



GEOLOGICAL  
SURVEY  
OF  
CANADA

DEPARTMENT OF MINES  
AND TECHNICAL SURVEYS

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**BULLETIN 136**

**SURFICIAL GEOLOGY, DAWSON,  
LARSEN CREEK, AND NASH CREEK MAP-AREAS,  
YUKON TERRITORY**

(116B and 116C E $\frac{1}{2}$ , 116A and 106D)

Peter Vernon and O. L. Hughes

MANUSCRIPT AND  
CARTOGRAPHY

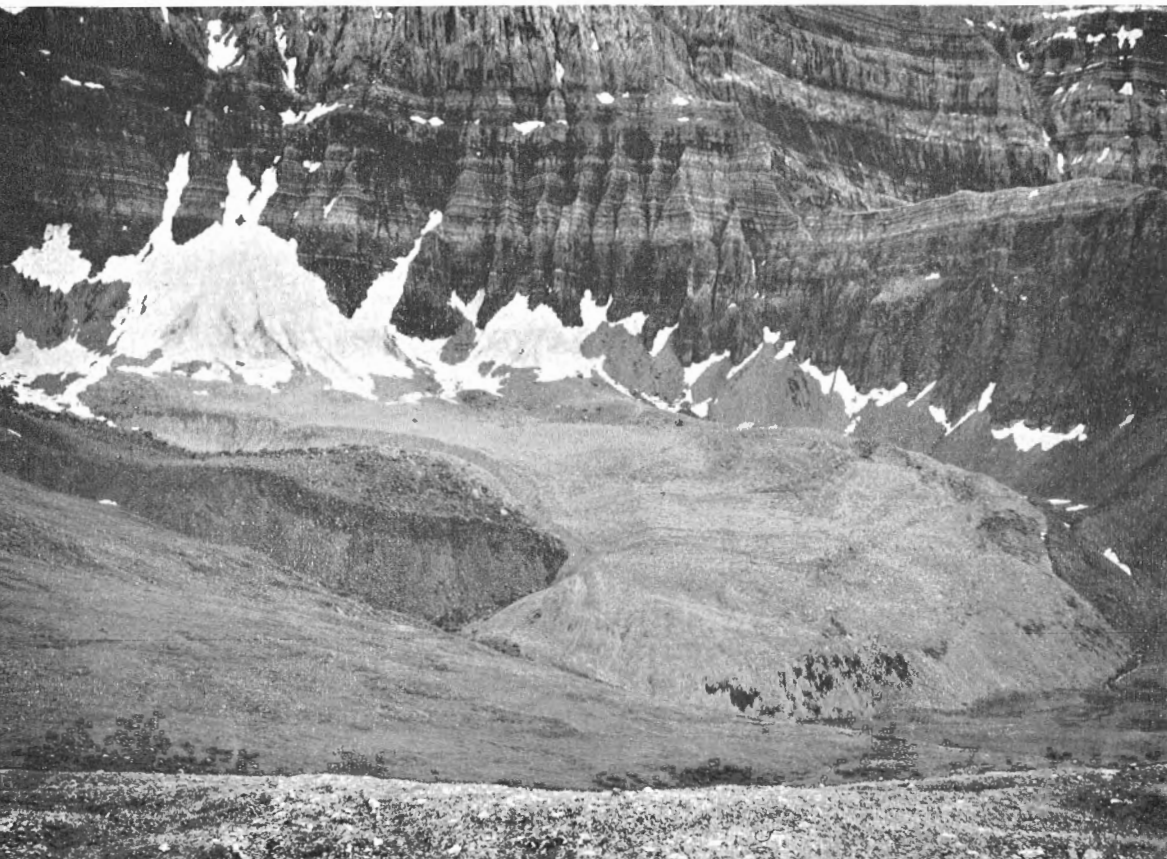
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SECTION

*Index  
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*2,000-1965-5293*



*P.V. 2, 7-61*

**PLATE I.** A debris-covered glacier superimposed on a rock glacier or older debris-covered glacier. The overlying tongue contains mainly light grey carbonate rocks from high on the cirque wall; the underlying tongue contains mainly maroon quartzite from near the base of the cirque wall. Six miles west of Hart Lake, central part of Nash Creek map-area.



