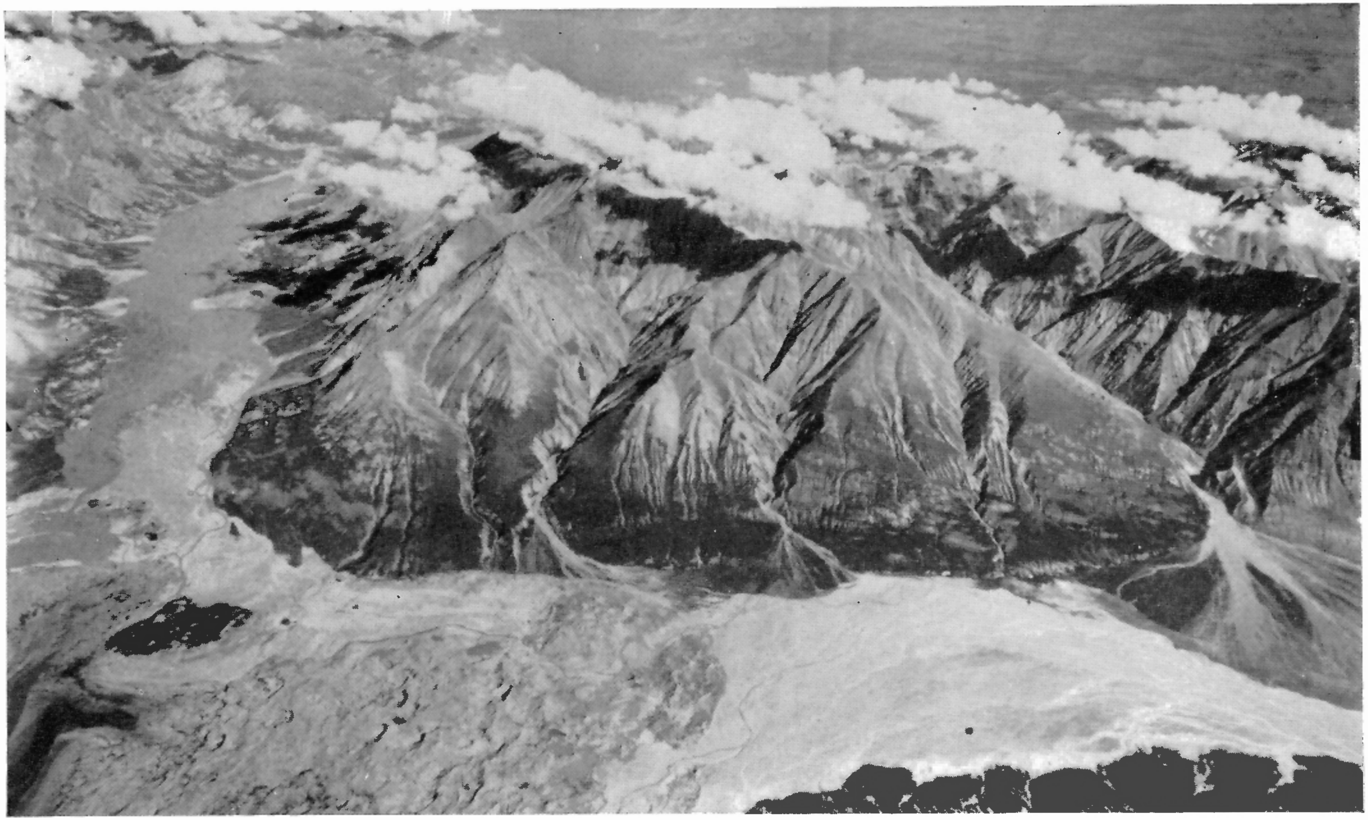
MEMOIR 267

GEOLOGY OF NORTHWEST SHAKWAK VALLEY, YUKON TERRITORY

BY

H. S. BOSTOCK

GEOLOGICAL SURVEY
DEPARTMENT OF MINES AND TECHNICAL SURVEYS
OTTAWA
1952



View from an elevation of 20,000 feet across the end of Kaskawulsh Glacier to Kluane Ranges. The stagnant ice of the glacier shows in the left foreground. From its left or west side the water drains northward by Slims River down the valley on the left to Kluane Lake, faintly visible in the distance over the clouds, and thence 1,400 miles to Bering Sea. From the foreground in the centre the water flows to the right into Kaskawulsh River eastward into Alsek River, reaching the Gulf of Alaska in about 140 miles. On the left a hill of bedrock clothed by mature spruce forest and with moraines banked against it forms the present divide. (Photo by U.S.A.A.F., negative 41-F-28-R-79; and Geol. Surv., Canada, negative 104188.) (Page 6.)

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 267

GEOLOGY OF NORTHWEST SHAKWAK VALLEY, YUKON TERRITORY

BY

H. S. Bostock

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1952

Price, 75 cents No. 2507

52458—1½

CONTENTS

CONTENTS—*Conc.*

CHAPTER V

Illustrations

PREFACE

Much of the territory adjacent to the Alaska Highway, in northeastern British Columbia and southern Yukon Territory, has been mapped geologically in the past few years, or is in process of being mapped, by the Geological Survey of Canada. The present report deals with an area that includes the extreme northwestern section of this highway in Canada, from south of Kluane Lake in the Yukon to the Alaska boundary, a distance of some 170 miles. In this distance the highway follows a prominent, furrow-like depression known as Shakwak Valley, in which lies most of Kluane Lake and parts of several glacier-fed streams draining northerly to the Arctic or southerly into the Pacific Ocean.

The report deals at some length with the physiography and glacial features and history of Shakwak Valley and of broad mountainous areas on either side; with the complex geology of the region, which comprises sedimentary, volcanic, and intrusive rocks of various ages ranging from Precambrian to Recent; and with the economic possibilities of an area that prior to the construction of the Alaska Highway had been relatively inaccessible. In addition, it includes a full account of the widespread Recent deposit of volcanic ash in southwest Yukon Territory.

GEORGE HANSON,
Chief Geologist, Geological Survey of Canada

OTTAWA, January 2, 1952

Geology of Northwest Shakwak Valley, Yukon Territory

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

The Northwest Shakwak Valley of this report embraces a region extending diagonally northwestward from near the intersection of the 138th meridian and latitude 61° to that of the 141st Meridian, the International Boundary, and latitude 62°40′. This is essentially the region readily accessible from the Alaska Highway[1], but includes adjoining areas that have been explored and mapped geologically. Kluane, Burwash Landing, and Snag were the only settlements in the region before the construction of the Highway. Since then small centres have risen at the maintenance camps along the Highway and at the Snag airport.

ACCESSIBILITY

The construction of the Alaska Highway and the Haines Road have made much of southwestern Yukon Territory readily accessible for prospecting and mining development. These roads connect the railhead at Whitehorse and the seaport of Haines with Kluane, on Kluane Lake, and distant 140 and 201 miles, respectively, from it.

Formerly, though relatively close to Whitehorse, this region was a comparatively difficult part of southern and central Yukon to enter, as navigation of those branches of the great waterway of Yukon River that penetrate it is not generally practical. By 1904, a rough wagon road had been built from Whitehorse to Kluane (21, p. 16)[2] and became the thoroughfare to southeastern parts of the region. The general route of this old road is followed to Kluane by the present Alaska Highway.

During the stampede to the upper White River and Chisana areas in Alaska in 1913 (8), many prospectors and much freight were transported up White River from the Yukon by river boats, including two or three small stern-wheel craft, as far as the mouth of Donjek River, and in some instances to Snag. Though a small stern-wheel boat is reported to have made the trip from Yukon River to Kluane Lake by ascending Donjek and Kluane Rivers this route has proved impractical, and is only used by canoes and small boats for travel downstream.

A less important route into the northwest part of the region, also used during the 1913 stampede, was the pack-trail from Coffee Creek, on Yukon River, past Wellesley Lake, to Snag.

[1] *See* Index map on geological map in pocket.

[2] References in parentheses are to Bibliography at the end of this chapter.

The generally light snowfall of the region enables horses to range throughout the winters in parts of the main valleys, and because of this, the open nature of the country, and the abundant grass in summer, horses are the chief means of transport away from the roads. In summer they can be used in most parts of the area mapped. The chief obstacles are the larger glacial streams, and these can generally be forded during the mornings after cool nights.

Kluane Lake affords a means of reaching the areas adjacent to its shores, but the lake itself is subject to storms, the prevailing wind in summer blowing from the southeast. Streams entering the lake are unsuited for navigation, though Brooks Creek can be ascended by canoe to Mineral Creek.

Several lakes, such as Teepee Lake, can be utilized by planes on pontoons in otherwise out of the way parts, and the Snag airport and the airstrip west of Burwash Landing are serviceable throughout much of each year.

FIELD WORK AND ACKNOWLEDGMENTS

Information for this report and accompanying map has been gathered from several sources, but mainly from publications and field notes by officers of the Geological Survey of Canada. Almost all of the geological work has been of a reconnaissance character along exploratory routes and, except that of the Steele (Wolf) Creek area by R. P. Sharp (27), detailed data have been acquired only incidentally.

The first exploratory work done in the region by a geologist was by C. W. Hayes (17) of the United States Geological Survey, who in 1892 crossed from Fort Selkirk to White River and thence into Alaska. In 1898 and 1899, A. H. Brooks (5, 6), also of the United States Geological Survey, conducted explorations through parts of the region. In the first year he ascended White River to Snag, turning west from there into Alaska; and during the second year he traversed from Pyramid Harbour on Lynn Canal to the head of White River.

The first work by the Geological Survey of Canada was that by R. G. McConnell, who explored Kluane Lake district in 1904 (21) and the headwaters of White River in 1905 (22). In 1913, D. D. Cairnes (8, 10) explored and mapped an area adjacent to the International Boundary west of White River. In 1914 (9) he traversed from Whitehorse to Kluane, thence to Nansen Creek, and, returning to Kluane, continued northwestward to Canyon City where he turned north along the west side of White River, crossed to Wellesley Lake, and reached Yukon River at Coffee Creek. He had planned maps and a memoir to cover the entire region of southwestern Yukon including Fort Selkirk and Whitehorse, but the completion of this work was prevented by his untimely death in 1917, and only the principal map, a compilation of the geology on a scale of 1 inch to 8 miles (12), and two small maps were published. Considerable information contained in his field notes of 1914 has been made use of in this report.

R. P. Sharp (27) accompanied the Wood Yukon Expedition in 1941, and explored and mapped the geology of the Steele (Wolf) Creek area. His work constitutes the most complete study of any part of the region. In 1944, C. E. Mitchener and G. B. Leech (24) traversed parts of the area north of Kluane Lake and the Alaska Highway, and have supplied some notes and a sketch map showing the outlines of the granitic intrusions.

In 1945, the writer examined the parts accessible from the Alaska Highway, paying particular attention to those that had not been explored previously.

The compilation has been made from the above sources, each of which has been the main source of information for some particular part of the map-area, and for this reason their contributions are delineated below.

Information on the area south of Snag Creek and west of White River and along the old pack-trail route from Burwash Landing to Canyon City has been obtained from the work of D. D. Cairnes (8-12). For those parts around the shores of the main body of Kluane Lake and to the east reference has been made, first to the work of R. G. McConnell (21) and second to that by D. D. Cairnes (12). For the Steele (Wolf) Creek area in the southwest, full use has been made of the report and map by R. P. Sharp (27). Information supplied by C. E. Mitchener and G. B. Leech (24) has been used to extend the north border of the mapped area east of Kluane River and in places between Kluane and White Rivers. The areas around the north arms of Kluane Lake, westward along the Alaska Highway to White River and north of Snag Creek were visited, in 1945, by the writer, who also collected information on the geology between Slims Valley and the heads of Burwash and Quill Creeks. In addition, the writer assumes the responsibility for certain adjustments and correlations in assembling the data available from these various sources. In the field he was ably assisted by R. M. Thompson, J. O. Wheeler, E. Stinson, and J. H. C. Hughes.

BIBLIOGRAPHY

1. Black, R. F.: Eolian Deposits of Alaska; Arctic, vol. 4, No. 2, pp. 89-112 (Sept. 1951).
2. Bostock, H. S.: Physiography of the Canadian Cordillera, with Special Reference to the Area North of the Fifty-fifth Parallel; Geol. Surv., Canada, Mem. 247, 1948.
3. ———Carmacks District, Yukon; Geol. Surv., Canada, Mem. 189, 1938.
4. ———and Lees, E. J.: Laberge Map-area, Yukon; Geol. Surv., Canada, Mem. 217, 1938.
5. Brooks, A. H.: A Reconnaissance in the Tanana and White River Basins, Alaska, in 1898; U.S. Geol. Surv., Ann. Rept. 20, pt. 7, pp. 425-494 (1900).
6. ———A Reconnaissance from Pyramid Harbour to Eagle City, Alaska, including a description of the Copper Deposits of the Upper White and Tanana Rivers; U.S. Geol. Surv., Ann. Rept. 21, pt. 2, pp. 331-391 (1900).
7. Cairnes, D. D.: Lewes and Nordenskiöld Rivers Coal District, Yukon Territory; Geol. Surv., Canada, Mem. 5, 1910.
8. ———Upper White River District, Yukon; Geol. Surv., Canada, Sum. Rept. 1913, pp. 12-28 (1914).
9. ———Explorations in Southwestern Yukon; Geol. Surv., Canada, Sum. Rept. 1914, pp. 10-33 (1915).
10. ———Upper White River District, Yukon; Geol. Surv., Canada, Mem. 50, 1915.
11. ———Kluane Lake, Yukon Territory; Geol. Surv., Canada, Map 152A, 1917.
12. ———Southwestern Yukon; Geol. Surv., Canada, Map 154A, 1917.
13. Capps, S. R.: An Ancient Volcanic Eruption in the Upper Yukon Basin; U.S. Geol. Surv., Prof. Paper 95, pp. 59-64 (1916).
14. ———Glaciation in Alaska; U.S. Geol. Surv., Prof. Paper 170-A, 1931.
15. Cockfield, W. E.: Sixtymile and Ladue Rivers Area, Yukon; Geol. Surv., Canada, Mem. 123, 1921.

16. Dawson, G. M.: Report on an Exploration in the Yukon District, N.W.T., and adjacent Northern Portion of British Columbia, 1887; Geol. Surv., Canada, Ann. Rept. 1887-88, pt. 1, Rept. B (1889).

17. Hayes, C. W.: An Expedition through the Yukon District; Nat. Geog. Mag., vol. IV, pp. 117-162 (May 15, 1892).

18. Kindle, E. D.: Geological Reconnaissance along the Canol Road from Teslin River to MacMillan Pass, Yukon; Geol. Surv., Canada, Paper 45-21, Second edition, 1945.

19. ———Dezadeash Map-area, Yukon; Geol. Surv., Canada, Paper 49-24, 1949.

20. Lees, E. J.: Geology of Teslin-Quiet Lake Area, Yukon; Geol. Surv., Canada, Mem. 203, 1936.

21. McConnell, R. G.: The Kluane Mining District; Geol. Surv., Canada, Sum. Rept. 1904, pt. A, pp. 1-18 (1905) and accompanying Map 894.

22. ———Headwaters of White River; Geol. Surv., Canada, Sum. Rept. 1905, pt. A, pp. 19-26 (1906).

23. Mertie, J. B., Jr.: The Yukon-Tanana Region, Alaska; U.S. Geol. Surv., Bull. 872, 1937, and Map.

24. Mitchener, C. E., and Leech, G. B.: Personal communication, 1944.

25. Moffit, F. H., and Knopf, A.: Mineral Resources of the Nabesna-White River District, Alaska, with a section on the Quaternary by S. R. Capps; U.S. Geol. Surv., Bull. 417, pp. 42-44 (1910).

26. Schwatka, Frederick: Along Alaska's Great River; George M. Hill Company, Chicago, New York, 1898.

27. Sharp, R. P.: Geology of the Wolf [Steele] Creek area, St. Elias Range, Yukon Territory, Canada; Bull. Geol. Soc. Amer., vol. 54, pp. 625-650 (1943).

28. Yukon Territory: Kluane Lake, White and Alsek Rivers; from surveys by the International Boundary Commission, 1893-95; J. B. Tyrrell, 1898; A. C. Talbot, 1899; and J. J. McArthur, 1900; Department of the Interior, Canada, 1905.

CHAPTER II

PHYSIOGRAPHY

GENERAL STATEMENT

The area mapped lies astride the border between two major physiographic subdivisions (2), the Yukon Plateau and the St. Elias Mountains, and includes parts of their subdivisions. Shakwak Valley forms a great furrow separating the plateau on the northeast from the mountains on the southwest. On the northeast, the Yukon Plateau is represented by parts of two of its subdivisions, Kluane and Klondike Plateaux. Kluane Plateau includes parts of Ruby Range and of Wellesley Basin, and Klondike Plateau is represented by only a small area, north of Snag Creek. On the southwest, Kluane Ranges form the northeast front of the St. Elias Mountains adjacent to Shakwak Valley, and are separated from them by the broad hollow of the Duke Depression. To the southwest of this depression are the Icefield Ranges, the main body of the St. Elias Mountains, of which only a fringe, including Donjek Range, lies within the area mapped.

