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AN ANCIENT VOLCANIC ERUPTION IN THE UPPER YUKON BASIN

BY

STEPHEN R. CAPPS

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ILLUSTRATIONS.

AN ANCIENT VOLCANIC ERUPTION IN THE UPPER YUKON BASIN.

By Stephen R. Capps.

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 or 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. The first published description of this material is that given by Schwatka,[1] who observed the ash layer along the banks of Lewes River and its headward tributaries in 1883. In 1887 Dawson[2] extended the known area of the ash and estimated its total area, the direction from which it came, and the approximate length of time since it was deposited. In 1891 Hayes,[3] in company with Schwatka, conducted an exploration from Fort Selkirk, on the Yukon, to the Copper River basin. They traveled westward into an area in which the ash gradually increased in thickness to its maximum near the international boundary and rapidly thinned west of that line. In 1898 and 1899 Brooks[4] explored the headwaters of White and Tanana basins and made many observations on the areal distribution and thickness of the ash. The present article is based largely upon information personally obtained or collected by Mr. Brooks. The writer first became interested in this occurrence in 1908, when working in the Nabesna and White River district: and a second expedition into the same general region in 1914 gave opportunity for a more extended study of the ash fall. Records of the outer limits of the ash-covered area have been taken from many sources, especially from the published and unpublished notes of the members of the Geological Survey of Canada and of the United States Geological Survey.

The general outlines of the ash fall are shown on figure *23*, the relative thickness of the deposit being indicated by contours. The outer limits of the area are drawn to include all points at which the ash has been observed and at which it is still recognizable as a distinct layer. Without question a thin film of dust could at the time of the eruption have been observed over an enormously greater area than that here outlined, but, as will be shown, the ejection of the ash antedates recorded history in America, and the area affected can now be determined only by the presence of the ash that has been preserved. Less than one-fourth inch of ash falling at the time of this eruption over a vegetation-covered upland would probably be insufficient to form a layer that would now be generally recognizable.

The outermost observations recorded include, on the west, observations on Nabesna, 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 Lakes Marsh and 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 the writer.

The ash usually appears along the cut banks of the rivers as a thin white band near the top of the bank, covered by only a few inches or a foot or two of soil, silt, or vegetable humus. It is remarkably persistent and is in places continuously exposed for miles. Over any given

[1] Schwatka, Frederick, Along Alaska's great river, Cassell & Co., New York, 1885.

[2] Dawson, G. M., Report on an exploration in the Yukon District, Northwest Territory, and adjacent northern portion of British Columbia: Canada Geol. and Nat. Hist. Survey Ann. Rept., vol. 3, pt. 1, pp. 43 B–46 B, 1889.

[3] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, pp. 146–150, 1892.

[4] Brooks, A. H., A reconnaissance in the White and Tanana river basins, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 475, 1900.

[5] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska, with a section on the Quaternary by S. R. Capps: U. S. Geol. Survey Bull. 417, pp. 42-44, 1900.

district of small area the ash tends to be rather uniform in thickness, although locally it thicknse 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 continuous shower in which there were no time breaks of sufficient length to interrupt the vertical continuity of the deposit. At a few localities two or more ash beds, one above the other, separated by beds of soil or silt, have been observed, but the sporadic nature of these occurrences and the great preponderance of areas with but a single layer indicate that where two or more superposed layers occur the upper layers are composed of ash derived by erosion from the lowest one and deposited later by wind or by streams. The evidence, therefore, is strongly in favor of but a single period of eruption.

The ash bears a close relation to the present topography, occurring not only over the valley floors of the present stream basins but also over the intervening hills and ridges. Shallow excavations on hillsides and in valleys everywhere reveal its presence. Burrowing animals,