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By

Peter Vernon and O. L. Hughes

DEPARTMENT OF  
MINES AND TECHNICAL SURVEYS  
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Catalogue No. M42-136

*Price subject to change without notice*

ROGER DUHAMEL, F.R.S.C.

Queen's Printer and Controller of Stationery

Ottawa, Canada

1966

## PREFACE

In 1961, a helicopter-supported Geological Survey field project, Operation Ogilvie, presented an opportunity for the writers to study glaciation in Ogilvie and Wernecke Mountains, western Yukon Territory. Glacial information on this region had hitherto been known only from the study of trimetrogon airphotos by H. S. Bostock. The availability of vertical airphotos plus the opportunity for ground checking permitted recognition of at least three glacial advances in the region. The limits of the two most recent of these glaciations have been determined tentatively throughout the area.

J. M. HARRISON,  
*Director, Geological Survey of Canada*

OTTAWA, October 1, 1963

Bulletin 136—Oberflächengeologie der Kartenblätter von Dawson, Larsen Creek und Nash Creek im Yukonterritorium.

Von Peter Vernon und O. L. Hughes

Bericht über die Ergebnisse der im Jahre 1961 vorgenommenen Untersuchungen glazialer Verhältnisse im westlichen Teile des Yukonterritoriums. In diesem Gebiet ist ein mindestens dreimaliges Vorrücken des Eises festgestellt worden.

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БЮЛЛЕТЕНЬ 136. П. Вернон и О. Л. Юз. Поверхностная геология районов Даусона, Ларсен Крик и Нэш Крик Юконской территории.

Приведены результаты рекогносцировочных исследований ледниковых образований западной части Юконской территории произведенных в 1961 году. Установлено не меньше трёх наступлений ледника в этом регионе.

## CONTENTS

	PAGE
<i>Introduction</i> .....	1
Scope of investigation.....	1
Notes on map-units and symbols.....	1
<i>Physiographic Setting</i> .....	3
<i>Pleistocene Geology and History</i> .....	6
Glaciations in the western region.....	11
Glaciations in the eastern region.....	12
Ice retreat following the last glaciation.....	14
Pleistocene chronology.....	15
<i>Rock Glaciers and Debris-covered Glaciers</i> .....	17
<i>References</i> .....	23
<i>Index</i> .....	25
Table I. Geomorphic criteria differentiating areas covered by ice during the intermediate and last glaciations.....	6

## Illustrations

Map 1170A. Surficial geology, Dawson.....	<i>In pocket</i>
Map 1171A. Surficial geology, Larsen Creek.....	<i>In pocket</i>
Map 1172A. Surficial geology, Nash Creek.....	<i>In pocket</i>
Plate I. A debris-covered glacier, west of Hart Lake.....	<i>Frontispiece</i>
II. View westward of pingo 2 miles northeast of Caldwell Lake, northern part of Dawson map-area.....	5
III. Moraines, headwaters of Ogilvie River.....	8
IV. Cirques in ridge at headwaters of Little Wind River.....	9

	PAGE
V. Moraines of the last glaciation in a valley tributary to Hart River..	10
VI. A stabilized, sparsely forested spatulate rock glacier, Bonnet Plume River.....	18
VII. A debris-covered glacier, east of Nash Creek map-area.....	19
VIII. A typical debris-covered glacier, southwest of Gillespie Lake.....	20
IX. Ice exposed in the wall of a furrow in a debris-covered glacier, 6 miles west of Hart Lake.....	21

Figure 1. Relationship of Operation Ogilvie area to physiographic divisions of north-central Yukon.....*Facing p. 1*

# SURFICIAL GEOLOGY, DAWSON, LARSEN CREEK, AND NASH CREEK MAP-AREAS, YUKON TERRITORY

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## *Abstract*

The area mapped during Operation Ogilvie includes physiographic elements ranging in character from the moderately high but rugged Wernecke and Ogilvie Mountains through parts of the deeply dissected Yukon Plateau, to low broad valleys such as that part of Tintina Trench lying southeast of the junction of Rock Creek and Klondike River.