SHAKWAK VALLEY

Shakwak Valley separates Kluane Plateau from the St. Elias Mountains. It is the most significant physiographic feature of the region mapped, and forms a great furrow through this mountainous terrain, a natural passage followed by the Alaska Highway. Its remarkably straight southwest side, broken at intervals by large stream valleys, rises in steepening slopes to the front ridges of Kluane Ranges. Its northeast side is less regular, and is cut into many, less well alined and lower plateau segments by both major and minor valleys.

The floor of Shakwak Valley is 2 to 5 miles or more wide, and is covered by till, gravel, sand, silt, and alluvium, the whole mantled by a thin deposit of volcanic ash and areas of loess. The drift forms extensive, undulating moraines, long, narrow, drumlin-like ridges, pitted outwash areas, lake terraces, deltas, and alluvial fans. The moraines are mainly on the northeast side, notably between Kluane and Donjek Rivers and west of White River. The drumlin-like ridges are on the southwest side of the valley and occur here and there from Halfbreed Creek northwest to a point a few miles beyond White River. Their long axes parallel the valley side, and are approximately straight except at the junction of Donjek Valley. Donjek River has entrenched its course across the floor of Shakwak Valley, removing the glacial drift and replacing it with a broad flood plain of gravel, sand, and silt. Duke and Koidern (Edith Creek) Rivers and Burwash Creek, and to a less degree the smaller streams entering Shakwak Valley from the southwest, have steep gradients and are heavily loaded during times of flood. They, too, have cut away or covered the glacial debris where they enter the valley, and have built large fans that have diverted the main streams, Kluane and Koidern Rivers, to the northeast side of the valley floor.

KLUANE LAKE

Kluane Lake is an outstanding feature of Shakwak Valley, and exhibits unique characteristics. At irregular intervals during the last 45 years its mean annual level is reported to have fluctuated as much as 10 feet. These fluctuations are a result of several variable factors. One is the quantity of gravel, etc., deposited annually by Duke River in Kluane River, which is the outlet of the lake. When this quantity is large, it clogs Kluane River, and raises the lake level. At times, as at present, Kluane River, whose course is in unconsolidated materials for several miles below the lake, is able to remove this load and maintain a relatively low level for the lake.

This simple control is greatly complicated by other factors. One of these has been the variation in the quantity of water reaching the lake by Slims River, which is the main stream entering the lake. It is reported that at times in the last 45 years much of the water from the glacier at its source, which normally flows to Slims River, escaped to Kaskawulsh River, as evidenced by the dry channels between the heads of these rivers at the front of the glacier (Plates I and II A). Another factor has been the changes in the course of Duke River, which at times before this century flowed directly into Kluane Lake by a channel southeast of its present course known as Duke Meadows and, still earlier, by other courses farther east, clearly discernible in air photographs. Under these conditions the volume of Kluane River was increased, without the load being added to, so that the ability of the river to erode the loose materials of its channel, enlarge the outlet, and lower the level of Kluane Lake was enhanced. In addition, climatic variations, including those of annual precipitation and ablation of the mountain glaciers, play their parts. Normally these factors modify one another, but at times they become synchronized to cause changes in lake level of the order referred to above.

Other features bear witness to earlier changes in the level of Kluane Lake on a grander scale. Among these is a group of fresh shorelines only readily distinguishable at favourable places where exposure to wind and waves enabled them to be developed in a comparatively short time. These shorelines occur up to 30 feet above the summer level of 1945, and record an extensive but short-lived inundation that ended sufficiently long ago for the present mature spruce forest to have grown over the flooded areas.

Also, a former level for the lake, lower than the present level, is evidenced by the estuaries of several of the creeks entering the lake. Gladstone Creek estuary is an important example. It is about $\frac{3}{4}$ mile long and $\frac{1}{2}$ square mile or more in area, and is bounded by steep banks of drift, 75 feet or more high in the outer part along the lake shore and more than 250 feet high at its head. The first outcrop in the valley floor is $1\frac{3}{4}$ miles from the estuary. Up to this outcrop, the creek has entrenched a deep, broad valley in the drift, and above it the valley continues for many miles 100 to 200 feet deep in the drift, so that the quantity of drift removed in forming the valley is immense as compared with the small delta the creek is now building in the estuary. Gladstone Creek has an average fall of more than 100 feet a mile in the lowest 4 miles, and though the grade is flatter as it reaches the delta there are numerous riffles over gravel almost to its mouth. The outer part of the estuary was observed to be more than 20 feet deep. The creek gradient and length of the estuary suggest that it is 40 feet or more deep, and that the former level of the lake was at least that much below the present level. Comparison of Gladstone Creek Valley and its present delta show that the creek required a much longer period to cut the valley of the estuary down to the lower level of the lake than it has required to build the small delta in the estuary. Stumps of drowned spruce trees in the shallows of the lake and, along the beaches, an abundance of driftwood exhibiting a soft, stained and porous condition characteristic of wood long submerged, are witness of the recentness of this flooding.

Christmas Creek, at the southeast end of Kluane Lake, meanders on the floor of a valley entrenched 100 to 200 feet in drift. At the lower end, the valley forms a large estuary, 1½ miles long, at Kluane Lake. Upstream, the valley continues eastward over the divide beyond the head of Christmas Creek to the drainage area of Jarvis River, where it is no longer traceable in a pitted area of drift. The valley was evidently cut by a stream much larger than Christmas Creek and heading east of the divide; to obtain this condition part of Jarvis River drainage must have been diverted from its present course, which was probably choked by drift and bodies of ice during the ablation of the ice of the last major glaciation. These features of Christmas Creek Valley show that the valley was formed when Kluane Lake was much lower than at present, and suggest that the lake had this low level early in Recent time.

Soundings made along a line between Sandspit Point and a promontory about 1½ miles east of Burwash Landing indicate a maximum depth of 30 feet. West of this line, the lake is shallow, and no soundings of more than 20 feet were obtained to the entrance to Brooks Arm, where depths of 40 feet were recorded in places. West of Jacquot Island, the greatest depth measured was 65 feet. South and west of Cultus Creek, the greatest depth obtained was 270 feet, though Talbot Arm and the extreme southern part of Kluane Lake were not sounded and may be deeper. These depths suggest that it is improbable that an outlet 20 feet deeper than the present ever existed at the west end of the lake.

The only likely outlet for Kluane Lake basin at levels 20 feet or more below the present, essential for the development of the estuaries, is by Slims and Kaskawulsh Valleys (Plates I and II A). The junction of these valleys, about 14 miles south of Kluane Lake, has been blocked by Kaskawulsh Glacier, which projects about ½ mile down Slims Valley and about the same distance into Kaskawulsh Valley. A moraine ½ to 1 mile in front of the present ice marks the limit reached by the last advance, which ceased about 150 years ago (21, p. 10). Since then the ice-front has retreated, and now allows water issuing from its medial parts to flow into either Slims or Kaskawulsh Rivers, as previously noted. In 1945, the main source of Slims River was the area where the alternate courses can be followed.

Other phenomena that shed light on the history of Kluane Lake are exhibited by Slims River Valley and Delta. Old timers proclaim the rapid advance of Slims Delta into Kluane Lake, and point to broad, dry, mud flats where formerly they rowed their boats. An advance of as much as ¼ mile in a year is claimed, and although this may actually apply to only a small part of the delta front and may be partly due to minor fluctuations of lake level, it is apparent that Slims River is heavily loaded with silt, sand, and gravel from Kaskawulsh Glacier and that it is building its delta rapidly out into Kluane Lake.

The only means of obtaining even a rough estimate of the rate of this advance is by comparing some of the earlier maps (28 and 11) with the latest map (Kluane Sheet, in preparation for publication), and with the available air photographs. Comparison of the positions of the delta relative to the island in the south end of Kluane Lake shows that the delta advanced 0·7 mile between 1899 and 1914 and 1 mile between 1914 and 1947, or, in the 48 years from 1899 to 1947, the advance was 1·7 miles. These figures give the average rates per year as 243 feet, 158 feet, and 185 feet, respectively. Using the minimum figure of 158 feet, it is apparent that Slims River could have filled the 14 miles of valley, between the moraines in front of Kaskawulsh Glacier and the front of its delta in Kluane Lake, in less than 500 years.

These figures are based, among other things, on the assumption that the section of the valley filled by the river was uniformly as large as that of the present delta, whereas for most of its 14 miles it was considerably smaller, due to the large alluvial fans of Vulcan, Bullion, and the other tributary creeks that enter the valley. From this it is thought that the time required to fill the valley may have been less than 500 years.

Capps (13, pp. 4-6) gives evidence indicating that the front of Russell Glacier at the head of White River in Alaska, a few miles west of the area mapped, has not advanced beyond a point 8 miles from its present front for 8,000 years or perhaps longer. It is more than probable that at least as long a time has elapsed since Kaskawulsh Glacier retreated above the present south end of Kluane Lake.

It is concluded that Slims River and Kluane Lake have been in existence as they are today for only a relatively short part of Recent time. At the close of the last major glaciation, Kaskawulsh Glacier receded at least some miles above its present position, and the basin of Kluane Lake drained up Slims Valley and thence by Kaskawulsh Valley into Alsek River. This condition has persisted through most of Recent time. Some centuries ago the outlet was closed by the advance of the glacier, and Slims Valley and the basin of Kluane Lake were flooded to a level 30 feet above that of 1945. The lake then overflowed to westward, developing the present outlet of Kluane River, which has quickly cut through the drift to its present level.

As a result of the present continued retreat of Kaskawulsh Glacier, and the steep gradient of Kaskawulsh River, about 28 feet per mile, in contrast with that of Slims River, about 10 feet per mile, the recapture of Slims River by the Kaskawulsh is apt to begin in the near future, and the capture of Kluane Lake may follow when a channel has been cut back through the unconsolidated drift fill on the floor of Slims Valley.

SHAKWAK VALLEY FAULT

The straight, steep front of Kluane Ranges along the southwest side of Shakwak Valley and the marked difference in the geology on each side of the valley, illustrated by the restriction of the old Yukon group rocks largely to the northeast and of the younger formations to the southwest, are evidence of a great fault zone along the valley, extending from west of White River southeastward beyond the mapped area to at least Dezadeash Lake (20, p. 28). The persistent drift-cover a mile or more wide everywhere along the valley prevents close study of the fault zone, but a general relative uplift of the northeast side is indicated, though this may not represent the more recent movements along the fault.

Examination of air photographs of the valley on the east side of Donjek River reveals a line of small, irregularly spaced, elongated mounds surmounted by relatively large trees traversing the slopes of tundra and stunted spruce (Plate IV). The mounds follow a nearly straight line along the general direction of the valley regardless of local changes in directions of slope or the interposition of glacial features, such as drumlinoid ridges, but are missing where the streams have been active recently, as on the flood plains of Donjek River and in the courses and alluvial fans of the creeks in line with the mounds.

This line of mounds is most apparent on the east side of Donjek River, but can be traced at intervals from west of White River in the northwest to the far side of Kluane Lake in the southeast. The feature is believed to mark the trace of a fault along Shakwak Valley in which there has been movement in recent centuries. Although the bedrock geology indicates a general vertical displacement, the alinement of the mounds marking the fault suggests significant lateral movement.

KLUANE PLATEAU

Northeast of Shakwak Valley the rolling upland surface of Kluane Plateau has a general elevation of 5,000 feet, above which Ruby and smaller ranges and mountains rise 1,000 to 2,500 feet. East of Kluane River a terrace-like border area 3 to 7 miles wide lies between Shakwak Valley and Ruby Range, and together with the range is dissected at intervals of about 10 miles into segments of plateau and mountains by deep, U-shaped valleys. Ruby Range is the highest part of the plateau, and its rugged peaks, cut into by alpine cirques, reach elevations up to 8,000 feet. Within each segment an irregularly branching system of high ridges, commonly topped by remnants of the undulating upland surface of the plateau, connects the peaks.

North of Ruby Range the upland surface of Kluane Plateau slopes down into a broad hollow beyond which it rises again to Nisling Range, which lies beyond Talbot Creek, northeast of the area mapped. The hollow follows a line along Talbot Creek Valley and extends northwest beyond the north end of Tincup Lake. The terrain north of Talbot Arm and stretching northwest to Swanson Creek is a net of drift-filled, poorly drained, wide valleys, with flat, intricate divides between Kluane River and Nisling River drainage basins. The upland areas between the valleys are bordered by steep slopes surmounted by mature, rolling, open surfaces.

West of Kluane River, Kluane Plateau is similarly dissected by deep valleys into upland segments, but on a smaller scale, and elevations on it decrease to the northwest to about 4,500 feet near White River.

West of White River, the upland surface of the plateau is represented on widely scattered hills surrounded by broad valleys that merge northward and form Wellesley Basin.

WELLESLEY BASIN

Broad, undulating areas of drift and wide, pitted terraces of thick deposits of gravel, sand, silt, and till are characteristic of the floor of Wellesley Basin. The general slope is northward from an elevation of about 2,400 feet on the south side of the basin to less than 1,900 feet near Snag. Here and there above this surface hills of bedrock rise 500 to 1,500 feet or more. Within the basin, Beaver and Snag Creeks have established broad flats along their meandering courses, and the divide between Snag and Mirror Creeks is very flat. Dry Creek and White River have entranched themselves deeply in the drift.

KLONDIKE PLATEAU

North of Beaver, Snag, and Mirror Creeks, Klondike Plateau rises along a persistent but broken line of undulating hills to elevations that reach 2,200 to 3,125 feet in the south and become higher to the north. The Pleistocene ice-front pushed tongues northward into the valleys along the border of the plateau for a few miles, choking the valleys with drift and disrupting the drainage (Plate III). Bedrock is rarely exposed, drift mantling the lower slopes, and residual soil the upper and unglaciated areas.

KLUANE RANGES

Kluane Ranges rise from the southwest side of Shakwak Valley as a steep, straight, wall-like front, and form a broad, composite, outer ridge of the St. Elias Mountains. This ridge is dissected by the transverse valleys of Slims, Duke, Donjek, and White Rivers into segments each of which comprises one or more, long, nearly parallel, mountain ridges, with peaks 6,500 to 8,000 feet high. The segment between Slims and Duke Rivers is composed of a single, broad ridge. In the segment between Duke and Donjek Rivers two ridges spread northwestward, and beyond the Donjek to White River the adjoining segment widens from two into three ridges. West of White River, Kluane Ranges are less regular in their plan of nearly parallel ridges, and the broad valley of Tchawsahmon Lake divides them into two almost detached block-like areas of mountains with branching divides and summits.

DUKE DEPRESSION

The Duke Depression is an upland valley lying behind or southwest of Kluane Ranges and separating them from the main body of the St. Elias Mountains, the Icefield Ranges (Plate II B). It trends northwesterly with the mountains, and is characterized by more mature profiles within it and on the mountains forming its flanks. Within the area covered by the map, the depression is narrowest on the divide between Sheep Creek and Duke River, where it is represented only by the smooth profiles of the slopes on each side of the high pass between these streams. Northwest of this divide it opens to a width of 2 or 3 miles where Duke River enters it, and from there, with some local constrictions on the divides between the major streams that cross it, it steadily widens westward to White River where it reaches a maximum width of about 20 miles. West of White

River, mountains at the International Boundary confine it to about a width of 12 miles. Northwestward across White River the broad valley of Tchawsahmon Lake continues the line of the northeast side of the Duke Depression, at about the same levels, but the valley diminishes westward into the mountains and forms only a branch of the main feature.

The general level of the floor of Duke Depression is 1,500 feet or more above that of Shakwak Valley. Duke, Donjek, and White Rivers are deeply entrenched across the depression below this level, and other large streams are cutting into it.

The northeast side of Duke Depression slopes steeply up to Kluane Ranges. On the southwest side, a belt of plateaux stands with steep, northeasterly facing slopes overlooking the floor of the depression and forming a terrace-like step in front of the Icefield Ranges. East of Donjek River, the belt is dissected into individual mountain blocks, including Amphitheatre Mountain, whose flat top is about 6,500 feet above sea-level; west of the river it forms more continuous areas of smooth uplands, which, south of Wolverine and Harris Creeks, reach an elevation of about 5,500 feet. In many parts the uplands surface of the plateaux of this belt slopes southward from the terrace front to high open valleys along the foot of the Icefield Ranges. Beyond St. Clare Creek, the plateau belt is represented by broad rounded hills, 4,300 to 4,700 feet high, that slope down to the wide, rolling, drift-covered floor of the depression.

ICEFIELD RANGES

Southwest of the plateau belt bordering Duke Depression, the Icefield Ranges stand along a broken front. Their ridges lack a defined parallel pattern, and commonly lead back from their outer spurs into the interior where they reach elevations of 10,000 feet or more near the great peaks at the heart of the ranges.