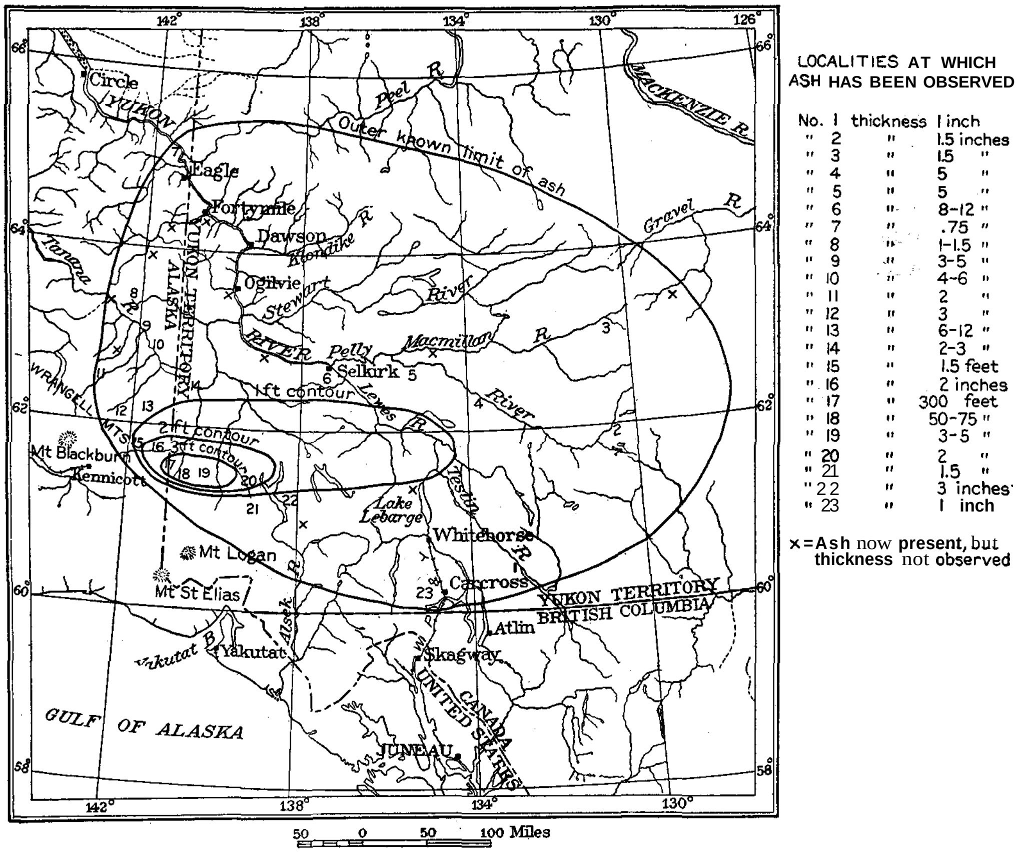


FIGURE 23.—Map of upper Yukon basin, Alaska and Yukon Territory, showing distribution of volcanic ash.

especially the spermophiles, or striped gophers, avail themselves of the ease with which the ash can be excavated, and their mounds are in many places composed almost entirely of this material. Furthermore, the low terraces of streams, covered with an ash layer, show that the material fell at a very late stage in the development of the present stream gravels. The ash overlies all but the most recent stream deposits and is much younger than the glacial materials deposited during the last great period of glaciation.