Glacial deposits record at least three advances both of a large transection glacier in the eastern part of the area and of independent valley glaciers in the west. High north-facing cirques of Ogilvie and Wernecke Mountains are occupied now by rock glaciers and debris-covered glaciers; the latter seemingly persist only by virtue of the protection afforded by their thick debris covers.

## *Résumé*

La région cartographiée au cours de l'Opération Ogilvie englobe des zones dont les traits physiques varient du relief de hauteur modérée, mais accidenté, des monts Wernecke et Ogilvie aux vallées larges et basses de la partie du sillon Tintina, situé au sud-ouest du confluent rivières Rock et Klondike, en passant par les aires fortement disséquées du plateau du Yukon.

Les dépôts glaciaires rappellent au moins trois avancées: d'abord, un grand glacier transversal dans la partie orientale de la région et, aussi, des glaciers isolés de type alpin dans l'Ouest. Les cirques de haute altitude, faisant face au nord, et qui sont situés dans les monts Ogilvie et Wernecke, sont actuellement occupés par des glaciers de pierres et de débris; ces derniers ne fondent pas apparemment en raison de l'abri que constitue leur épais manteau de débris.

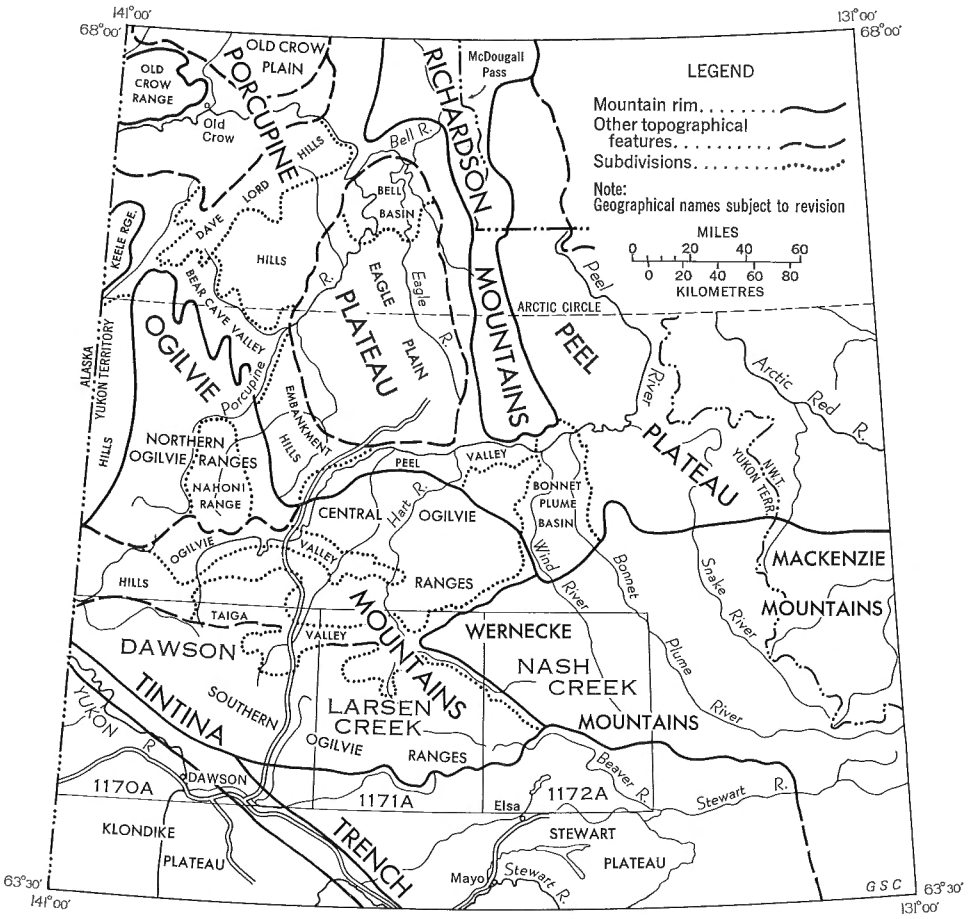


FIGURE 1. Relationship of Operation Ogilvie area to physiographic divisions of north-central Yukon Territory (adapted from Bostock, 1961).

## INTRODUCTION

### Scope of Investigation

The interpretation presented here of glaciation of the mapped area (Fig. 1) is based mainly on airphoto studies, supported by widely scattered ground observations during Operation Ogilvie (Green and Roddick, 1962). The conclusions reached are tentative and doubtless will be modified as more detailed information becomes available. The sequence of glaciation outlined is based mainly on studies by Hughes along North Klondike River and northward into the headwaters of Blackstone River. Correlation of the glacial sequence determined there has been extended by airphoto interpretation throughout the Southern Ogilvie Ranges, western Wernecke Mountains, and northern Stewart Plateau.

The wisdom of correlating glacial features over a large area mainly on the basis of airphoto interpretation may well be questioned. However, establishment of at least a tentative chronologic framework is a necessary step in understanding a multiglacial sequence.