Donjek Range forms a part of the front of the Icefield Ranges, but is partly isolated from the main area by the upper reaches of Donjek River Valley (Plate II B). It is composed of sharp ridges and peaks rising to elevations of 8,000 to 10,000 feet and contains several small glaciers.

Behind the Donjek Range, Donjek Valley forms a wide hollow in the mountains and exhibits smooth profiles, particularly on the southwest side, resembling those of the Duke Depression. The great Donjek Glacier enters the valley from the southwest and covers the full width of its floor for a length of 6 miles. At the lower end of the glacier, the ice-front lies across the valley floor at an elevation of 3,500 feet. Above this glacier the valley continues free of ice for 13 miles to the front of the Kluane Glacier, which lies at latitude 61 degrees and at an elevation of 4,500 feet. Farther south the Kluane Glacier fills the floor of the valley up into the mountains. Between the Donjek and Kluane Glaciers the valley is wide, and its relatively smooth, open, lower slopes are clothed with groves of spruce trees.

Donjek Valley has no large tributary valleys on the northeast, but is joined from the southwest by a series of deep valleys, each headed by its own large glacier or group of glaciers. The most important of these is the valley of Steele (Wolf) Creek[1] and the Steele (Wolf Creek) Glacier,

[1] Recently the names Steele Creek and Steele Glacier have been officially given by the Canadian Board on Geographical Names, Department of Mines and Technical Surveys, to the creek and glacier named Wolf Creek and Wolf Creek Glacier in earlier publications.

which occupies its upper reaches. This valley forms part of a high passage between the valleys of Donjek and Klutlan Rivers behind the front ranges south of Wolverine and Harris Creeks and at the foot of the spurs of Mount Wood and other great peaks to the south. It is broad and U-shaped (27, p. 627), its floor lying 4,000 to 8,000 feet below the flanking ridges, and rising from an elevation of 3,500 feet near the lower end of Steele Creek to 6,500 feet near the upper end of the Steele Glacier shown on the map. The mountains rise on the north side of the valley in a precipitous wall of summits 9,000 to 9,600 feet high. Large ice-fields lie behind the crest, and extrude small tongues of ice between the peaks. South of Steele Creek Valley the slopes, though steep, are less precipitous, and tributaries are longer. On this side the mountain spurs are capped by ice-fields, and glaciers extend down the tributary valleys. The permanent snowline has an elevation of between 8,000 and 9,100 feet, and timber-line is nearly 4,500 feet above sea-level in this valley, but somewhat lower in other parts of the area mapped.

CHAPTER III

GLACIATION

Evidence of Pleistocene glaciation is widespread in most of the region mapped. It is lacking in the extreme northwest where the ice did not reach, and on high summits that stood above the ice. Only one major advance has been recognized, and the glacial phenomena referred to here are attributed to this last well-marked major glaciation, which is tentatively considered late Wisconsin. It is probable, however, that earlier and more extensive advances took place in this region, as in areas farther north, and that in a few places features attributed to the last advance may represent an earlier one (3, pp. 10-11, and unpublished work).

The extent and maximum elevation of the ice surface during the last well-marked glaciation have been recorded in many localities. They were greatest in the St. Elias Mountains. On the mountain between Halfbreed Creek and Duke River, glacial drift and erratics and scoured rock surfaces are apparent above an elevation of 5,350 feet, but were not seen at 5,950 feet. On Amphitheatre Mountain, erratics were found just below 6,000 feet, but not higher. On the plateau areas south of Wolverine and Harris Creeks, they were observed at 5,700 feet. On the ridges around Tchawsahmon Lake the ice reached an elevation of between 5,000 and 5,300 feet (10, p. 105). Its highest levels along Shakwak Valley seem to have been near the mouth of Slims River, and probably declined northward, northwestward, and northeastward from this locality. In the Kluane Hills and Ruby Range east of Kluane Lake, the ice surface reached elevations of 5,150 and 5,200 feet, but many large summit areas here were not covered (21, p. 9). Between the arms of Kluane Lake, it reached to 5,000 feet or a little higher, and to nearly 4,800 feet north of Mineral Creek. Northwest of the junction of Donjek and Shakwak Valleys, on the northeast side of Shakwak Valley, the maximum elevation of the ice surface was 5,000 feet, or a little more, but to the westward, near Grafe Creek, it declined to 4,700 feet, and on the mountain northeast of White River bridge it apparently did not exceed an elevation of 4,600 feet. The decrease northwesterly along this part of Shakwak Valley is paralleled on the southwest side by the slope of the uppermost glacial drift.

Glacial drift and erratics occur on the top of the beam station hill north of Snag at an elevation of 2,500 feet. Looking east from the beam station, the south profile of the hills north of Wellesley Lake exhibits a distinct upper limit of surface irregularities at an elevation of about 3,000 feet, believed to mark the level reached by the ice. The limit is also apparent in air photographs north of Wellesley Lake and west of White River a few miles north of the beam station (Plate III). At the latter locality a belt of moraines is piled against the higher ground, and beyond it no evidence of glaciation can be identified.

Glacial drift, including till containing much foreign material, is exposed in gravel pits along the Alaska Highway near Mirror Creek up to elevations of at least 200 feet above the stream, but north from a point 6 miles south of the highway crossing of the International Boundary no drift deposits attributable to glaciation were noted, and the limit reached by the ice is believed to lie near this locality.

The main courses of the ice are indicated by a few striæ and by drumlin-like features in the main valleys. Most of the ice came from the Icefield Ranges, entering Shakwak Valley by the valleys of Slims, Donjek, and White Rivers. It spread into Shakwak Valley, moving northwesterly in most places to where it could escape northward along channels through the northeast side of the valley, such as those of the north arms of Kluane Lake, Kluane, Donjek, and White Rivers, and other intervening gaps. On its passage northward from Shakwak Valley the ice divided into many valley glaciers, spreading around mountains and hills too high to override, and finally lost movement in the mountain valleys northeast of the region mapped. To the northwest, it entered Wellesley Basin, where it coalesced into a broad sheet and pushed northward across this depression onto many of the lower hills, or came to rest against the slopes of higher ones, projecting tongues for some miles down the valleys of White and Donjek Rivers.

Table 1. Correlation of Formations, Northwest Shakwak Valley Map-area, Yukon Territory

NORTHWEST SHAKWAK VALLEY (H.S. Bostock)

ERA	PERIOD OR EPOCH		
CENOZOIC	RECENT		LOESS, SOIL, PRESENT STREAM DEPOSITS VOLCANIC ASH
	UNCONFORMABLE CONTACT		
	PLEISTOCENE AND RECENT		LOESS GRAVEL, SAND, SILT GLACIAL TILL
	UNCONFORMABLE CONTACT		
	POST-EOCENE TO PLEISTOCENE	TERTIARY ACIDIC IGNEOUS ROCKS	RHYOLITE, GRANITE-PORPHYRY, DYKES, AND SMALL STOCKS
	PALEOCENE AND LATER	TERTIARY VOLCANIC ROCKS	ANDESITE, RHYOLITE, DIABASE, BASALT, AND RELATED PYROCLASTIC ROCKS
	PALEOCENE TO OLIGOCENE	TERTIARY SEDIMENTARY ROCKS	CONGLOMERATE, SANDSTONE, AND SHALE, CONTAINING TUFFACEOUS MATERIAL AND, IN PLACES, LIGNITE
	UNCONFORMABLE CONTACT		
MESOZOIC AND CENOZOIC	CRETACEOUS AND TERTIARY	INTRUSIVE ROCKS	MAINLY GRANODIORITE AND GRANITE BUT INCLUDING PORPHYRIES AND INTRUSIVE ROCKS OF INTERMEDIATE, BASIC, AND ULTRABASIC COMPOSITIONS
MESOZOIC AND EARLIER	CRETACEOUS AND EARLIER	VOLCANIC ROCKS ASSOCIATED WITH MESOZOIC AND (?) OLDER SEDIMENTARY ROCKS	ANDESITE, DIABASE, BASALT; RELATED PYROCLASTIC ROCKS; EQIVALENT OF THE 'OLDER VOLCANICS'
		PALÆOZOIC (?) AND MESOZOIC SEDIMENTARY ROCKS	SHALE, SANDSTONE, CONGLOMERATE, LIMESTONE. AGE UNDETERMINED, BUT PROBABLY MAINLY CRETACEOUS AND JURASSIC
PALÆOZOIC	SILURIAN (?) TO CARBONIFEROUS (?)	DONJEK RANGE	LIMESTONE, SHALE, FELDSPATHIC SANDSTONE, TUFFACEOUS SANDSTONE, SLATE, SCHIST
	SILURIAN TO CARBONIFEROUS	SLIMS RIVER VALLEY	LIMESTONE, SHALE, ARGILLITE, GREENSTONE
	PRE-SILURIAN TO CARBONIFEROUS	SLIMS RIVER VALLEY	CLOSELY FOLDED CHLORITE SCHIST, PHYLLITE, LIMESTONE, SHALE, AND CHERT
	(the three Palæozoic units above, bracketed)		NORTH OF SNAG CREEK, LIMESTONE, SLATE, SANDSTONE, IN THIN BEDS, MUCH CONTORTED, FOLDED AND FAULTED
PRECAMBRIAN AND (?) LATER		YUKON GROUP	IN THE NORTHWEST, MAINLY QUARTZITE, QUARTZ-MICA SCHIST, LIMESTONE, AMPHIBOLITE IN THE SOUTHEAST, 'KLUANE SCHISTS': QUARTZ-MICA SCHIST, GNEISS

UPPER WHITE RIVER DISTRICT (D.D. Cairnes, 10, p. 68. 1915)

RECENT AND PLEISTOCENE	SUPERFICIAL DEPOSITS	GRAVELS, SANDS, BOULDER-CLAYS, SILTS, VOLCANIC ASH, PEAT, SOIL, AND GROUND-ICE; DOMINANTLY GLACIAL AND GLACIO-FLUVIAL DEPOSITS, WHICH ARE STILL ACCUMULATING
POST-EOCENE		RHYOLITES, LATITES, AND RELATED ROCKS
	NEWER VOLCANICS	MAINLY AUGITE ANDESITES AND BASALTS, DOMINANTLY AMYGDALOIDAL OR PUMICEOUS, WITH RELATED PYROCLASTIC ROCKS. NOT PERCEPTIBLY DISTURBED
EOCENE; POSSIBLY IN PART OLIGOCENE		CONGLOMERATES, SANDSTONES, AND SHALES, LOOSELY CONSOLIDATED IN MOST PLACES. CONTAIN SEAMS OF LIGNITE
CRETACEOUS OR JURASSIC	GRANITIC INTRUSIVES	INTRUSIVE PLUTONIC ROCKS RANGING IN CHARACTER FROM GRANITES TO GABBRO OR EVEN HORNBLENDITES, AND POSSESSING DOMINANTLY A GRANITIC HABIT. APPARENTLY REPRESENT OUTLYING PORTIONS OF THE COAST RANGE BATHOLITH
CRETACEOUS; POSSIBLY IN PART OLDER		SHALES, ARGILLITES, SANDSTONES, CONGLOMERATES, AND RELATED SEDIMENTS, CONSIDERABLY DEFORMED AND INDURATED. ONLY CRETACEOUS FOSSILS WERE FOUND, BUT JURASSIC OR EVEN TRIASSIC MEMBERS MAY BE PRESENT
CRETACEOUS; POSSIBLY IN PART OLDER	OLDER VOLCANICS	ANDESITES, DIABASES, BASALTS, AND RELATED ROCKS WITH THEIR ACCOMPANYING TUFFS. THESE ARE INTIMATELY ASSOCIATED WITH THE MESOZOIC AND CARBONIFEROUS SEDIMENTS AND ARE, IN PART, CONTEMPORANEOUS WITH THEM
CARBONIFEROUS (MAY INCLUDE SOME PERMIAN BEDS)		SHALES, SANDSTONES, CONGLOMERATES AND OCCASIONAL BEDS OF LIMESTONE, CONSIDERABLY DEFORMED, INDURATED AND IN PLACES METAMORPHOSED
		MASSIVE LIMESTONE WITH SOME ASSOCIATED CHERTS, CONSIDERABLY METAMORPHOSED
PRECAMBRIAN (?)	YUKON GROUP	MICA SCHISTS, QUARTZ-MICA SCHISTS, QUARTZITE SCHISTS. SCHISTOSE QUARTZITES, AND SCHISTOSE AMPHIBOLITES

WOLF (STEEL) CREEK AREA (R.P. Sharp, 27, p. 630. 1943)

QUATERNARY	RECENT GRAVELS	FEW HUNDRED FEET THICK AT MOST, LARGELY BOULDERY OUTWASH GRAVELS OF MODERN GLACIERS
	RECENT MORAINES	100 TO 200 FEET, FRESH, BOULDERY TILL OF PRESENT GLACIERS AND MODERN ADVANCE 100 TO 200 YEARS AGO
	LATER OR POST-WISCONSIN MORAINES	100 FEET, BOULDERY TILL, SLIGHTLY WEATHERED, COVERED WITH VEGETATION, EXACT AGE UNKNOWN
	EARLIER WISCONSIN MORAINES	100 FEET, BOULDERY TILL, NOTICEABLY WEATHERED, SUBDUED TOPOGRAPHY 500 TO 1500 FEET ABOVE PRESENT STREAMS, OLDER THAN PRECEDING LATER OR POST-WISCONSIN MORAINES, BUT STILL PROBABLY LATE WISCONSIN
TERTIARY	VOLCANICS	4,600 FEET, WELL-LAYERED BASALT, ANDESITE, TRACHYTE, QUARTZ LATITE, OBSIDIAN, ASH, TUFF, AGGLOMERATE, BRECCIA, ALL OF LOCAL ORIGIN; VOLUME OF FLOWS AND PYROCLASTICS ABOUT EQUAL, MAFIC DIKES, SILLS, PLUGS ASSOCIATED
[UNCONFORMABLE CONTACT] (27, p. 628)		
EARLY TERTIARY OR LATE MESOZOIC	GRANITIC INTRUSIVES	LARGE BATHOLITHIC BODY PORPHYRITIC BIOTITE GRANITE AND HORNBLENDE-BIOTITE QUARTZ MONZONITE, LOCALLY MINERALIZED AND CONTAINING MOLYBDENITE
PERMIAN	SEDIMENTARY ROCKS	1,500 FOOT, WELL-STRATIFIED LIMESTONE, LIMY SANDSTONE, SANDSTONE, GRIT, CHERT, SANDY TUFF, AND WATER-LAID TUFF, CONTAINING PERMIAN FOSSILS
[UNCONFORMABLE CONTACT] (27, p. 628)		
PENNSYLVANIAN (?)	GABBRO	STOCKLIKE BODY OF MEDIUM-TO COARSE-GRAINED AUGITE-HORNBLENDE GABBRO, INTRUDING PRE-PERMIAN ROCKS
MISSISSIPPIAN, DEVONIAN, OR BOTH	UNDIFFERENTIATED METAMORPHIC ROCKS	SEVERAL THOUSAND FEET OF SLATE, PHYLLITE, SCHIST, FISSILE MARBLE, QUARTZITE, GREENSTONE, GRANULITE, ORIGINALLY SEDIMENTARY AND VOLCANIC, CLOSELY AND COMPLEXLY FOLDED
DEVONIAN	MARBLE	1,000 FEET OR MORE, MASSIVE, UNIFORM, GRAY MARBLE, SLIGHTLY CHERTY AND ARGILLACEOUS, SPARSE CORALS

Geological Survey of Canada

CHAPTER IV

GEOLOGY

GENERAL STATEMENT

(*See* Table I)

East of White River, the area mapped is divided by Shakwak Valley into two geological regions. To the northeast of the valley the terrain is underlain mainly by intrusive and older rocks, the latter altered by regional and contact metamorphism and in general providing little evidence of their age or stratigraphic relationships. These older rocks, here placed in the Yukon group, include sedimentary and volcanic members that are almost certainly of Precambrian age and other metamorphosed rocks of uncertain age and origin.

Southwest of Shakwak Valley, crystalline rocks are minor constituents. Metamorphism is a local feature and intrusions occupy a comparatively small part of the area. The invaded rocks comprise a great succession of Palæozoic and Mesozoic stratified formations in which fossils of several ages, from Silurian to Cretaceous, have been found. The succession extends below the Silurian and a late Precambrian (Proterozoic) age has been suggested (9, p. 15) for the pre-Silurian part of the assemblage. Intrusions of many different compositions have invaded these Palæozoic and Mesozoic rocks at different periods dating back to pre-Permian time (27, p. 635). All the rocks are overlain in places by Tertiary strata, some as old as Paleocene, capped by thick masses of Tertiary volcanic rocks. At the close of Tertiary time, and perhaps continuing later, small intrusions, accompanied by local volcanic outbursts, invaded all the older rocks.

West of White River, the formations characteristic of the southwest side of Shakwak Valley spread northward, and overlap the crystalline rocks that outcrop to the east of White river.