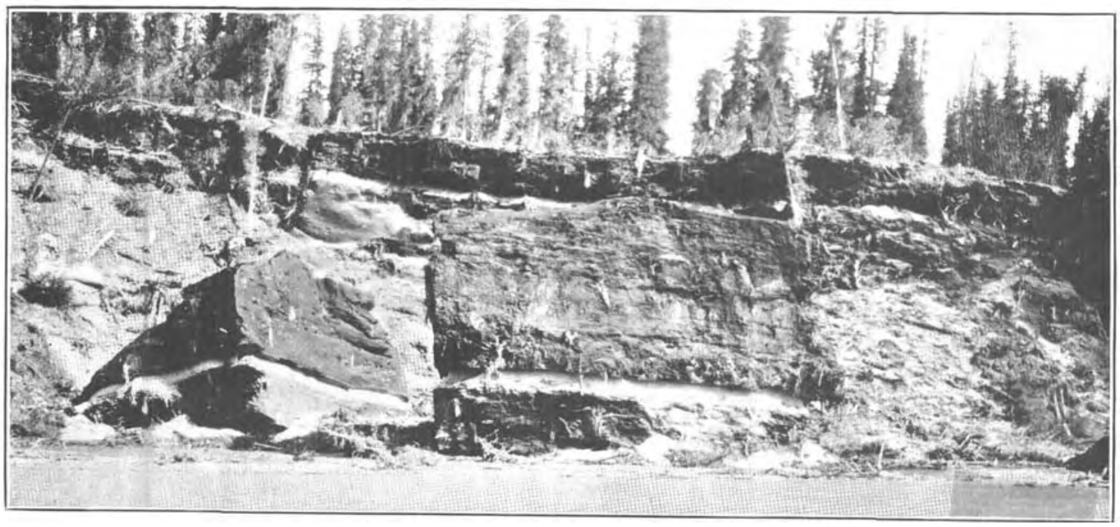
The thickness of the ash increases gradually, but by no means symmetrically, from the edges toward the center of the area covered. The great highway through this part of Yukon Territory and Alaska by way of the White Pass & Yukon route to the navigable waters of the Yukon basin follows directly across the ash-covered area, from southeast to northwest. Along this route the ash is particularly well exposed in the river banks. It first appears near Lake Bennett as a layer an inch or less in thickness, but increases to a maximum of about 1

A. AN ASH-COVERED LANDSCAPE, UPPER KLETSAN CREEK, NORTHERN FOOTHILLS OF MOUNT NATAZHAT. ALASKA.

White deposit is ash except on high summits, which are covered with snow. Photograph by United States Coast and Geodetic Survey.

B. ASH DRIFT ON NORTHERN FOOTHILLS OF ST. ELIAS RANGE, ALASKA, NEAR INTERNATIONAL. BOUNDARY.

Snow on high summits.



C. PEAT BLUFF, WITH VOLCANIC ASH LAYER, ON WHITE RIVER, ALASKA.

Overturned peat blocks in foreground.

foot toward the northwest in a portion of the Teslin and Lewes river basins. Below Fort Selkirk it thins gradually northwestward, and beyond Eagle it is only an inch or less in thickness. Dawson[1] early recognized that the ash thickens from the Pelly westward toward the Lewes and must have come from the west. He suggests that it may have been derived from a volcano of the Mount Wrangell group. Hayes,[2] however, who crossed from Port Selkirk to the head of White River in 1891, observed the increasing thickness of the ash to an area between Klutlan Glacier and Kletsan Creek, on the north flank of the St. Elias Range, and a rapid decrease in thickness west of that area. Brooks[3] confirmed Hayes's observations in 1899. It was thus proved definitely that the material was not derived from the volcanoes of the Mount Wrangell group, but from some source much farther east. By a plotting of the observations obtained from all sources the data shown on figure 23 as to distribution and thickness of the ash were obtained. Within the area outlined by the 3-foot contour the ash occurs locally in great thickness. Hayes noted beds between 75 and 100 feet thick on the western bank of the Klutlan, where there is no reason to suppose that the original thickness had been increased at the expense of surrounding regions, except, perhaps, by wind drift. Near the head of Kletsan Creek, on both sides of the international boundary, there is an area 2 to 4 miles wide, along the mountain flank, in which the entire surface is covered with great white banks and dunes of ash (Pl. VI, *A*). The area is for the most part above timber line, vegetation on its surface is sparse or lacking, and from a little distance one receives the impression that he is looking over great banks of snow (Pl. VI, B). The surface of this area is dotted with lakelets, the ash shifts with the winds, and the hills are modified dunes. The presence of ground frost close to the surface, however, retards to some extent the movement of the ash by winds. The belt of thick ash has a relief of 200 to 400 feet, which is believed to be largely in the ash, as exposures of the underlying rocks are almost completely lacking.

It is quite evident from the great thickness of the ash along the south flank of the St. Elias Mountains near the international boundary that the vent from which it was ejected is in that neighborhood. Thomas Riggs, jr., while engaged in surveying the international boundary line, noticed a small crater in a glacial cirque 4 miles north-northeast of Mount Natazhat, from which he thinks it probable that the ash was ejected. The writer, in 1914, attempted to visit this crater, but a heavy snowfall early in July and a shortage of provisions prevented waiting until the snow should melt sufficiently to allow an inspection of the reported crater. All the evidence so far obtained, however, 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 the vent from which the ash came, and it is not improbable that the locality suggested by Riggs is the true one.