### Notes on Map-units and Symbols

The units and symbols on the three accompanying maps are perforce based on geomorphic features determinable from airphotos. The numbering of the units has only limited stratigraphic significance. In any restricted area, the glacio-fluvial deposits are younger than the glacial deposits on which they may lie and fluvial deposits associated with immediately adjacent streams are still younger. No distinction is made, for example, between two areas of morainic topography relating to two different stages of glaciation, except that the maximum terminal positions of glaciers of the intermediate and last glaciations are distinguished by the colours red and blue respectively, where evidence appears to support such distinction.

The glacial deposits (map-unit 1) consist of till derived from the predominantly sedimentary rocks of the region. Typically, the till is sandy, has loose texture, and contains irregular lenses of washed gravel. The deposits are relatively thick on the floors of major valleys (probably in excess of 100 feet locally), and form a thin discontinuous veneer on valley slopes. Although at least a discontinuous veneer of glacial deposits occurs below the upper limit of glaciation throughout the area, only areas of distinctive morainic topography have been mapped. The morainic topography is designated "1a" where associated with terminal positions of glaciers, "1b" where it is judged to be the product of actively moving but retreating ice, and "1c" where it is judged to have resulted from the melting in situ of a stagnated segment of a glacier (dead ice). Areas of irregular kettled terrain

Dawson, Larsen Creek, and Nash Creek Map-Areas, Yukon

in the vicinity of McQuesten and Clark Lakes, and along Keno-Ladue River, interpreted originally as unit 1c (dead ice deposits) were found by Hughes in 1964 to be underlain by silt and silty clay, locally overlain by peat. The areas (map-unit 3d) are characterized by abundant depressions occupied by ponds and small lakes, many bounded in part by steep banks 8 to 15 feet high, exposing thawing perennially frozen ground containing abundant segregated ground ice. Many of the ponds and lakes lack exposures, but thawing is indicated by collapse of trees along their shores. These have been called cave-in lakes or thaw lakes, and the landform thermokarst topography. The glacio-fluvial deposits (map-unit 2) consisting of gravel and sand deposited by glacial streams are differentiated from fluvial deposits (map-unit 3) on the basis of form and inferred relationship to ice-frontal positions. At points distant from inferred ice-fronts, the distinction between glacio-fluvial deposits and fluvial deposits (map-unit 3) becomes arbitrary. Almost all streams within the area mapped were affected by glaciation at their heads at least, and sediment released from melting glaciers has been carried far by the resulting meltwater.