YUKON GROUP

Intensely metamorphosed rocks are found in many large and small areas northeast of Shakwak Valley. They comprise two assemblages. One, composed mainly of mica schists and gneisses, occupies the area east of Kluane Lake and south of the main contact of the granitic rocks as far west as Outlet Hill and was named by McConnell the 'Kluane schists' (21, pp. 4-6); the other forms the remaining areas of metamorphic rocks to the north and west and includes quartzites, limestones, and many varieties of schists. As both assemblages lack fossil and other evidence of Palæozoic or later age they have been tentatively mapped with the Yukon group, which elsewhere is composed of similar rocks.

'KLUANE SCHISTS'

The 'Kluane schists' comprise a distinct assemblage of Yukon group rocks. They are well-foliated, quartz-mica schists and gneisses, varying in colour, degree of metamorphism, and coarseness of texture, but are very homogeneous throughout in composition, and do not exhibit any distinct stratification that might represent original sedimentary bedding. In detail they consist essentially of seams and small lenses of quartz and feldspar separated by corrugated laminæ of biotite and white mica. No quartzite or limestone has been recognized. In the lower part of Gladstone Creek and along Kluane Lake to the south, their uniformity in composition in large exposures lends them a massive appearance suggestive of altered batholithic rocks, but elsewhere they are believed to be of clastic origin (21, p. 5). In general their foliation strikes between north 60 degrees west and west and dips northeasterly to northerly at 20 to 60 degrees, but locally the attitude varies widely and dips may be steeper.

In Slims River Valley, beds containing Silurian fossils (9, p. 20) overlie green schist that shows less intense metamorphism than the Kluane schists. The green schist (21, p. 6) is correlated with a thick section of schists that overlie the Kluane schists southeast of the map-area. These facts indicate a pre-Silurian, and suggest a probably Precambrian, age for the Kluane schists.

OTHER ROCKS OF THE YUKON GROUP

The rocks of the Yukon group lying within areas underlain mainly by granitic intrusions in the north and northwest parts of the area mapped comprise the second distinctive assemblage.

East of Kluane River, they are composed mainly of micaceous quartzite, mica schist, garnet-mica schist, and limestone, with, in addition, minor quantities of chloritic and amphibolitic schists and some less altered argillaceous strata. The quartzite forms beds ½ inch to 2 feet or more thick. It varies in colour from nearly white to light and dark shades of grey and brown. Schists are interbedded with the quartzite in beds of similar thickness. The limestone is commonly coarsely crystallized, is white to grey, and occurs both as massive beds as much as 100 feet or more thick and thinly interbedded with quartzite and schist. Garnet, andalusite, and other metamorphic minerals are common in the schists. At least 1,000 feet of strata, mainly quartzite, with 500 feet of limestone strata apparently overlying it conformably are exposed on the east side of Talbot Arm.

North of the Alaska Highway, between Kluane and White Rivers, the principal rocks are relatively pure, dark purple-grey quartzite interbedded with micaceous quartzite and limestone, but include some chlorite schist, grey quartz-mica schist, and greywacke. Near Pickhandle Lake, they include dark, altered rocks, originally basic lavas. The associated limestone is massive, white or grey, and coarsely crystalline or thinly bedded and finely crystalline, and emits a fetid odour when freshly broken. Some tuffaceous beds 2 inches to 2 feet thick occur among the quartzite beds. East of Donjek River, the sedimentary strata are commonly metamorphosed near intrusive contacts, as evidenced by the occurrence of coarsely crystalline garnet, epidote, and other contact metamorphic silicate minerals.

In the northwest part of the area mapped, where the Alaska Highway approaches the 141st Meridian, the rocks are interbedded mica schist, quartz-mica schist, quartzite, and limestone. The limestone is grey, and occurs in thin, contorted beds between quartzite and schist. Strikes average about north 75 degrees west, and dips are steep. Locally, numerous small quartz veins intersect these rocks at an angle to the schistosity, and small bodies of slightly schistose greenstone, composed mainly of chlorite, quartz, and mica, intrude them.

Southeast of Siwash Camp (10, pp. 68-71) the rocks of the Yukon group resemble those near the 141st Meridian, but are more intensely metamorphosed and include sillimanite schist, graphitic mica schist, and amphibolite.

The rocks of this second assemblage differ from the Kluane schists in that in many places they include quartzite, limestone, and schist of undoubted sedimentary origin, and in showing less intense regional metamorphism. These rocks strike northwestward towards areas in Alaska underlain by known Palæozoic rocks that include types showing some degree of metamorphism. However, because of the lack of fossil evidence and their generally metamorphosed character, they are retained in the Yukon group and are regarded as of doubtful Precambrian age, and it is probable that further study may reveal that some parts or most of them are younger.

PALÆOZOIC ROCKS

In the southwestern parts of the area mapped, no single locality examined has contained any considerable part of the thick section of Palæozoic and Mesozoic strata known, from fossil collections, to be represented. Except along Steele (Wolf) Creek Valley (27), the work done in these parts has been of an exploratory character, and only the briefest general account of each local section has been recorded. Carboniferous fossils have been found in most localities, and give a general basis for correlation, but the similarity of strata of different ages and the lack of distinct horizon markers make correlation and mapping of separate groups arbitrary, and necessitate the separate description of the rocks of each locality.

PRE-SILURIAN TO CARBONIFEROUS ROCKS OF SLIMS RIVER

A great section of Palæozoic rocks is exposed in the walls of Slims River Valley. Part of it has been explored along the lower levels of the valley on both sides of Bullion Creek and for a few miles south of Vulcan Creek (21, pp. 6-7; 9, pp. 14-22). There, a steeply dipping group, composed mainly of greenish grey, chlorite schist and phyllite with, here and there, some limestone, shale, and chert, forms the base of the section. The greenish grey schist is the most abundant rock, but the degree of alteration in the group varies greatly from place to place. In some places the strata have been altered to glossy chlorite schist and in others a fragmental origin is still evident. The phyllite is prevailingly green, grey, or yellow, and cleaves readily into thin plates. Nearly everywhere the limestone is crystalline, and is white, yellow, or black. The shale and chert are mainly dark grey to black and thinly bedded, but include a few massive beds of chert.

On Sheep Creek, basal Palæozoic rocks are overlain by strata containing Silurian fossils (9, pp. 15, 20). South of Kluane, the group contains altered greywacke, shale, and related sedimentary rocks associated with schistose, andesitic tuff. In several places the rocks of this group are intruded by diorite, granite, and related rocks. To the southeast, beyond the limits of the area mapped, several thousand feet of green schist, probably a part of this group, overlie the 'Kluane schists' of the Yukon group (21, p. 6). McConnell (21, p. 6) regarded these rocks as probably of late Palæozoic age, but Cairnes (9, p. 15) correlated them with the Tindir group, which he regards as probably Precambrian.

SILURIAN TO CARBONIFEROUS ROCKS OF SLIMS RIVER

Massive limestone containing Silurian fossils overlies the pre-Silurian group in the lower part of Sheep Creek Valley (9, p. 18), but drift obscures the relationships with the rocks exposed in the surrounding hills and all are contorted, brecciated, and faulted. Limestone, shale, and argillite, associated with intrusive greenstone, outcrop north of Sheep Creek and along Bullion Creek where the limestone contains a few fragments of corals indicating a Carboniferous age (9, p. 19).

On this basis, it seems probable that Devonian and Mississippian strata equivalent to those of Steele (Wolf)[1] Creek and elsewhere, described below, may occur in this section. No attempt, however, has been made to delineate these separately on the accompanying map.

DEVONIAN ROCKS OF STEELE (WOLF)[1] CREEK VALLEY

A section of Palæozoic strata is well exposed around the east end and along the south and southeast sides of Steele Creek Valley. The rocks in this valley have been studied in some detail by Sharp (27, pp. 629-633), and all information in this report pertaining to them has been taken from his account.

Sharp (27, p. 629) describes Devonian strata, mainly marble, as comprising the lowest member exposed in the Steele Creek section. They outcrop to the west of Steele (Wolf Creek) Glacier, and consist of uniformly massive, light to dark grey, and medium-grained marble that "weathers grey, brown or reddish and contains a few thin argillaceous layers and irregular chert nodules. White coarsely crystalline calcite fills veinlets and replaces bryozoans and corals. Stratification is obscured by fracturing, metamorphism, and weathering".

"A species of *Cladopora* and one other distorted coral with Devonian characteristics are among the poorly preserved fossils in the marble", and are regarded as of pre-Carboniferous age and probably not older than Devonian.

UPPER DEVONIAN (?) TO MISSISSIPPIAN (?) ROCKS OF STEELE (WOLF) CREEK VALLEY

"The massive (Devonian) marble is overlain conformably by a considerable thickness of schist, phyllite, and thin marble beds unless the entire section on Wolf Creek is inverted which seems unlikely.

"Marble and phyllite dominate. The marble, is gray to black, finely crystalline, fissile schistose and crenulated. It weathers gray to brown. Impure calcareous beds contain dolomite, sand, clay, and carbonaceous material. Veinlets of coarse-grained white calcite are numerous in frac-

---

[1] *See* footnote, page 11.

tured strata, and small pods of hydrothermal quartz are locally abundant. Black, paper-thin phyllite forms partings between layers of marble, and phyllite beds in groups 200 to 300 feet thick alternate with similar groups of marble strata. Most phyllite is shiny gray to nearly black, brownish weathering, and thin-bedded. Paper-thin beds are rich in clay, and platy strata contain some sand and calcite. Small-scale sharply asymmetrical crenulations, less than 0·5 mm. high, give many phyllites a prominent linear marking on schistosity planes, and across crenulations locally produce a reticulated pattern. Slates are not abundant, although much of the phyllite is slightly recrystallized and resembles slate. Scattered beds of gray, brown-weathering, fine, argillaceous quartzite were noted.

"Near intrusives, phyllite and marble gradually give way to schist and granulite. Quartz-biotite, quartz-sericite, and sericite-chlorite schists of medium grain are common. The various granulites consist of interlocking granules of calcite, quartz, diopside, hornblende, biotite, chlorite, zoisite, sericite, plagioclase, and traces of pyrite. In some beds a distinct compositional interlayering of biotite and quartz with pyroxene and calcite is apparent.

"Greenish calcareous sericite-chlorite schists and greenstones crop out on lower Wolf Creek. The greenstones consist of chlorite, epidote, hornblende, plagioclase (near albite), sericite, calcite, sphene, and traces of pyrite in interlocking granules without well-developed foliation. Veinlets and pods of coarse-grained hydrothermal quartz and ankerite(?) are abundant in these rocks.

"The rocks composing this formation were developed by low-grade regional metamorphism of shale, calcareous sandy shale, limestone, impure sandy dolomitic limestone, and argillaceous sandstone. In the lower Wolf Creek, mafic volcanics, presumably flows or tuffs, and possibly tuffaceous limestone were included. Granitic intrusions locally produced more intense metamorphism. The thickness of these rocks cannot be determined accurately due to their complex folding. One to several thousand feet appears a not improbable figure.

"The only direct evidence on the age of this unit is its conformable position above marble containing Devonian fossils and its unconformable altitude beneath Permian beds."

Sharp discusses many indicative but inconclusive factors that show that these rocks are improbably of Pennsylvanian age, and concludes by referring to their age as either Mississippian or Devonian or both.

PALÆOZOIC ROCKS NORTH OF SNAG CREEK

A group of sedimentary rocks consisting of thinly bedded, friable, black carbonaceous shale, limestone, white cherty slate, and sandstone outcrops on both sides of the Alaska Highway between the Snag Creek bridge and a point 4½ miles south of the International Boundary crossing. These rocks strike 60 degrees west of north and dip steeply to the southwest. The beds are much contorted by drag-folds, and are intersected by faults. Similar, thinly bedded, grey, cherty quartzite, also exhibiting much corrugation and a slightly developed schistosity, outcrops on the hill east of the radio beam station north of Snag and is thought to be part of the same rock group.

The age of these rocks is uncertain. Their southwest dip suggests that they overlie the rocks to the northeast that are placed in the Yukon group, but that may be younger than Precambrian. They strike westward across the International Boundary into areas of Carboniferous and Devonian rocks in Alaska (23). For these reasons they are regarded as of late Palæozoic age.

CARBONIFEROUS ROCKS OF DONJEK RANGE

The rugged ridges of Donjek Range exhibit fine exposures of strata, mostly massive limestone associated with hard shale, slate, and feldspathic sandstone. A section is well exposed along Donjek Valley for 9 miles below the Donjek Glacier and is described by McConnell (22, p. 22). The northwesterly end of the range, near Wade Creek, is composed of diorite, which "is followed by a wide band of crushed, reddish weathering limestone underlaid by greyish, massive limestone and alternating limestone and shale. The latter are succeeded by feldspathic sandstone and limestone, both holding fossils of Carboniferous age. The tuffaceous beds are cut by diorite, above which is a second band of massive grey limestone, followed by dark slates, altered in places into a schist. The slate is succeeded by reddish granites and diorites.

"The limestone and associated rocks strike in a northwesterly direction and dip uniformly to the northeast at angles of from 30 to 70 degrees . . ."

"At the head of Burwash creek the range is built of massive limestone, and bands of limestone and shale similar to those on the Donjek Valley side but dipping at high angles in a southwesterly direction. North of the limestone—and apparently underlying it—are hard feldspathic quartzite, dark shale and ironstained tuffaceous beds. These beds have a nearly vertical altitude, and their age relationship to the limestone is uncertain."

CARBONIFEROUS ROCKS WEST OF KLUTLAN AND WHITE RIVERS

West of Klutlan and White Rivers, Cairnes found Upper Carboniferous fossils in two groups of rocks, which he called the limestone-chert series and shale-limestone series and described together under "Carboniferous Sediments" (10, pp. 71-83). The following information is taken from his report.

The limestone-chert series outcrops near the upper canyon of White River and is poorly exposed. It consists mainly of limestone, but includes some chert and shale. The limestone is grey, massive, and crystalline, and is underlain by altered and crushed, dark chert and shale. Fossils in the limestone are of Carboniferous age, probably Pennsylvanian.

The other series, referred to as the shale-limestone series, is widely exposed. It is at least 1,500 feet thick, and is composed mainly of shale, but includes some sandstone, conglomerate, and limestone. The shale is predominantly dark grey, nearly black, and reddish brown. It occurs interbedded with limestone, and in some places the rocks are finely interlayered, in alternate beds 1 inch to 2 inches thick, but at other points limestone beds up to 4 feet thick are intercalated in the shales at intervals of 10 to 15 feet. Individual limestone and dolomite beds are rarely more than 5 feet thick, but one bed commonly ranges from 100 to 200 feet in thickness and reaches a maximum of 400 feet. The sandstone and finely textured conglomerate constitute only a small part of the group. They form thin beds, generally in some shade of dark grey, green, or brown. The sandstone is more or less calcareous.

The rocks of the shale-limestone series are much indurated near contacts with intrusions, particularly those of granitic rocks. In such places, the shales become hard, cherty, and bleached, and exhibit a ribbon-like appearance, in which interbanded light grey to nearly white strata occur interbedded with dark greenish grey, or even reddish or brownish, layers. Such rocks break into irregular, sharply angular fragments rather than into shale-like slabs or plates.

The structure of these rocks is very complex, and they are extensively invaded by dykes and irregular masses of igneous rocks in most places. Though in general they strike northwest and dip prevailing north, several closed or even overturned folds may occur within a distance of 100 feet or less.

"Upper Carboniferous" fossils were found in the limestone of the shale-limestone series. The limestone-chert series may represent the thick limestone bed of the shale-limestone series, but is probably older as the latter is overlain directly by Mesozoic rocks.

PERMIAN ROCKS OF STEELE (WOLF)[1] CREEK VALLEY

On the north wall, near the entrance of Steele (Wolf)[1] Creek Valley, about 1,500 feet of well-stratified limestone, limy sandstone, grit, chert, sandy tuff, and water-lain tuff are exposed and are described by Sharp (27, pp. 633, 634). Limestone, sandstone, and tuff are about equally abundant, and contain Permian fossils. "The calcareous strata are light-grey, fine-grained, soft, argillaceous limestone; black, dense, brittle limestone with irregular fracture; and various shades of grey, medium- to fine-grained arenaceous and tuffaceous limestone. Most of these beds weather light brown or grey. The large fragments of chert suggest that it occurs as beds rather than solely as nodules. Grey, green, white and brown dense chert layers are interbanded on a ½- to 1-inch scale. Arenaceous strata consist of light grey to brownish grey, fine- to medium- and even-grained quartz sandstone some of which is tuffaceous and some calcareous. Nearly all the sandstone is distinguished by a vivid warm-brown weathering colour. Tuff beds are grey, fine-grained, weather brown, and contain considerable quartz and feldspar. The tuff is well cemented and lacks the lamination noted in calcareous strata, although it appears to be well bedded in outcrop and is presumably water laid. The grits are brownish to greenish grey and consist of subangular to subrounded fragments of quartz, tuff, limestone, chert and unidentified materials up to ⅜-inch in diameter. The matrix is variously sandy, calcareous, or tuffaceous. The fossiliferous beds are dark grey, arenaceous limestone and light- to brownish-grey, limy sandstone". These Permian strata continue northward beyond the exposed, Steele Creek section, and thicknesses greater than 1,500 feet are believed to be represented.