The distribution of the ash from its center of dispersion indicates that the winds at the time of the eruption blew from the west and south. The long east-west axis of the ash-covered area and particularly that of the area of ash 1 foot or more thick shows that the wind at the time of the greatest ash fall blew almost directly from west to east. The great breadth of the area in the north-south direction near its western margin also points to a shifting of the wind to the south, probably during the later stages of the eruption, for although ash was carried northward a distance of 300 miles from the crater, the 1-foot contour extends northward less than 50 miles from the center, whereas it reaches eastward a distance of at least 220 miles. The greatest distance from the center at which the ash layer has been recognized is on the eastern slope of the Mackenzie-Yukon Divide, in the basin of Gravel River, where J. Keele[4] reports it, 450 miles from the center of dispersion. The southern limits of the ash area in the vicinity of the crater are not known, for they lie in an unexplored and almost inaccessible field of glaciers and rugged mountains. In figure 23, therefore, the southern margin is extended little beyond the area of thickest ash, though the ash may have fallen considerably farther south.

Estimates of the area covered by this ash deposit have been made from time to time, based on the facts as to distribution then available. The first of these estimates was made by Dawson,

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[1] Op. cit., p. 44 B. [2] Op. cit., p. 148. [3] Brooks, A. H., unpublished notes. [4] Letter to A. H. Brooks.

in 1887. Although stating that the total area must necessarily be much greater than the area of his observations, he estimated a minimum area of 25,000 square miles covered by ash. Hayes, in 1891, with additional information at his disposal, increased the estimate to 52,280 square miles. Brooks, in 1906, after having extended the known distribution westward to longitude 143° W. and northward to the Yukon below Eagle, placed his estimate at about 90,000 square miles. By using some additional data, in particular Keele's observation of the ash in the basin of Gravel River, the writer has mapped (fig. 23) an area of 140,000 square miles covered by a layer of ash. It is well known that in volcanic eruptions of this kind, with extensive ejections of pumice, the dust remains in the air for a long time, and a film of ash, too thin to be observable after the lapse of centuries, is deposited over large areas of the earth's surface. No doubt if the facts were known, the area over which a visible layer of volcanic dust was deposited after this eruption would be measured as several hundred thousand or perhaps several millions of square miles.

Two estimates of the volume of ash ejected have been published. Dawson, assuming an area of 25,000 square miles and an average depth of ash of 3 inches, estimated that the ash would form a prism 1 mile square and 6,240 feet high. Hayes, taking an area of 52,280 square miles, assumed that the ash had the shape of a flat cone of that base, and an apex 50 feet in height. His estimate gave a volume of 165 cubic miles, over 138 times the figure reached by Dawson. It is obvious that this estimate is not based on defensible grounds, for the ash is not in the form of a cone, but if deposited on a level area its surface slopes would be decidedly concave. The distance from the head of Kletsan Creek north to White River is only about 12 miles, yet in that distance the ash decreases in thickness from 200 feet or more to less than 3 feet. According to Hayes's assumption, the ash should be 25 feet thick at distances of 110 to 185 miles from the center of dispersion. Observations over the area affected are still far too few to afford a basis on which accurate estimates of the amount of ash discharged can be made, but a provisional estimate, from the data now at hand, is given here. In making this estimate it has been assumed that in the outer zone, beyond the 1-foot ash contour, the ash averages 2 inches in thickness. This assumption seems reasonable, for over a large area of the outer zone average thicknesses of 5 to 6 inches have been observed, and even near the outermost margins a thickness of 1 to 1½ inches is common. Between the 1 and 2 foot contours an average thickness of 15 inches is assumed, and between the 2 and 3 foot contours a thickness of 27 inches. The average thickness in the inner zone, with 3 feet or more of ash, is placed at 10 feet, although it is known that several hundred square miles is covered to depths of 25 to perhaps 300 feet or more with ash. The amount of ash derived by a calculation from the above figures gives a total volume of about 10 cubic miles. This figure is nearly eight and a half times that obtained by Dawson but only 6 per cent of that obtained by Hayes. The true figure is probably considerably more than 10 cubic miles, for no account has been taken of the great quantity of ash that fell as a thin film of dust far beyond the boundaries here shown.