## PHYSIOGRAPHIC SETTING

The area studied comprises, from west to east, Dawson, Larsen Creek, and Nash Creek map-areas (Fig. 1), and lies within the Northern Plateau and Mountain area of the Interior System of the Canadian Cordillera (Bostock, 1948, 1961). Six physiographic units lie wholly or partly within the area: *Wernecke Mountains*, the western extremity of the Selwyn Mountains; *Southern Ogilvie Ranges* and *Taiga Valley*, both part of the Ogilvie Mountains; and *Tintina Trench*, *Klondike Plateau*, and *Stewart Plateau*, all within the Yukon Plateau.

The steep and rugged *Wernecke Mountains* are developed mainly on Precambrian phyllite and dolomite and on lower Palaeozoic carbonate rocks (Green and Roddick, 1962). Peaks reach elevations of nearly 8,000 feet in the northeastern corner of Nash Creek map-area and 6,750 feet near the western extremity of the range.

The *Southern Ogilvie Ranges* are developed on Precambrian to Middle Jurassic quartzite, grit, chert, and shale, with minor carbonate rocks. The peaks in general are less rugged than those of the Wernecke Mountains, except for Tombstone Mountain and adjacent peaks north of Dawson, which are developed on porphyry of syenitic to monzonitic composition. The porphyry weathers, as described by McConnell (1906, p. 41AA) "into ruinous wedge shaped ridges, surmounted by lines of sharp pinnacles and lofty tower-shaped peaks". Peaks along the axis of the ranges reach elevations of 6,500 feet in the east and 7,500 feet in the west.

*Taiga Valley*, to the north of the Southern Ogilvie Ranges, has been described by Bostock (1961, p. 114) as "irregular in plan, resembling a dachshund looking westward. Overall it is about 120 miles long and in places nearly 40 miles wide. Its surface is largely long, undulating, northward draining slopes and hills . . . The Blackstone and Hart Rivers flow across it and into the Central Ogilvie Ranges to the north regardless of the general conformation of the topography around them". Taiga Valley is underlain mainly by weak shales of Late Devonian or Mississippian age.

*Tintina Trench*, which divides the Southern Ogilvie Ranges from the Klondike Plateau, is "a great valley feature comparable with the Rocky Mountain Trench" (Bostock, 1948, p. 60). At the southern limit of Dawson map-area, Tintina Trench is as much as 12 miles wide; to the northwest, the trench narrows and is about a mile wide at the Yukon-Alaska boundary. Although from Rock Creek northwest the trench is crossed by numerous streams flowing from the Southern Ogilvie Ranges to the Yukon River, it is nevertheless a well-defined feature, especially when viewed from the air. The floor of the trench is occupied by faulted

and tilted early Tertiary coal-bearing sediments. To the southeast of Rock Creek these Tertiary deposits are overlain by gravels (Flat Creek Beds; McConnell, 1905, p. 24B) and by terrace and flood-plain deposits of Klondike River.

The topography of the *Klondike Plateau* has been described by Bostock (1948, p. 69) as "a maze of deep narrow valleys separated by long smooth-topped ridges whose elevations are very uniform, and which are remnants of an old uplifted erosion surface. This surface shows gentle undulations rising here and there along converging ridges to culminate in monadnocks that consist of dome-like eminences or groups of relatively smooth-sloped mountains".

That part of the *Stewart Plateau* lying in the southern part of Larsen Creek map-area is similar to Klondike Plateau, but in southern Nash Creek map-area, Stewart Plateau has a much more mountainous aspect. As recognized by Bostock (1948, p. 64), "...glaciation seems to have been a major factor in developing the present topography. Here the larger valleys have been accentuated, and form a network surrounding tablelands on which the tributary valleys are shallow where the ice cover was thin or lacking. Isolated mountains or small ranges crown the higher parts of most of the tablelands".