"The Permian beds of Wolf [Steele] Creek have a gentle northward tilt and are cut by a number of high-angle oblique faults. They are unconformable on Palæozoic gabbro and metamorphics at the mouth of the canyon and discordantly overlain by Tertiary volcanics. The pre-Permian erosion surface is smooth throughout the short distance exposed."

Fossils collected in float, believed to come from these rocks "consist of species of the brachiopod genera *Chonetes, Productus, Marginifera,*

---

[1] *See* footnote, page 11.

Spirifer (*Neospirifer*), *Punctospirifer*, and *Rhynchopora*. Two species of bryozoans are also present. ...... The faunule is typical of the Alaskan faunules at present generally referred to the Permian period".

VOLCANIC ROCKS ASSOCIATED WITH THE PALÆOZOIC AND MESOZOIC SEDIMENTARY STRATA

Volcanic rocks are associated with the Palæozoic and Mesozoic sedimentary strata at various horizons and form a thick assemblage at the top of the succession of these strata in the Kluane Ranges. Cairnes grouped these volcanic rocks together and designated them as the 'Older volcanics' (10, pp. 87-93). Elsewhere in Yukon Territory and northern British Columbia volcanic rocks of similar composition, relationship, and ages have been correlated with them.

The 'Older volcanics' are distributed along Kluane Ranges and in the hills north of Shakwak Valley west of White River. Their strong resistance to erosion enables them to form more than their normal share of outcrops, and many prominent hills and ridges are composed of them. They consist mainly of lavas, exhibiting flow structures, associated with tuffs and breccias, but in many places they are intrusive and form dykes and irregular masses. In some instances the dykes quite evidently were the sources of the extrusive lavas.

The 'Older volcanics' west of White River are typical of other localities and are described by Cairnes (10, pp. 87-93) in some detail. Most of the information in the following paragraphs is drawn from his account.

In general these 'Older volcanic' rocks are of intermediate to basic composition, comprising flows, dykes, and irregular masses of augite, andesite, hornblende andesite, mica andesite, augite diorite porphyry, basalt, and diabase, with related tuff and breccia. They vary considerably in colour, texture, structure, and mineralogical composition. Although characteristically unaltered, they are much distorted and fractured, and are veined with calcite and quartz. In a few localities, however, they are metamorphosed and sheared, even developing a schistose structure. In colour, they are prevailingly dark green, but brown, red, and purple shades are also common. In texture, they range from aphanitic to coarse grained, with large phenocrysts embedded in a crystalline groundmass. Phenocrysts are mainly of light grey to pale greenish plagioclase, and dark green to black hornblende and pyroxene. In places, these rocks are amygdaloidal, the amygdules ranging in size from microscopic to an inch or more, and composed of zeolites, calcite, chlorite, epidote, and chalcedonic quartz, with zeolites and calcite predominating in most places. These porphyritic and amygdaloidal types commonly have a mottled appearance, due to scattered phenocrysts or amygdules.

The tuffs and breccias range from dense, fine-textured, ash rocks to massive, coarse breccias resembling conglomerates in appearance.

In most places where the 'Older volcanics' are exposed in contact with the Carboniferous to Cretaceous sedimentary group, they either intrude or overlie them. In turn, they are overlain by Tertiary rocks. Not far to the west, in Alaska, similar appearing volcanic rocks are of "Upper Carboniferous" age. It is probable, therefore, that these 'Older volcanics' include rocks of different ages ranging from late Palæozoic to Lower Cretaceous.

PALÆOZOIC AND MESOZOIC ROCKS OF KLUANE RANGES

Reconnaissance surveys have shown that most of Kluane Ranges from Slims River to White River is composed of sedimentary rocks of Carboniferous to Cretaceous age closely associated in distribution and structure with the 'Older volcanics'. These groups have only been separated in a most general way in mapping, and the following notes are additional to the information given on the map.

BETWEEN SLIMS AND DUKE RIVERS

The northeast front of Kluane Ranges along Kluane Lake is composed of hard, greenish grey, tuffaceous beds, andesite lava, breccia, dark shale, quartzite, and limestone. These rocks are closely folded, commonly overturned, and are intersected by numerous faults, but their general strike is persistently northwestward along the range.

A typical section of these volcanic rocks is exposed along the northeast side of the mountain northwest of Halfbreed Creek. The general strike there, as elsewhere, is northwesterly but the direction in which the top of the section faces is unknown. Green or reddish brown, porphyritic, amygdaloidal, andesitic lavas underlie about half of the outcrops of the range. Some of these contain small, greenish feldspar phenocrysts and amygdules of dark glassy material, and others hornblende phenocrysts, with amygdules of calcite. Individual flows are not distinguishable.

The succession from northeast to southwest is as follows: the most northeasterly outcrops comprise some hundreds of feet of lavas with a bed of limestone a few feet thick intercalated with them. Beyond a drift-covered interval of 30 to 50 feet, grey, rusty weathering, splintery slate, containing several scattered beds of slaty conglomerate and sandstone, each a few feet thick, is exposed. The slate continues as the principal rock for more than a mile. Within it is a zone, 100 feet or more thick, including 75 feet of grey, finely fractured, fine-grained limestone, 10 feet of grey slate, and 2 feet of brown sandstone, succeeded to the southwest by andesite lava. Beyond an interval of some hundreds of feet, in which the bedrock is concealed by talus, beds of light brown, fine-grained tuff up to 15 inches thick and speckled with pyrite are interstratified with slate for a few hundred feet. These rocks are succeeded by a mass of andesitic lava, which forms the main peak and is in turn succeeded by talus and a few outcrops of slate beyond which Tertiary rocks form a capping. All these rocks, with the exception of the Tertiary, are cut by dykes of granite-porphyry, diorite, quartz porphyry, and pegmatite.

BETWEEN DUKE AND DONJEK RIVERS

West of Duke River, andesite lava and small intrusions of similar composition resembling those east of the river form most of the outcrops. With them are intercalated some grey and black, cherty slate and thin, grey and black, limy tuff beds. In addition, in a small tributary valley on the north side of Tetamagouche Creek, 100 feet of limestone, in beds 2 to 12 inches thick, is overlain on the northeast by 200 feet of conglomerate. The conglomerate is composed of rounded cobbles and boulders of limestone and volcanic rocks, most of which are 6 inches to 2 feet in diameter, with only enough fine material to fill the interstices between the closely packed larger stones. The conglomerate has been squeezed, and numerous small fractures in it have been filled with epidote and quartz, forming veins up to 6 inches thick. The volcanic boulders are mainly of amygdaloidal and porphyritic, fine-grained, purple and green andesite. A section of volcanic rocks of unknown thickness overlies the conglomerate and is succeeded in turn by slates intermixed with some andesite. A bed of limestone in the volcanic rocks overlying the conglomerate and within 300 feet of it, is about 3 feet thick, crystalline in places, and contains poorly defined impressions of fossils. Rocks of the same types, except limestone, form the whole ridge up to where its base is reached in Shakwak Valley, where they are somewhat altered and schistose.

In the ridges north of the trail extending from Burwash Creek to Arch Creek, Cairnes (9, pp. 22-25) describes the same group of igneous rocks as predominant, with, in addition, intrusions of diorite, diabase, and dunite. Greenish and reddish amygdaloidal lavas are locally very prominent. The sedimentary rocks are principally shale, slate, argillite, chert, limestone, and cherty conglomerate, among which Carboniferous and Triassic fossils have been found. These sedimentary rocks have been invaded by basic igneous rocks and by granitic intrusions. The whole assemblage is cut by dykes of nearly white, light greyish, or yellowish rhyolitic rocks, thought to be of Tertiary age.

On lower Arch Creek, the sedimentary rocks predominate and are believed to be of Carboniferous age. But massive limestone, which may represent the lowest horizon in the section, resembles the Silurian beds of Sheep Creek. This section, too, has been invaded by the same igneous rocks as on Burwash Creek.

The northeast side of Kluane Ranges, from Quill Creek to Donjek River and thence to near White River, has not been explored, but viewed through field glasses and examined in air photographs many peaks exhibit stratified rocks cut by dykes, and most of them are believed to be composed of the same great assemblage of strata of Carboniferous, and perhaps Silurian, to Cretaceous ages found to the southeast and northwest, and like them probably containing abundant volcanic rocks.

MESOZOIC ROCKS NORTH AND WEST OF WHITE RIVER

West of White River, a group of Mesozoic sedimentary strata overlies the Carboniferous rocks and is described by Cairnes (10, pp. 83-87), from whose report the following information has been taken. The two groups resemble each other closely, and it is generally impossible to distinguish them except by their contained fossils.

The Mesozoic strata consist predominantly of shale and argillite, but also include much greywacke and lesser amounts of conglomerate and sandstone, the entire series bieng notably more siliceous than the underlying Carboniferous beds. These rocks have an aggregate thickness of about 1,000 feet. The shale and argillite are dark grey and slate coloured or have a ribbon-like appearance, due mainly to the alternation of light and dark weathering layers, and, in places, to varying texture and composition. Fresh surfaces are dark grey to nearly black and dark greenish or reddish. The layers range in thickness from less than an inch to more than 2 feet, but are commonly ¼ inch to 2 inches thick. They break across the bedding into sharp angular fragments, and near intrusions are in places commonly bleached and indurated, and transformed to hard, cherty rocks, with alternating white or greyish and dark bands.

The sandstone and greywacke are dominantly greyish or greenish, and mainly finely textured. Conglomerate was seen at only a few localities. Most of it consists of small pebbles and forms thin beds. Along the range north of Tchawsahmon Lake, most exposures of these rocks are also characterized by abundant pebbles of dark argillite and chert. An unusual quantity of coarse conglomerate occurs about half-way up Boulder Creek. Here conglomerate greatly exceeeds sandstone in amount, and contains well-rounded stones mainly from 1 inch to 4 inches in diameter of principally granitic and volcanic rocks. The associated sandstone is a coarse-grained yellowish to greyish or greyish green rock, and like the conglomerate is well consolidated. One lens of coal-like, carbonaceous material 12 inches long and 1 inch thick was seen in the sandstone.

Folds are open and regular in some places, but in others as along Beaver Creek, they are steeply dipping to overturned.

The fossils found in these beds are of Lower Cretaceous age, but similar strata in the Nutzotin Range in Alaska contain both Jurassic and Triassic as well as some possibly Cretaceous fossils. Southeast of the area mapped, in Dezadeash map-area along the strike of these rocks, a great assemblage of similar strata has been found to contain fossils of early Lower Cretaceous age and some of doubtfully Jurassic age (19, p. 19). It is probable, therefore, that in places along Kluane Ranges this Mesozoic group contains strata of Jurassic, and perhaps Triassic, as well as Cretaceous age.

INTRUSIVE ROCKS

GENERAL STATEMENT

Much of the northeastern part of the area mapped is underlain by intrusive rocks. These vary in composition from granitic to ultrabasic types, but most of them range from granite to quartz diorite. They are older than the Paleocene to Oligocene rocks of the area, and are referred to below under separate localities.

NORTHEAST OF SHAKWAK VALLEY

East of Kluane River

The granitic intrusion exposed around the north arms of Kluane Lake exhibits a variety of phases. In some parts, the rock is a pale pinkish grey, coarse-grained granite, composed mainly of pinkish feldspar, with less white feldspar and much coarse, grey quartz; in places it contains large phenocrysts of Carlsbad twinned feldspar. In other parts the rock varies in composition to granodiorite or quartz diorite.

On the east side of Talbot Arm, much of the granite is a uniformly medium-grained, light grey rock composed of quartz and white feldspar, and speckled with biotite. In places it contains a little hornblende, and titanite is a common accessory mineral. Along contacts with the Yukon group and in many places within the intrusions where xenoliths occur, the granitic rock is commonly darker, carries abundant biotite, and is more or less foliated. In these places, too, all the feldspar is white, but in the interior of the intrusions and to the north pinkish orthoclase appears. Pegmatite dykes of white feldspar, quartz, biotite, pyrite, and red garnet cut the granitic rocks.

Two or more small ultrabasic bodies are exposed west of Brooks Arm and Creek (24). These lie in the areas of Yukon group rocks, which they intrude. A body of serpentine outcrops in the valley near the outlet of Dogpack Lake.

West of Kluane River

The granitic rocks that outcrop between Kluane and White Rivers are, like those just described, predominantly granite to quartz diorite in composition, but include small amounts of more basic types. In general, they are more commonly granitic to the east of Donjek River, and granodiorite, with large feldspar phenocrysts, to the west, with local minor areas of biotite quartz diorite and some monzonite. In most places, hornblende is the more common mafic mineral, in contrast with intrusions farther east in which biotite is almost the only dark constituent, and a hornblende-rich granodiorite occurs near White River. Near Grafe Creek, dykes of granodiorite intrude biotite quartz diorite. In places between Kluane and White Rivers, aplite forms abundant small dykes, and some pegmatite bodies composed of biotite, quartz, white feldspar, pyrrhotite, and specularite cut the granodiorite.

West of White River, the granitic intrusions include the same wide range of rocks from granite to gabbro and hornblendite, with the more acidic types least abundant. Small bodies of diorite, diorite-porphyry, and allied rocks intrude the pre-Silurian to Carboniferous rocks north of Snag Creek.

The small intrusions that outcrop along the Alaska Highway north of Mirror Creek are composed of diorite and monzonite. One body contains phenocrysts of feldspar up to half an inch long, and smaller hornblende crystals, together with a little quartz. Other bodies are of more uniformly medium grain.

Much of the larger intrusion northeast of Snag is a massive, blue-green schist of chlorite and quartz. The quartz has a glassy appearance, and occurs in scattered rounded grains. In other parts of the mass, the rock is only vaguely schistose, and is composed of chlorite, with scattered, relict crystals of feldspar and hornblende. The intrusion is believed to represent an altered dioritic stock.

SOUTHWEST OF SHAKWAK VALLEY

Kluane Ranges

Southwest of Shakwak Valley, the intrusive rocks of Kluane Ranges comprise a great variety of types. Many small bodies of intermediate to basic composition, mainly diorites, are associated with the volcanic rocks, including the 'Older volcanics' of Palæozoic and Mesozoic ages.

The granitic bodies that outcrop on either side of the mouth of Slims River vary greatly in composition and grain. On the east side, much of the intrusive rock resembles a true granite, but parts of it near the shore of Kluane Lake are more basic, rich in hornblende, and slightly alkaline. On the west side, the rocks include granite, diorite, and hornblende syenite, and appear to be rich in sodic feldspar.

Some bodies of dunite, partly altered in places to serpentine, occur on Burwash Creek and on a branch of Quill Creek (22, p. 23).

The granitic body north of the upper part of Wade Creek is composed of hornblende and feldspar, with a little quartz. The intrusion lower on Wade Creek and nearer Arch Creek is in part light coloured and rich in feldspar and in part dark rocks largely composed of hornblende. A small body of hornblende syenite-porphyry outcrops near the lower part of Wade Creek. The intrusion on the south side of lower Wolverine Creek varies in composition from hornblende diorite to hornblendite. The stock north of Wolverine Creek is composed of a light-coloured granitic rock consisting of hornblende and feldspar, with some biotite and little quartz. The large intrusive mass north of Harris Creek is a coarse hornblende granite or granodiorite, with locally large feldspar phenocrysts, and to the west it contains bodies of darker, more basic material.

Steele (Wolf)[1] *Creek Valley*

Sharp describes the intrusions of Steele (Wolf)[1] Creek Valley under three headings: Pennsylvanian (?) gabbro, late Mesozoic or early Tertiary granitic bodies, and Tertiary plugs, dykes, and sills (27, pp. 635-636). The rocks of the first two groups are included here with the intrusive rocks, and the Tertiary plugs, dykes, and sills are referred to later in describing the igneous rocks with which they are correlated.

"A stocklike body of gabbro composes the north wall of Wolf [Steele] Creek at its mouth. The rock is a dark-green altered augite-hornblende gabbro of xenomorphic granular texture and medium grain size, containing finer diabasic phases and extremely coarse pegmatitic segregations. Secondary serpentine, chlorite, epidote and calcite are abundant, and some talc is seen in hand specimen and thin section.

"...The gabbro intrudes the Devonian-Mississippian metamorphics and is unconformably overlain by Permian beds. It is certainly late Palæozoic and probably Pennsylvanian...

"The south wall of Wolf [Steele] Creek westward from its midpoint is composed largely of granite and monzonite. Aerial photographs suggest a considerable southward extension of the granitic rocks, and debris on the glaciers shows that many of the high snow- and ice-covered peaks to the southwest are composed of similar material. A body of batholithic proportions is indicated.

