widely separated localities. The Fairbanks region to-day is the one region in the world where deeply buried bones of Pleistocene animals may be recovered without the collector himself having to dig them out, as the thick overburden is being removed for him by hydraulic 'giants' in their search for the underlying gold.

[1]*Loc. cit.*, p. 10, fig. 23.

[2]Similarly, if the Fairbanks ash layer and that studied by Capps (1915, p. 64) have the same origin, and provided Capps' estimate is approximately correct, the average of 3 feet of muck found above the ash in the Fairbanks region was formed during the last 1,400 years; and if the rate of deposition was fairly constant for the muck before and after the eruption, 18,000 to 19,000 years is an estimated age of the deposits, allowing 40 feet of muck as an average thickness below the ash layer.