The entire field area lies within the zone of discontinuous permafrost shown by Brown (1960, Fig. 6, p. 171). Permafrost occurs throughout the area to depths which locally exceed 400 feet (McTaggart, 1960, p. 7), except beneath well-drained south-facing slopes and beneath narrow strips along major streams, where development of permafrost is inhibited by percolation of groundwater.

Permafrost features noted in the area include: (1) solifluction lobes, abundant on slopes above timber-line in Southern Ogilvie Ranges and Wernecke Mountains; (2) patterned ground, best developed on smooth till or outwash surfaces, as at the junction of Bear Creek with Wind River in the northeastern part of Nash Creek map-area; and (3) palsa bogs, found above timber-line in poorly drained shallow depressions and along the edges of shallow lakes. The floors of the larger valleys, particularly in Tintina Trench and Yukon Plateau, are covered with thick accumulations of organic silt and woody or sedgy peat containing large amounts of ground ice. Much of the ice is in the form of polygonal networks of ice-wedges, as described by Péwé (1948, p. 295; 1957, p. 20) from the Fairbanks area, Alaska; the polygons have diameters of from 10 to 100 feet. If insulating moss and turf is disturbed, as it was during construction of a new road<sup>1</sup> up North Klondike valley in 1959, the ice-wedges melt out to leave longitudinal depressions up to 10 feet wide and 6 feet deep. There are also other large irregular masses of ground ice, which on melting leave irregular depressions or small ponds.

One known and two possible pingos occur in the area. On the east side of Blackstone River, 2 miles northeast of Caldwell Lake, in the northern part of Dawson map-area, a low circular feature is surrounded by a broad ring of bog and a shallow lake (Pl. II). On the rim of the central feature is a conical mound about 60 feet high, and a broad arcuate ridge. The conical mound is clearly a

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<sup>1</sup> Now designated as Dempster Highway.



P.V. 4, 7-61

PLATE II. View westward of pingo 2 miles northeast of Caldwell Lake, northern part of Dawson map-area.

pingo, but it is not known whether the arcuate ridge is part of the rim of a collapsed much larger pingo, or an ice-heaved structure comparable in age to the small pingo. A pingo-like form 4 miles to the northeast is somewhat obscured by trees, and another pingo-like form in the valley of Beaver River near Kathleen Lake (in the southeastern part of Nash Creek map-area) is similarly obscured.

## PLEISTOCENE GEOLOGY AND HISTORY

For discussion of Pleistocene geology and history the three map-areas are arbitrarily divided into eastern and western regions by meridian 137° 30' west.

In the western region, glaciation was characterized by successive advances of valley glaciers originating in cirques along the axis of the Southern Ogilvie Ranges. For the most part the ice flowed outward in the direction of modern drainage and extended only short distances beyond the mountains, thus leaving much of the western part of Dawson map-area and Taiga Valley unglaciated. The valleys of the eastern region were filled by ice of a vast transection glacier system (Ahlmann, 1933, p. 163) that flowed generally northwesterly and westerly from sources southeast of the three map-areas. This ice was augmented by local ice from cirques within the region.

Three glaciations, hereinafter referred to as *old*, *intermediate*, and *last*, are inferred with intervening periods when ice was absent or nearly absent from the three map-areas. Evidence for these three glaciations is best displayed in and near the valley of East Blackstone River in the western region (northeast part of Dawson map-area), where the limits of the intermediate and last glaciations are marked by recognizable moraines. The distribution of the more extensive old glaciation is marked by erratics outside the moraines of the later glaciations: moraines of the old glaciation have not been identified.

The respective glacial features associated with the intermediate and last glaciations have been found (mainly by airphoto interpretation) throughout the glaciated parts of the three map-areas. Table I summarizes the general criteria that distinguish cirques, tributary valleys, and main valleys occupied by ice during the last glaciation from those unglaciated since the intermediate glaciation, and also the criteria separating terminal moraines of the intermediate glaciation and those of the last glaciation. The criteria apply only to the intermediate and last glaciations because glacial features of the old glaciation have not been recognized: furthermore, although these criteria are generally applicable, they may not be applicable to individual features.