"The chief rocks are a pink porphyritic biotite granite between middle Wolf [Steele] Creek and the bend and varieties of white to grey hornblende-biotite-quartz monzonite farther south. These rocks are of medium grain...The porphyritic granite has pink orthoclase phenocrysts $1\frac{1}{2}$ inches long, and a melanocratic phase of the quartz monozonite contains considerable sphene. Gneissic structure and inclusions are prominent in the granitic rocks only near intrusive contacts. Small aplite and pegmatite dykes, some with black acicular tourmaline, were noted, and three plugs of dark biotite-hornblende tonalite containing considerable sodic oligoclase intrude the Devonian marble on the west wall of upper Wolf [Steele]

[1] *See* footnote, page 11.

Creek. One plug is truncated by the erosion surface below the Tertiary volcanics, and since the tonalite is peripheral to the granitic rocks it is assigned to the same group...

"The porphyritic biotite granite is highly silicified and pyritized, and contains a few flakes of molybdenite and chalcopyrite in a 200- to 300-foot border zone north and east of peak 9761 [elevation in feet of peak about 2½ miles southeast of the bend of Steele (Wolf Creek) Glacier]. A large medial moraine on Wolf [Steele] Creek Glacier consists of highly silicified quartz monzonite containing chalcopyrite, pyrite, specular hematite, and considerable molybdenite in small veinlets and flakes. The abundance of mineralized debris in the moraine indicates a large exposure farther up the valley outside the map area...

"The granitic rocks intrude the Devonian-Mississippian metamorphics, but their relationship to the Permian beds is not known. They are unconformably overlain by Tertiary volcanics, and intrusion probably occurred before deposition of the lignite-bearing late Eocene beds (9, p. 15) a short distance east of Donjek River as indicated by the lack of metamorphism and marked deformation in the latter. On a stratigraphic basis, the Wolf [Steele] Creek granitic rocks may be tentatively dated as post-Devonian or Mississippian and pre-late Eocene..."

"It seems prudent for the present to recognize that the Wolf [Steele] Creek bodies may be either Laramide or Coast Range (late Middle Jurassic to early Eocene) with intrusion during the Mesozoic considered most likely."

AGE AND RELATIONSHIPS

Most of the granitic intrusions in the area mapped cannot be closely dated. The gabbro at the mouth of Steele Creek is the only one proved to be as old as Palæozoic and is pre-Permian, probably Pennsylvanian (27, p. 636). Northeast of Shakwak Valley and east of White River, where the largest bodies occur, the only evidence of the time of their intrusion is that they cut the Yukon group, are similar in general composition to, and in prolongation of, the Coast Range composite batholith of which they are believed to be the northwest extension. Elsewhere many bodies intrude volcanic rocks considered to be as young as Cretaceous, but none is known to cut the Paleocene sedimentary rocks. Without doubt these intrusive rocks include bodies of different ages, but the bulk of them is believed to have been emplaced in late Mesozoic time, and many of them can probably be correlated with the Coast intrusions.

TERTIARY SEDIMENTARY ROCKS

GENERAL STATEMENT

Isolated areas of continental sedimentary rocks lie in the Duke Depression at the head of Sheep Creek, between Halfbreed Creek and Donjek River, and west of White River on the northern flanks of Rabbit Mountain.

Amphitheatre Mountain Area

Between Duke and Donjek Rivers, the Tertiary sedimentary rocks lie in the hollow of the depression between Donjek Range on the southwest and Kluane Ranges on the northeast. They are best exposed on the branches of Badlands Creek (Plate V). There a tributary stream has developed a huge, amphitheatre-like basin of 'badlands' topography in these rocks, from which Amphitheatre Mountain takes its name, and has exposed a section on the southeast face of the mountain (Plate II B). The section is 1,800 to 2,100 feet or more thick. It consists of 1,200 to 1,500 feet of sedimentary beds at the base surmounted by about 100 feet of lava in cliffs overlain, in turn, by 250 feet of sedimentary beds. The beds above the lava are capped by 250 feet of fragmental volcanic rocks, which form the summit of the mountain and together with the lava are part of the Tertiary volcanic rocks.

The strata lie practically horizontally, are only slightly consolidated, and are characteristically light coloured, with here and there occasional blue-grey and brown beds. The lower half of the section in the amphitheatre below the lava is composed of a mass of conglomerate, sandstone, and shale with coal seams, all intercalated in an irregular sequence, which forms the steep sides of the spurs of the badlands (9, pp. 32, 33). A bed of conglomerate about 100 feet thick lies midway of the section, and caps many of the spurs. It contains pebbles and cobbles of hard, fine-grained rocks, including chert, quartzite, and andesite. These stones are rarely more than 5 inches in diameter, and are well rounded, and polished. The conglomerate and the section as a whole, contain much clay. The conglomerate is overlain by clay and soft shale, and these, in turn, are capped by a brown shale forming the gentler slopes about one-third of the way up the upper half of the section below the cliffs. Three or more seams of coal up to 18 inches thick lie in the clay and shale. The brown shale is overlain by 300 feet of interbedded sandstone and shale, forming steeper slopes up to the base of the cliffs. Many detached lumps of clean coal 1 foot to 3 feet in diameter project from some beds in the steep slopes above the brown shale. These lumps of coal commonly envelop stumps of distorted and partly silicified wood in which the grain is well preserved. A collection of Paleocene plant remains was obtained from these beds and is listed on a later page.

At least twelve seams of coal more than 12 inches thick occur in the section below the cliffs and have an aggregate thickness of 30 feet or more, probably more nearly 50 feet, of coal; some of the seams are as much as 5 feet thick (9, pp. 32-33).

The sedimentary beds that overlie the lava cliffs comprise 250 feet of partly consolidated and indistinctly horizontally bedded conglomerate composed of rounded pebbles and cobbles in which a thin sill or lava flow is intercalated. This conglomerate, in turn, is capped by 250 feet of lava, tuff, and coarse fragmental volcanic rocks that form the summit of the mountain. To the south and northwest the conglomerate above the cliffs wedges out, and its place is taken by volcanic rocks, with a few thin beds of conglomerate and sandstone among them.

On the northeast side of the amphitheatre section, the strata lie horizontally, and appear to abut against the irregular surface of the older pre-Tertiary rocks, which rise steeply above them in hills and mountains. On the southwest side, at the head of Badlands Creek, the strata are tilted and faulted.

Similar strata outcrop in the open valley between the heads of Badlands and Burwash Creeks and along the lower slopes of the Donjek

Range to the south (9, pp. 32-33). Here they have dips up to 30 degrees, and are reported to be more consolidated than in the amphitheatre. Seams of coal are reported among them, one said to be 14 feet thick, with roof and floor indurated.

West of the head of Burwash Creek, above the bend, the mountain slopes of pre-Tertiary rocks rise steeply to form the high plateau-like step in which Wade Creek heads in front of the Donjek Range. Patches of similar strata rest in hollows of this plateau surface high above Burwash Creek. Similar strata also extend northwest and west through the pass from Burwash Creek to Wade Creek, but no coal has been reported in these areas.

Sheep Creek Area

The area of Tertiary sedimentary rocks at the head of Sheep Creek contains 1,000 feet or more of strata similar to those of Amphitheatre Mountain, but more indurated and including a large proportion of green, red, and brown tuff beds (21, pp. 7, 18; 9, p. 42). Several seams of clean coal have been observed, including one 6 feet and another 3 feet thick. Small lumps of resin are common in some of these seams.

Other Areas

Northwest of White River, north of Rabbit Mountain, similar Tertiary sedimentary rocks are exposed in three small areas, the northernmost of which extends west for some distance into Alaska. These rocks are described by Cairnes (10, pp. 95-97). In nearly all respects they resemble those of Badlands Creek, and contain thin seams of coal and much fossil wood. They lie nearly flat, but have been invaded by both the Tertiary acidic igneous rocks and the Tertiary volcanic rocks that intrude or overlie them wherever they are exposed.

It is probable that Tertiary sedimentary rocks underlie the Tertiary volcanic rocks in places on the south side of Harris and Wolverine Creeks and in Donjek Valley, where a thick seam of coal is reported to have been found many years ago.

AGE AND RELATIONSHIPS

A small collection of plant remains was obtained in 1945 by the writer at an horizon in the Tertiary sedimentary beds about 300 feet below the cliffs of lava on the east point of Amphitheatre Mountain. The plants were examined by W. A. Bell of the Geological Survey, who reported on them as follows:

> "Conifers
> *Sequoia langsdorfii* (Brongniart) Heer
> "Angiosperms
> *Trochodendroides arctica* (Heer)
> *Corylites hebridica* Seward and Holttum
> "Age indicated is Paleocene"

On the basis of this collection, the sedimentary beds in this exposure and in the numerous others of this group of rocks in the area mapped are regarded as Paleocene. This somewhat older age than that formerly assumed (21, p. 7; 9, p. 15) narrows slightly the upper limit of the period of intrusion of the granitic rocks that they overlie, and to the same degree widens the lower limit of the age of the closely associated Tertiary volcanic rocks that, in turn, overlie the sedimentary group.

The Tertiary sedimentary rocks occur along the Duke Depression in small scattered areas that commonly contain relatively thick sections of horizontal strata. The strata, as for instance those in the area of Amphitheatre Mountain, are mainly horizontal and undisturbed, but are tilted and faulted along the southwest side against the pre-Tertiary rocks. On the east side, however, their beds overlap undisturbed the steeply sloping surface of the pre-Tertiary rocks, which exhibits a relief of some hundreds of feet. It is concluded that the Paleocene strata were deposited in the hollows of an old land surface of marked topographic relief and that local warping and faulting took place later.

TERTIARY VOLCANIC ROCKS

GENERAL STATEMENT

Areas of Tertiary volcanic rocks are distributed along and to the southwest of the Duke Depression. They consist predominantly of lava flows and assorted pyroclastic rocks, but include some undifferentiated, related intrusions. The thick, persistent flows impart a massive, stratified appearance that is commonly characteristic of the larger exposures. These rocks have been referred to in this and other parts of Yukon Territory and British Columbia as the 'Newer volcanics' (10, pp. 97-101).

Within the mapped area, the 'Newer volcanics' occupy four large and several small areas. In the southern part of Duke River Valley they are more than 5,000 feet thick (22, pp. 22-23); on the northwest side of Steele (Wolf) Creek they are 4,600 feet thick (27, p. 641); south of Wolverine and Harris Creeks they are 2,000 feet or more thick in parts of the large area they cover; and in the White River area they are about 3,000 feet thick (10, p. 98).

Steele (Wolf)[1] *Creek Valley*

On the north side of Steele (Wolf)[1] Creek Valley a thick section of the Tertiary volcanic rocks or 'Newer volcanics' is well exposed for many miles, and Sharp describes it in detail (27, pp. 639-644). The following paragraphs summarize his account:

"Well-layered nearly horizontal volcanic rocks at least 4,600 feet thick compose much of Wolf [Steele] Creek's north wall. Small outliers are preserved south of the canyon, and volcanics cover a large area west of Wolf [Steele] Creek bend. Pyroclastics, largely tuff and agglomerate, compose at least half this sequence, the remainder being basalt and andesite flows. Quartz latite, trachyte, and obsidian are minor constituents."

The flows predominate near the base of the sequence, where basalt is most plentiful. The middle third contains a larger proportion of pyroclastic material than elsewhere, with white ash and lapilli tuff particularly abundant. The upper third consists of about equal amounts of agglomerate and lava. Beds of conglomerate, sandstone, and other water-lain beds containing materials of local origin are interbedded with the volcanic rocks at many horizons.

Most of the flows consist of augite andesite and olivine-augite basalt, but are associated with some quartz latite and trachyte. Except for

[1] *See* footnote, page 11.

obsidian, all the flows are holocrystalline, and rather more than half are porphyritic, the andesite lavas carrying phenocrysts of augite, labradorite, and in places biotite, and the basalts, olivine, and, more rarely, basaltic hornblende. The quartz latite contains large crystals of quartz, anorthoclase, andesine, and aegirine-augite.

Some flows are moderately vesicular and others scoriaceous; amygdules up to $1\frac{1}{2}$ inches in diameter are composed of quartz, chalcedony, calcite, and aragonite. Columnar jointing is locally well developed in a few flows near the base of the sequence.

Obsidian, showing flow lines and crude layering, outcrops in cliffs 200 feet high west of the bend of Steele Creek Valley.

The pyroclastic rocks range from fine ash and tuff to coarse agglomerate and breccia. The fine deposits are white, grey, or brick-red. The ash beds are soft and friable, but the tuff layers are indurated, and some near the base of the section in the west are hard, platy, and silicified. Scattered beds of conglomerate and tuffaceous sandstone 2 to 6 feet thick are associated with water-lain ash and tuff. The conglomerate contains well-rounded stones of lava, 2 to 12 inches in diameter, in a sparse, sandy matrix.

Distinctive white, grey, and red lapilli tuffs in groups of beds up to 200 feet thick are more abundant than the finer layers. The materials of these rocks are mainly pumiceous and scoriaceous, with some dark lava and obsidian.

Crudely stratified agglomerate and breccia are abundant in beds 50 to 75 feet thick, and consist of pieces of basalt and andesite up to 5 feet in diameter embedded in a tuffaceous matrix.

In the Steele Creek area, these volcanic rocks rest on a surface with a maximum relief of about 200 feet. The underlying material is a decomposed regolith several feet thick, beneath which the rocks are oxidized and weathered to depths of 30 feet.

Other Areas

In the area at the head of Wolverine Creek the younger volcanic rocks are dark greenish grey, vesicular, olivine-bearing basalt flows, with reddish, crumbly tops 6 to 12 inches thick, associated with some brown and red vesicular lava. Altogether, the section is nearly 2,000 feet thick.

On Halfbreed Creek and Amphitheatre Mountain, the rocks of this group rest on Paleocene sedimentary beds. The basal lava in the mountain section is about 100 feet thick and is overlain in part by about 250 feet of conglomerate that appears to record a continuation of the conditions under which the sedimentary beds below were deposited. About 250 feet of volcanic rocks overlie the conglomerate and form the top of the mountain. They are composed mainly of coarse fragments, but include andesite and some more basic flows and dykes.

West of White and Klutlan Rivers the 'Newer volcanics' are described by Cairnes (10, pp. 97-100). Lavas predominate but tuffs and breccias are intercalated with them. The rocks are characteristically fresh in appearance. Black and grey are the chief colours, but lavender and dark bluish slate shades are represented as well as pink, red, and yellow. The tuffs and breccias are commonly lighter than the lavas.

The lavas and the associated fragmental rocks have a maximum thickness of about 3,000 feet, and are piled up as a series of superimposed sheets lying nearly horizontally in most places. The lavas exhibit columnar structure, and the tuffs and breccias commonly weather to tall, irregular, craggy pillars or hoodoos up to 50 feet high.

These lavas are for the greater part porphyritic rocks of medium coarseness, containing phenocrysts of the intermediate feldspars, basaltic hornblende, pyroxene, biotite, or olivine. The feldspars are generally recognizable, and in many specimens two or three of the other minerals. These volcanic rocks are mainly augite andesites, diabases, or basalts, although there appears to be a practically complete series of transitional forms from fairly acidic andesites to olivine basalts. In texture, they range from glassy to holocrystalline, and from extremely pumiceous to quite dense. They are, in addition, dominantly vesicular, the vesicles being in most cases empty, although in some of the older members they are partly or entirely filled, mainly with calcite, zeolites, epidote, or chlorite.

"In addition to these extrusive facies, dykes and other intrusive forms pierce not only the rocks older than the lavas themselves, but in addition cut the earlier members of this group. These intrusives are dominantly dense, dark, greyish green to nearly black rocks having a marked basaltic habit."

AGE AND RELATIONSHIPS

Sharp (27, p. 642) describes the structure of the Tertiary volcanic rocks or 'Newer volcanics' in Steele Creek Valley as "largely undeformed except along sharp linear flexures and faults", and he shows some faults intersecting them near the lower end of the valley. This is characteristic of the areas of 'Newer volcanics' along the Duke Depression, where they exhibit horizontal to gentle dips and do not appear to have suffered any general disturbance within their areas. Along the depression, however, these rocks appear to end abruptly on the south and southwest where pre-Tertiary rocks rise steeply above them in the high peaks, and where post-'Newer volcanics' flexures or faults are suspected in the southern exposures of many of the areas of these rocks.

In Steele Creek Valley, the Tertiary volcanic rocks, according to Sharp (27, p. 643), "rest unconformably on older rocks including the late Mesozoic or early Tertiary intrusives". On Amphitheatre Mountain, the lowest member of the volcanic rocks rests on beds containing Paleocene plant remains and, in turn, is overlain by conglomerate. These relationships suggest that the period of deposition of the Paleocene sedimentary beds was not completed when the volcanic extrusions began. Thus, the basal rocks of the volcanic group may in some localities be of Paleocene age.