The violence of the eruption at the time this ash was ejected may well be inferred by comparison with volcanic eruptions of historic times. Martin[1] has collected statistics on a number of such eruptions, and the figures used below are taken from his paper. The most violent volcanic eruption of historic record was that of Tomboro, on the island of Sumbawa, east of Java, in 1815. Estimates of the volume of material ejected reach figures of 26.6 to 50 cubic miles, and the area over which the ash fell was probably much greater than during the eruption here discussed. Krakatoa, in 1883, is said to have ejected an amount of ash about equal to that thrown out by Katmai, in June, 1912, or about 5 cubic miles. From the Katmai eruption the ash fall was perceptible at a distance of 1,200 to 1,500 miles. The greatest distance from the probable center of eruption in the White River basin to the margin of the ash fall, as now known, is only 450 miles, but it seems probable that if observations had been made at the time of the eruption, the distance would have been at least equal to that at which the Katmai ash was recognized. From the depth of the ash from the White River volcano at its thickest

[1] Martin, G. C., The recent eruption of Katmai Volcano, in Alaska: Nat. Geog. Mag., vol. 24, No. 2, 1913.

development, the area covered by it, and the enormous volume of material ejected, it is evident that the eruption was comparable in magnitude to any that have occurred during historic times. Unfortunately no facts are available, or are likely to be, as to the duration of the eruption, the violence of the detonations and the accompanying earthquakes, and the intensity and duration of the ash fall, which must have darkened the sun for days.

The physical and petrographic character of the ash at a number of places has been described by others, and no special study has been made by the writer. As was to be expected, the ash or pumice is coarsest near the center of eruption and becomes progressively finer as the distance from the center increases. Within the area of thickest ash the particles average perhaps from 1 to 3 millimeters in diameter, though larger pieces are numerous, and single fragments 8 or 10 centimeters in longest diameter were seen. Near the outer limits of the ash-covered area the material consists only of very fine dust. A sample collected by J. Keele from the basin of Gravel River, about 420 miles from the center of eruption, was subjected to a screening test and also measured under the microscope. The ordinary wire screens of 60, 80, 100, and 200 meshes to the inch were used, and the results are shown below, these sizes being reduced to millimeters:

Caught on 0.423-millimeter screen	per cent	7.72
Caught on 0.317-millimeter screen	do	2.46
Caught on 0.254-millimeter screen	do	4.78
Caught on 0.127-millimeter screen	do	11.28
Passed through 0.127-millimeter screen	do	72.94

The material caught on the two coarsest screens contained a large proportion of vegetable matter and sand particles. As examined microscopically the largest particle of ash seen had a diameter of 0.25 millimeter; the smallest 0.002 millimeter; the average size appeared to be about 0.01 millimeter.

Dawson describes the ash from the Pelly and Lewes basins 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, part being merely frothy and pumaceous, but of which the greater portion has been drawn out into elongated shreds, frequently resembling the substance known as Pele's hair, and in which the inclosed vesicles become more or less completely tubular. In addition to this glass, fragments and small perfect crystals of sanadine feldspar occur, together with portions of minute crystals of hornblende and probably other minerals.

Knopf,[1] who studied the coarser material from the White River basin in Alaska, gives the following description:

The "ash" is a white frothy glass, light enough to float on water. The larger fragments of the pumice inclose numerous small hexagonal plates of biotite, short prisms of hornblende a millimeter in length, and less conspicuous crystals of glassy feldspar. In thin section the hornblendes, which are deeply pleochroic in tones of brown, show ideally perfect cross sections and terminated prisms; the biotites are also finely developed and hold some inclusions of apatite. The feldspars are less perfectly crystallized. Both unstriated and lamellated varieties are present, but all possess indices notably higher than balsam. Zonal banding is not uncommon. Optical tests on striated Carlsbad twins prove that the feldspars belong to a species somewhat more calcic than Al_1An_1. They inclose some minute foils of biotite. Grains of magnetite occur sporadically. The matrix holding these phenocrysts is a pumaceous glass, clear and colorless, with a marked drawn-out, twisted, and fluidal appearance. Some of the phenocrysts show that they were broken by the movements of the surrounding glass. According to the microscopical determination the ash is an andesitic pumice.