No younger bedrock formation overlies these volcanic rocks in the area mapped. In every exposure their uppermost members have suffered erosion, but as much as 5,000 feet of their strata still remain. Exposures bear evidence of Pleistocene glaciation, and in no place in the area mapped have these rocks been found to be extruded into the present valleys. Indeed, on Amphitheatre Mountain and south of Wolverine Creek, they are truncated by an old rolling elevated surface. It appears, therefore, that since their extrusion was completed, these rocks have been faulted, warped, uplifted in places, and suffered great erosion, suggesting that the whole group is pre-Pleistocene and that their accumulation ended as early as mid-Tertiary time.

TERTIARY ACIDIC IGNEOUS ROCKS

In many localities throughout the area mapped fine-grained acidic igneous rocks occur as dykes, small and moderately large intrusive bodies, and, in a few places, as surface flows.

The main occurrences of these rocks are exposed north of White River and northwest of Canyon City. They are described by Cairnes (10, pp. 101-103), from whose report the following information has been extracted. Throughout this area, narrow dykes of these rocks are plentifully distributed, and at a few points surface flows and larger intrusive bodies are exposed. The volcanic rocks are most widely exposed along the eastern parts of Rabbit and Canyon Mountains, but they also comprise the rocks of a small mountain lying about 2 miles to the north of the summit of Rabbit Mountain. The larger areas range from 1 mile to 3 miles in their greatest dimensions, but in width nowhere exceed a mile and in most places are not more than $\frac{1}{4}$ to $\frac{1}{2}$ mile wide.

The rocks are light-coloured, porphyritic types ranging from nearly white, light grey, or yellowish, to pale lavender or darker greenish grey shades. The groundmass is invariably fine grained to aphanitic. Phenocrysts are mainly of feldspar, hornblende, and biotite.

"Volcanic rocks representing possibly the most extensively developed facies of this group [in these areas northwest of Canyon City] have a pale lavender or greenish grey groundmass which includes numerous, fine, needle-like hornblende phenocrysts. These rocks are well exposed along Rabbit Creek where they have a marked and very perfect vertical prismatic jointing, the columns being in places 50 feet or more in height. Members of another characteristic and more acidic rhyolitic type consist of a white to light grey groundmass which is in places stained yellow with iron, and in this groundmass are embedded occasional quartz and feldspar phenocrysts, the quartz being prevailingly in four or six-sided, often corroded forms. Rocks of both of these types break characteristically into irregular, thin plates or slabs which exhibit a roughly conchoidal fracture, and give a clear ringing sound when struck with a hammer. In places, these volcanics assume a somewhat more coarsely grained appearance, due to phenocrysts of feldspar, biotite, and hornblende becoming more abundant—such rocks apparently represent somewhat deeper seated phases of the types just described, these being all transitional forms between the different facies.

"These rocks are in places pumiceous or amygdaloidal, and are all notably rough to the touch, the lighter coloured varieties in particular having often somewhat the appearance of brick on a fresh fracture."

Dykes and small bodies of similar rocks considered to belong to the same group occur in many other parts of the area mapped. Several of these small bodies occur north of Mirror Creek and consist of fine-grained porphyritic rhyolite. The only hill along the Alaska Highway between Beaver and Snag Creeks is formed by light-coloured rhyolite and latite lavas that are regarded as belonging to this group of rocks. Three small intrusions along the north bank of Burwash Creek consisting of granite-porphyry and cutting the older rocks with which they are in contact are placed in this group by Cairnes (11 and 12). Sharp mentions a rhyolite-porphyry dyke in Palæozoic schist in Steele (Wolf) Creek Valley as possibly related to these rocks (27, p. 638).

AGE AND RELATIONSHIPS

Cairnes refers to the age and relationships of the Tertiary acidic igneous rocks as follows (10, pp. 102-103):

"These volcanics cut the newer volcanics wherever members of the two groups come in contact, showing that the rhyolite-latite volcanics are at least of late Tertiary and possibly early Pleistocene age. In places even, as on the eastern face of Rabbit Mountain, they have flowed over the present land surface since it has become uplifted and eroded to nearly its present form, the topographic features having since been modified only by glacial action and recent erosion."

OVERBURDEN

The overburden in the area mapped includes a variety of materials, of which Pleistocene drift forms the greater part. Others include volcanic ash, dealt with separately in this report, peat deposits that owe their origin to permafrost conditions, aeolian accumulations, and soils.

On the hills between Mirror and Scottie Creeks, beyond the limit of the last glaciation, the development of residual soil has been uninterrupted through much of Pleistocene time except by normal erosion and the settling of wind-borne materials, including volcanic ash and accumulations of dust from Pleistocene drift areas to the south. Here, too, weathering has penetrated deeply into the bedrock, and the soil forms a remarkably continuous mantle, covering the slopes and many of the summits of the hills almost to the exclusion of bedrock outcrops.

The Pleistocene drift of till, gravel, sand, and silt is typical of the northern glaciated regions of the Cordillera, and is notably little weathered.

Placer workings, road construction, and vegetation show that permafrost is a local feature of the southern part of the area mapped and more general in the northwesterly part.

Accumulations of frozen moss and other vegetable materials containing bodies of ground-ice occur on north slopes of hills and on flatter, poorly drained ground, notably north and west of White River. When thawed and dry, these materials form a soft, porous, incoherent brown peat containing variable proportions of silt.

In many places, unstratified silt forms the surface material for thicknesses of a few inches to many feet, and is believed to be of aeolian origin. In this aridly frigid region, expanses of flood plains and bars along the main, glacially fed streams—Slims, Donjek, and White Rivers—lie dry and bare of snow in spring and autumn, and dust from them is blown over the neighbouring areas. During Pleistocene time, and particularly when the ice was wasting, greater tracts of bare terrain bordered the ice and extended along the main drainage valleys. These factors suggest that loess and dunes form a considerable part of the overburden in parts of the region. For example, parabolic dunes, now overgrown by spruce forest and difficult to distinguish on the ground, cover about 5 square miles in Shakwak Valley on the west side of Donjek River and indicate a prevailing southeast wind during their formation (Plate IV). Other areas of wind-borne material will probably be found as a result of more detailed explorations, as they have in the adjacent areas to the west in Alaska (1, pp. 98-100).

Where the upper part of the overburden is composed of silt and rests on relatively level, well-drained ground, in the main valleys, a varicoloured zone, composed of conspicuous, nearly horizontal, reddish, yellow, and grey layers, is apparent. The zone has a thickness of from a few inches to several feet, and lies either at the surface or is covered by a few inches or feet of grey-brown soil, or by the volcanic ash, or by both, the ash commonly resting directly on the varicoloured zone and overlain in turn by the grey-brown soil. Wherever the varicoloured zone is exposed it shows the same sequence of layers, except that the lowest light grey layer is barely discernible in localities where the entire zone is only a few inches thick.

A particularly well-exposed section of the varicoloured zone was observed in the high bank northwest of Gladstone Creek estuary. The bank consists of bare cliffs of till and gravel, reaching 140 feet above Kluane Lake. The upper surface of the till and gravel is undulating, and is covered irregularly by a mantle of silt, a few inches to 9 feet thick. This silt mantle is divided by the volcanic ash layer, 1 inch to 3 inches thick, into upper and lower parts. Both parts are of variable thickness so that in different places the ash is near the top, midway of, or near the base of the mantle of silt. The upper part of the silt, above the ash, is from a few inches to 6 feet thick, grey to grey-sepia-brown, and contains vegetable material, but does not exhibit any colour zoning. It is still forming from dust blown up the cliffs and settling among the grass and other vegetation on the top, and shows a vague stratification. The silt below the ash is the varicoloured zone referred to above. It consists of three layers with an aggregate thickness of between 21 and 43 inches. The top layer, 8 to 15 inches thick, is composed of dull, brick-red silt. It grades downward into the middle layer of similar material but yellow-ochre in colour. The middle layer is about 10 inches thick, and grades, in turn, into the bottom layer 3 to 18 inches thick, consisting of yellow-grey silt lightly speckled with white salts in the upper part. The salts increase downward in the layer so that in places it appears almost white. The whole zone is very porous, the bottom layer particularly so, and rests directly on light buff, unweathered gravel and till. The entire section exposed here above the gravel and till is believed to be of aeolian origin, and, except for the ash, is regarded as loess.

VOLCANIC ASH

Volcanic ash is spread across a large part of the area mapped and over much of southern Yukon Territory. It occurs as a white layer at, or close to, the surface of the ground, where it is exposed in cutbanks along streams or similar localities. Its conspicuousness and wide distribution have aroused the attention of travellers in the territory, and it has been referred to or described by many, beginning with Schwatka (26, p. 196) in 1883 and Dawson (16, pp. 40-43) in 1887.

In the course of time, explorations have supplied many records of the occurrence and thickness of the volcanic ash deposit, and in 1915 Capps (13, pp. 59-64) wrote a comprehensive account of it. The present work in the Northwest Shakwak Valley region has added a number of new records and others have been gathered by the writer in recent years in different parts of Yukon Territory. Together with those given on a small map by Capps (13, p. 60), the records are assembled on Figure 1 and give a more detailed picture of its distribution than was hitherto possible.

Capps shows that the source of the ash was in all probability in an area near the 141st Meridian, the International Boundary, and about 10 miles south of White River. He describes an area, near the head of Kletsan Creek, on both sides of the meridian, 2 to 4 miles wide, along the mountain slopes in which the entire surface is covered with great white banks and dunes of ash. This area of thick ash, he says, has a relief of 200 to 400 feet, which is believed to be largely in the ash, as exposures of bedrock are almost completely lacking.

The distribution of the ash, as it appears in air photographs, suggests that the vent was in the locality mentioned by Capps, but no feature resembling a crater is discernible, though one may be concealed by snow in the cirques. Most of the ash, so conspicuously white against the dark rocks of the mountains, has been eroded from the steep upper slopes, but large masses of it can be seen covering most of the gentler slopes above the forest, at elevations of between 4,000 and 5,000 feet, for about 15 miles. Hayes (17, p. 147) describes the ash, some miles northeasterly from Capps locality, as 75 to 100 feet thick on the west bank of Klutlan River.

There is no information on the ash deposit farther south, in the inaccessible fastness of the St. Elias Mountains, but its presence has been recorded over wide regions mainly northerly and easterly from the areas of thick deposits.

The records of the thickness of the ash show discrepancies in some localities between measurements made by different individuals. This is to be expected, as the top and bottom contacts are commonly not sharply defined and exposures around a locality may differ due to variations in such factors as the slope of the ground upon which it lies, and exposure to wind or erosion. There is, however, general accordance among the measurements, so that isopachs of its thickness can be drawn with reasonable accuracy to represent the form of the deposit. The most remote record of its occurrence, on the headwaters of Keele River in the Northwest Territories, 450 miles from the source area, is credited by Capps (13, p. 61) to J. Keele.

It will be seen in Figure 1 that from the region of great thickness the ash radiates in two fans, one with its medial line pointing a few degrees west of north, and the other between 60 and 70 degrees east of north. Perhaps the most interesting feature of its distribution, besides the change of direction of the wind required to form the two fans, is the abrupt thinning of the ash on the north edge of the easterly fan. For instance, along the Alaska Highway for several miles east of White River, the ash is hardly noticeable, but becomes conspicuous east of Pickhandle Lake. From there it thickens very rapidly southeastward and reaches a maximum of 20 to 23 inches on the east side of Grafe Creek. Southeastward from there it thins again, and is only about 12 inches thick on the west bank of Donjek River. The same abrupt thickening is seen along Yukon River above Fort Selkirk (*See* Figure 1). At Fort Selkirk and around the mouth and up Pelly River for 70 miles or more the ash is barely noticeable, though west of Fort Selkirk it is about 1 inch thick in the bank of an island near the mouth of Selwyn River and about $\frac{1}{2}$ inch thick on an island a few miles above the mouth of White River. Along the Yukon above Fort Selkirk, the ash is only apparent in the more favourable localities for several miles, but it shows conspicuously and is about 6 inches thick in the river banks a few miles below Minto, and thickens rapidly to about 10 inches on the flat above Minto. It reaches a maximum thickness of more than 10 inches along the river between Minto and Rink Rapid, and from there thins gradually southeastward, upstream, to about 8 inches at Carmacks and 4 to 6 inches near the mouth of Teslin River.

These features of the distribution and thickness of the ash can be explained in two ways. The wind, after blowing steadily in the direction of one fan, may have changed suddenly and settled in that of the other fan during one prolonged eruption. It is more probable, however, that the two fans are due to two explosive surges in the same eruption during which the wind changed more or less continuously. A lull, long enough for the wind to swing from the direction of one fan to that of the other, occupied the interval between the two surges, during which the air was relatively lightly burdened with the thinning clouds of ash as the first surge subsided. From this interpretation it may be speculated that the steep, interior, northwest slope of the northeast fan was formed from the outburst of the second and major surge. On this basis it follows that the wind blew from the south during the initial stage of the eruption, and laid the fan northward near the International Boundary. As this surge subsided it changed progressively to the west and blew the thinning clouds of ash eastward. It had changed direction to south 60 degrees or more west when the second outburst took place, and, as the eruption died away, it spread a thinning sheet of ash more eastward and finally southeastward.

The volcanic ash has been examined in detail in a few places. It shows little variation in character where its thickness ranges up to about a foot, except that the coarseness of the larger fragments increases with the thickness. Along Yukon River, where it has been described by Dawson (16, p. 43), it is typical. Here it is a fine-grained, white or slightly speckled, gritty feeling powder. It consists of elongated shreds, enclosing tubular vesicles, and fragments of feldspar, quartz, and hornblende crystals, and, rarely, biotite and magnetite. Some of the crystal fragments are attached to blebs of vesicular glass. At Grafe Creek the ash is composed of the same minerals and is very similar, but more noticeably speckled, and, being nearer the source, contains coarser fragments. Most of it is fine grained, but it contains many grains up to 3 to 4 mm. long, commonly spherical, or egg-shaped, and containing vesicles. About one-tenth of the ash at Grafe Creek was found to float on water, due to its vesicular nature, and most of the rest of it could be readily separated in a pan from quartz sand and is judged to have specific gravities of between 1 and 2. Capps (13, p. 63) describes the material from the area of thickest deposits near the head of Kletsan Creek. There the particles average perhaps from 1 to 3 mm. in diameter, though larger pieces are numerous, and single fragments 8 to 10 cm. long were seen.

Some of the coarser material was examined under the microscope by Knopf (25, pp. 43-44), and the following is taken from his description: "The larger fragments of the pumice inclose numerous small hexagonal plates of biotite, short prisms of hornblende a millimetre 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 also are 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 Ab_1An_1. They inclose some minute foils of biotite. Grains of magnetite occur sporadically. The matrix holding these phenocrysts is a pumiceous glass, clear and colorless, with a marked drawn-out, twisted, fluidal appearance. Some of the phenocrysts show that they were broken by movements of the surrounding glass. According to the microscopical determination the ash is an andesitic pumice."

Dawson (16, p. 43), Hayes (17, p. 148), and Capps (13, p. 62) made estimates of the volume of ash erupted. The writer, with more data available, offers another estimate, and no doubt, as still further information is obtained, others more accurate will follow. The area enclosed by each isopach on Figure 1 has been measured. The profiles between the isopach lines were assumed to be straight, and for thicknesses greater than 4 feet, isopach lines were assumed at 8, 16, 32, 64, 128, and 256 feet. To obtain areas for these greater thicknesses of ash, an assumption of 48 and 108 square miles, respectively,[1] was made for thicknesses of 256 and 128 feet. These two figures and those for the 2- and 4-foot isopachs were then plotted on a graph; and the four points joined by a curve from which the areas for thicknesses of 8, 16, 32, and 64 feet were obtained.

The calculations give a total volume of 12·15 cubic miles for the ash deposit within the boundary of the 'noticeable limit' (Figure 1). Less than half of this has a thickness of more than 4 feet and the volume of ash less than 1 inch thick is estimated to be 1·53 cubic miles[2].

On the basis of the above volume, it is possible to calculate the approximate volume of solid rock that the ash represents by applying factors for the porosity of the pumice particles and for the interspaces of the deposit. Of the sample tested by the writer from near Grafe Creek 10 per cent was light enough to float on water, and the floating particles were mainly the larger ones, containing unbroken vesicles, whereas the finer material sank. Dawson (16, p. 43) remarks that the fine material is "more or less completely tubular". This being so, the finer material sinks because its vesicles are broken and fill when immersed. From these features a uniform porosity representing a specific gravity of 1·00 or less for the ash particles is assumed, whereas a specific gravity of 2·86 is regarded as probable for a solid rock of andesitic composition. Using these figures the porosity of the particles or pumice fragments is about 65 per cent. The ash deposit has suffered no compression by load, so that, quite aside from its innate porosity, it has a very high interspace porosity, and 50 per cent is judged a probable figure for this factor. These two factors reduce the 12·15 cubic miles of the ash deposit to 2·12 cubic miles of solid andesite.

In the upper part of White River Valley, about 25 miles northwest of the source area, Capps found good evidence to show that the volcanic eruption that spread the ash took place approximately 1,400 years ago (13, p. 64).

---

1 These figures are believed to be approximately correct, from the information available.

2 The volumes given by Dawson, Hayes, and Capps are 1, 165, and 10 cubic miles respectively. Dawson's figure of 1 cubic mile should, however, for purposes of comparison be 1·18 cubic miles, as he subtracted 0·18 cubic mile to allow for "interspaces in the comminuted material".

CHAPTER V

PROSPECTING AND MINERAL DISCOVERIES

HISTORICAL NOTES

The first white men to traverse any part of the Northwest Shakwak Valley map-area were those of Schwatka's party in 1891 (17), but in earlier times Indians had recovered native copper from the gravels of Kletsan Creek, near the International Boundary. Although prospectors had passed through the area since 1898, it was not until 1903 that the first gold was discovered in it, on Fourth of July Creek. Following this discovery, other placer creeks were investigated westward along Ruby Range as far as Kluane Lake and along the Kluane Ranges, and by 1905 most of the placer creeks now known had been explored. About 1908, prospectors became interested in the possibilities of lode copper in the upper White River country both in Yukon Territory and Alaska, and many copper prospects were staked on the ridges adjacent to Tetamagouche and Quill Creeks. Most of the claims, however, were soon abandoned. In 1912 to 1914, following the discovery of gold in the Chisana district in Alaska, many prospectors passed through the Shakwak area and some creeks were staked for gold on the west side of White River in Yukon Territory. However, little prospecting or placer mining was done in the area from that time until the construction of the Alaska Highway in 1942, except that each year one or more of the creeks were worked by individuals or small partnerships. Bullion, Sheep, and Burwash Creeks received most attention, but Fourth of July, Ruby, Arch, Gladstone, and Cyr Creeks, and upper Koidern River (Edith Creek) were also worked from time to time.

The Highway made for greater accessibility for the whole region, and brought with it new interest in prospecting both for individuals and companies. It also facilitated transportation of heavy mechanical equipment for working the placer deposits, and this, in turn, provided possibilities for exploring ground formerly regarded as too low grade or otherwise unworkable, due to too many boulders, excessive water, or lack of adequate grade for disposal of tailings. As a result, in the last few years several creeks have been re-examined with these possibilities in mind, and operations on a relatively large scale have developed on Burwash Creek.

PROSPECTING ACTIVITIES IN 1945

In 1945, several placer creeks were visited by the writer. J. Coglan was working on Bullion Creek near his cabin, which is at an elevation of 3,450 feet, $\frac{1}{4}$ mile or less below the lower end of the narrow canyon that the creek occupies below the mouth of Metaline Creek. In recent years C. Strandberg had also prospected various parts of Bullion Creek about half-way between the canyon and the mouth of the creek. Patches of gravel can be seen along each side of the creek valley, evidently remnants of a former, higher level channel. Those near Coglan's cabin are 10 to 15 feet above the present stream bed on the southwest side. Farther downstream, similar remnants, higher above the creek on the northeast side, mark a flatter gradient than that of the present stream. Old placer workings are apparent in many places in the creek bottom, where they are partly covered with gravel moved by the sudden torrential floods of the creek, and here and there on small patches of the high-level channel.

On Sheep Creek, three or four men were engaged in placer mining during the season, and others were prospecting for lode deposits in the vicinity of the creek. N. Varger was placer mining about a mile below Fisher Creek; H. Fromm, about a mile farther downstream; and another miner was established a little lower down. Old workings are to be seen nearly all along the creek below Fisher Creek.

On Gladstone Creek, some placer mining has been undertaken from time to time, and it is reported that small, rich pockets have been found in remnants of old bench channels at scattered localities for many miles along the creek valley above Cyr Creek. In 1945, two men were working in a canyon of Cyr Creek about ½ mile above its junction with Gladstone Creek, and in the 'Little Canyon' of Gladstone Creek, ⅓ mile up from Cyr Creek, there was evidence of many small workings of past years.

On Burwash Creek old placer workings can be seen, here and there, in many places, as far up as Cooper Creek, and it is reported that gold has been found still farther upstream. It is of interest, too, that gold is said to have been recovered from patches of old gravels, perhaps of Tertiary age, that lie high up on the elevated plateau area between the heads of Burwash and Wade Creeks.

During the writer's visit, G. Loland was mining on a small tributary of Burwash Creek, Johnson Gulch, which joins the main creek from the north a short distance below Cooper Creek. Here, about ½ mile from the mouth, small remnants of old, bench gravels 10 to 15 feet above the floor have been worked on both sides of the gulch, and small areas are said to have yielded sufficient gold to pay well to mine.

At the time of the writer's visit, operations had begun on Discovery claim, which is in the canyon about 1½ to 2 miles up Burwash Creek from the Alaska Highway. A small area was being worked, and preparations, including a long drain, were being made for mining a larger adjacent area on the downstream side. The chief items of equipment consisted of a bulldozer, used to push the dirt into the head of the boxes, and a dragline scraper driven by power from a tractor for stacking the tailings. In 1949, two such operations were reported to be in progress on Burwash Creek.

During 1945, a few scattered individuals were placer prospecting creeks west of Burwash Creek, including Arch Creek and upper Koidern River (Edith Creek).

EVIDENCE OF MINERALIZATION IN STEELE (WOLF) CREEK VALLEY

In the course of his geological study and exploration in Steele (Wolf) Creek Valley, Sharp discovered evidence of some interesting mineralization, which he refers to as follows (27, pp. 636-637): "The porphyritic biotite granite is highly silicified, pyritized, and contains a few flakes of molybdenite and chalcopyrite in a 200- to 300-foot border zone north and east of the peak [on the south side of the valley 13 miles in a straight line from Donjek River]. A large medial moraine on Wolf [Steele] Creek Glacier consists of highly silicified quartz monzonite containing chalcopyrite, pyrite, specular hematite, and considerable molybdenite in small veinlets and flakes. The abundance of mineralized debris in the moraine indicates a large exposure farther up the valley beyond the map-area".

TUNGSTEN

Crystals of scheelite occur with garnet and other contact silicate minerals in places where the granitic intrusions are in contact with limestone in the hills directly north of the Alaska Highway between Kluane and Donjek Rivers.

GYPSUM

Many blocks and boulders of white rock were noted along Bullion Creek. These were evidently derived from the prominent white hill to the north at the head of Coin Creek. Samples taken from them proved to be very clean gypsum, and indicate the possible occurrence of a large deposit of this industrial mineral. The construction of about 10 miles of truck road would be required to make such a deposit accessible from the Alaska Highway.

COAL

The coal in the Paleocene strata was formerly classed as 'lignite' on the basis of four samples collected by Cairnes and analysed in 1914 (9, pp. 32-33). But on the basis of the American Society for Testing Materials standard specifications, now in use, the material is 'coal', and four samples collected and analysed in 1949 and 1950 have been ranked as subbituminous C and B, as indicated in the following table.

The coal in the Sheep Creek area has been used by placer miners to heat their cabins, and small quantities from a seam in Amphitheatre Mountain have been packed on horses to Burwash Landing for use in a blacksmith forge.

With reference to Sample No. 5, the analyst reports that "the capacity moisture of this coal, which was obtained by rehydration, was found to be 13·7 per cent. In all probability, the correct value, obtainable by dehydration, would be about 15 per cent. Either of these moisture contents would classify the coal as sub-bituminous B, and that in spite of the fact that it agglomerates".

Sample No. 1 was taken across a seam 3 feet thick exposed in the southeast end of the Sheep Creek area. Sample No. 2 was obtained at the surface across 4 feet 6 inches of coal exposed near the head of the left fork of Burwash Creek. Neither roof nor floor of this seam was seen, the upper part having been removed by erosion and the floor of the seam inaccessible. The remaining two samples taken in 1914 were both from seams in the Amphitheatre Mountain area. Sample No. 3 was an average surface sample of a seam 4 feet 5 inches thick from the upper part of the amphitheatre, and the other, No. 4, was an average of a number of pieces of coal from 1 foot to 3 feet in diameter, from a seam at least 3 feet thick outcropping down in the amphitheatre. Sample No. 5, obtained in 1949 and sent in

COAL ANALYSES[1]

—	1	2	3	4	5	6		7		8	
						As rec'd.	Dry	As rec'd.	Dry	As rec'd.	Dry
Year collected	1914	1914	1914	1914	1949	1950		1950		1950	
Laboratory No.	......	......	......	......	30,974	32,618		32,619		32,620	
Proximate analysis (per cent)—											
Moisture	10·9	10·2	11·2	9·8	10·7	22·6	0·0	22·3	0·0	20·6	0·0
Ash	9·6	9·1	5·4	1·6	3·2	10·1	13·0	13·7	17·7	27·6	34·7
Volatile matter	41·0	42·0	40·9	43·9	39·4	35·9	46·4	32·3	41·6	27·7	34·9
Fixed carbon (by diff.)	38·5	38·7	42·5	44·7	46·7	31·4	40·6	31·7	40·7	24·1	30·4
Ultimate analyses (per cent)—											
Sulphur	......	......	......	......	0·4	0·1	0·1	Tr.	Tr.	Tr.	Tr.
Nitrogen	......	......	......	......	......	......	......	......	......	......	......
Calorific value—											
B.t.u. per lb. gross	......	......	......	......	10,880	8,065	10,415	7,485	9,635	5,750	7,245
Ash fusibility (°F.)—											
Initial	......	......	......	......	......	......	2,120	......	2,330	......	2,700
Softening temp.	......	......	......	......	......	......	2,240	......	2,430	......	2,750+
Fluid temp.	......	......	......	......	......	......	2,270	......	2,490	......	2,750+
Caking properties residue at 950°C.	......	......	......	......	Aggl.	Non-aggl.		Non-aggl.		Non-aggl.	
B.t.u. moisture and mineral matter free	......	......	......	......	......	9,426		9,287		9,300	
Classification	......	......	......	......	Subbit. B	Subbit. C		Subbit. C		Subbit. C.	

[1]These analyses were made by the Mines Branch of the Department of Mines, Ottawa.

by H. W. Adcock and associates of Whitehorse, is believed to have come from a seam reported to be 14 feet thick on the south side of Badlands Creek.

In 1950, J. E. Muller of the Geological Survey of Canada obtained three samples, Nos. 6, 7, and 8, at an elevation of 5,500 feet on a fork of Berry Creek, a small tributary of Badlands Creek, which comes down from the slope of Mount Hoge opposite Amphitheatre Mountain. Berry Creek enters Badlands Creek 4¼ miles in a straight line from its junction with Duke River. The section of the coal seams from which these three samples were taken is as follows:

	Feet	Inches
Roof: loose sand and gravel of Paleocene age.		
Coal, well-bedded, with occasional thin shale partings	5	0
(Sample No. 6 from the upper 3 feet)		
Shale	5	8
Coal (Sample No. 7); with a few thin shale partings	4	2
Clay, soft; with some grey shale at the bottom	0	8
Coal, interbedded with coaly shale and brown shale	3	0
(Sample No. 8, from the upper 2 feet 6 inches)		
Resting on beds of clay and coaly shale.		

Samples Nos. 6, 7, and 8 were channelled uniformly across the seams and placed directly into air-tight containers.

MANGANESE

A discovery of manganese was made in 1949 at mile 1212 on the Alaska Highway, and four claims were staked by Messrs. W. T. Batrick and W. Hammond. The following account is given by E. D. Kindle of the Geological Survey of Canada, who visited the discovery in 1949.

"The deposit is a vein, 20 inches wide, exposed for 25 feet on the north side of the Highway, approximately 725 feet east of mile-post 1212 and 30 feet north of the shoulder of the road. The wall-rock is fine, white-bedded rhyolitic tuff, and both vein and tuff strike northeast and dip 45 degrees northwest. At both ends the vein is obscured by drift. A dyke of diorite, 75 feet wide, intrudes the bedded tuffs 40 feet north of the vein exposure, and this dyke strikes easterly across the course of the vein. The possible continuation of the vein into and across the diorite had not been investigated.

"The vein is composed largely of the hard, hydrous manganese oxide mineral, psilomelane, but includes some, partly replaced rhyolitic tuff. A typical specimen of the ore, analysed by the Mines Branch, Department of Mines and Technical Surveys, Ottawa, gave the following results:

	Per cent
Manganese	32·83
Phosphorus	0·09
Sulphur	0·03
Iron	2·55

"A channel sample taken across 20 inches of the vein, analysed by R. J. C. Fabry, Geological Survey of Canada, gave:

	Per cent
Mn_2O_3	71·83
Fe_2O_3	1·38
CaO	Trace
H_2O	5·44
Insoluble	21·59
	100·24"

A. View south up Kuskawalsh Glacier. A flood plain of gravel outwash forms the immediate foreground. Behind it, moraines marking the farthest recent advances of the ice form an irregular, low, ragged ridge through which the river has washed a gap (left foreground). Beyond the ridge, narrow areas of outwash border the front of the stagnant, debris-covered ice. In the distance are areas of cleaner ice of the glacier. Mount Maxwell, about 8,600 feet elevation, shows in the left background among the clouds. (Photo by H. S. Bostock; Geol. Surv., Canada, negative 97879). Pages 6, 7.)

B. View south across Burwash Creek to the base of Amphitheatre Mountain, the top of which forms a nearly level profile against the snow-clad Donjek Range beyond. Coal outcrops occur in the area of cloud shadow in the left centre of the picture on the east slope of Amphitheatre Mountain. Mount Hoge, about 10,075 feet elevation, is the highest peak on the skyline. (Photo by H. S. Bostock; Geol. Surv., Canada, negative 97821.) (Pages 10, 11, 29.)

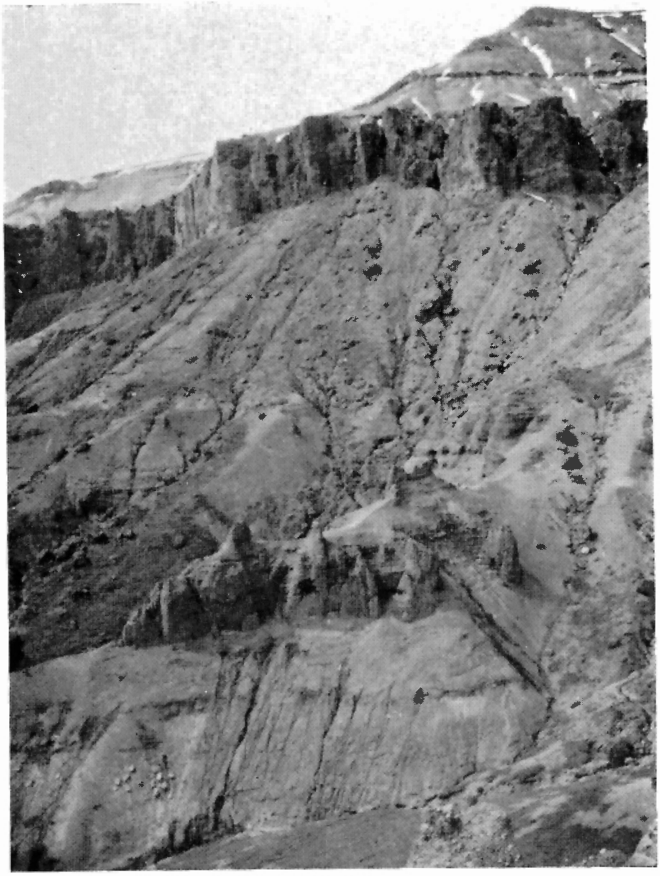
PLATE III

View from an elevation of about 20,000 feet above a point about 10 miles northeast of Snag, showing the limit of the last major glaciation. White River enters in the right foreground and flows northeast and north into the left distance. Near the centre background is its junction with Donjek River. The picture shows the contrast between the areas in the foreground and along White River Valley, which were covered by ice of the last glaciation, and the higher slopes on the left, which escaped this glaciation. The unglaciated parts exhibit the typical topography of the Klondike Plateau. (Photo by U.S.A.A.F., negative 41-F-24-R-74; and Geol. Surv., Canada, negative 104201.) (Pages 10, 13.)

PLATE IV

Vertical view from 20,000 feet elevation of Donjek River in Shakwak Valley showing the river channels in the bare flood plain. The lineament (fault-line scarp) transversing obliquely across the drumlinoid ridges in the foreground is believed to have formed as a result of recent movement along a fault in Shakwak Valley. In the upper part of the picture can be seen an area of forest-covered parabolic dunes, indicating southeasterly prevailing winds from the dusty Donjek River flats. (Photo by U.S.A.A.F., negative 41-F-21-I-6; and Geol. Surv., Canada, negative 104185.) (Pages 9, 35.)

PLATE V



View of badlands on the east slope of Amphitheatre Mountain. The lower slopes are carved in Paleocene sedimentary rocks. The prominent wall of cliffs higher up the mountain is in Tertiary lava, and the slopes above the cliffs are of gravels in which a thin lava flow or sill shows as a narrow dark line of cliffs. (Photo by H. S. Bostock; Geol. Surv., Canada, negative 97810.) (Page 29.)

INDEX