So far as is known, the ejection of the ash was unaccompanied by the outflow of lavas. No volcanic bombs or pyroclastic materials other than the ash have been noted, and it is probable that the outburst consisted solely of violent explosions which carried the ash outward but failed to yield other types of volcanic material.

All who have written of the volcanic ash in this district have recognized the fact that the eruption must have happened no great number of centuries ago. Dawson observed that as the rivers have not cut their beds perceptibly deeper since the deposit was laid down on their flood plains, the period to which the ash belongs can not be exceedingly remote. He also noted that at one place'on the Lewes the ash rests upon a layer of stratified sands a few feet thick, and the

[1] Moffit, F. H., and Knopf, Adolph, op. cit., pp. 43-44.

sands overlie a mass of drift logs still quite sound and undecayed. From these and other facts Dawson believes that the date of the eruption, though at least several hundred years ago, can scarcely be more than a thousand years ago. Hayes arrives at a similar conclusion, but from different facts. He believes that the freedom of large ash areas from tundra moss, which covers with great readiness even the most barren surfaces, indicates the youth of the ash. He states that although great quantities of ash must have fallen on the surface of Klutlan Glacier and its névé fields, the fact that nearly all the ash now found there is in the terminal moraines, that on the stagnant ice extending only a short distance back from its front, indicates that since the eruption the ice which then formed the névé has moved the entire length of the glacier and deposited its ash in the terminal moraine. This he thinks must have required at least several hundred years. He also notes a retreat of the glacier front of about 3 miles since the ash fell.

During the summer of 1914 the writer made observations in White River basin that afford an opportunity for a more accurate calculation of the time that has elapsed since the ash fell. On White River, about 25 miles northwest of the supposed center of eruption, an excellent exposure shows a deposit of 39 feet of peaty vegetable material, interrupted 7 feet below its top by a 2-foot layer of ash (Pl. VI, C). The peculiar appearance of the roots of spruce trees growing on the surface of the peat suggested the possibility of determining the rate of peat accumulation at that place. The ordinary spruce tree of this region has a flat root base and sends its roots out radially, parallel with the surface. The roots penetrate only a few inches below the surface of the ground. In the locality just mentioned, however, each spruce tree has a central stem root, some of them several feet long, from which roots branch off at irregular intervals, including an upper set of roots near the surface, corresponding to those of the normal tree. The lower roots are in permanently frozen ground, and only the upper ones are functioning. It therefore seems evident that the trees as they grew were surrounded by a constantly thickening layer of vegetable material. In this material the level of ground frost rose as the deposit increased in thickness, the lower roots of the trees became permanently frozen, and the trees were forced to throw off adventitious roots near the surface repeatedly, in their efforts to survive. This study, details of which have been published elsewhere[1] showed that dividing the age of a living tree, as indicated by the annual rings, by the thickness of the peaty deposit above the lowest roots gives a rate of accumulation of the peat of about 200 years to the foot. On that basis the volcanic eruption that caused the ejection of the widespread sheet of volcanic ash in the upper Yukon basin took place approximately 1,400 years ago.

Although perhaps the most recent volcanic eruption within the Yukon basin, the White River eruption offers by no means the only evidence of comparatively recent volcanic activity in that district, where lavas that were poured out subsequent to an earlier stage of Pleistocene glaciation are extensively developed. On the east branch of Dennison Fork of Fortymile River a volcanic crater, with associated lava flows, is so young that it still retains much of its original topographic form, and Quaternary lavas have been recognized elsewhere.

[1] Capps, S. R.: An estimate of the age of the last great glaciation in Alaska: Washington Acad. Sci. Jour., vol. 5, pp. 108-114, 1915.

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