Of the cirques that contributed ice to valley glacier systems of the western region during the intermediate glaciation, less than half contained active ice during the last glaciation, and most of these are on the sheltered northeast sides of the ranges (Pl. IV). Additional cirques were subject to nivation and intense mass wasting, which produced amphitheatre-shaped headwalls and sharp arêtes, but there is no evidence that ice actively flowed from them. The rock debris produced

Table I

*Geomorphic Criteria Differentiating Areas Covered by Ice During the Intermediate and Last Glaciations*

	Areas glaciated in last glaciation	Areas not affected by last glaciation
Cirques	Regular amphitheatre-shaped head-walls, with drainage centripetal into cirque basins; arêtes between cirques sharp; tarns common; debris-covered glaciers or rock glaciers common.	Cirque walls cut by dendritic system of gullies; arêtes between cirques somewhat rounded unless sharpened by nivation and mass wasting; tarns rare; few rock glaciers and debris-covered glaciers.
Tributary valleys	Valley bottoms U-shaped; lower part of valley walls smooth; stream incision slight or lacking.	Streams incised in valley floors; in some cases rounded glaciated floors removed to give V-shaped valleys; heavy talus of debris on lower slopes of valley walls; lower slopes of valley walls gullied.
Main valleys	Valley bottoms U-shaped; only moderate development of alluvial fans at mouths of most tributary valleys.	Inner valleys either incised below level of glaciated valley floor or aggraded by outwash from tributary valleys glaciated in last glaciation; large alluvial fans at mouths of tributary streams common.
Terminal moraines	Topography fresh; subsidiary ridges retain relatively sharp crests; oxidation of till comprising the moraines restricted to upper 1 foot; moraines small to moderate in size, and situated relatively close to source of ice (Pl. III).	Topography subdued; till comprising moraines oxidized to depths of 2 feet or more; moraines moderate to large in size, and situated relatively distant from sources of ice (Pl. III).

by nivation and mass wasting remains as talus, or is incorporated in rock glaciers. The restricted number of cirques containing glaciers in the last glaciation is paralleled by the restricted advance of the glaciers. In general they reached only one half or less the distance they advanced during the intermediate glaciation.

Terminal moraines of the last glaciation are also correspondingly smaller. Where a terminal moraine is weakly developed or lacking, the limit of ice-advance can usually be determined from a distinct change in the valley character (Pl. V). Upstream from the limit, the lower slopes and floors of the valleys are smoothly rounded, there is but minor gullying of the lower slopes, streams are only slightly incised into the valley floors, and both talus accumulations and alluvial fans are small. Downstream from the limits of the last glaciation, the valley slopes are moderately to deeply gullied and tributary streams are incised, locally to depths of 100 feet or more. Some of the main valleys contain inner valleys with narrow flood plains.



PLATE III. Vertical airphoto of moraines, headwaters of Ogilvie River, northern part of Dawson map-area ( $64^{\circ}47'N$ ,  $139^{\circ}10'W$ ); fresh moraine of the last glaciation lies within loops of subdued moraine of the intermediate glaciation. A—limit of intermediate moraine; B—limit of last moraine.  
(RCAF A13139—162, 163)



PLATE IV. Vertical airphoto of cirques in ridge at headwaters of Little Wind River, northwest part of Nash Creek map-area ( $64^{\circ}44'N$ ,  $135^{\circ}53'W$ ). The north-facing cirques, most containing tarns and debris-covered or rock glaciers, were active in the last glaciation, whereas south-facing cirques were inactive. 1,2,5—tongue-shaped rock glaciers; 3,6—debris-covered glaciers superimposed on rock glaciers; 4,7—debris-covered glaciers; 8—spatulate rock glacier.



PLATE V. Moraines of the last glaciation in a valley tributary to Hart River from the south, Larsen Creek map-area ( $64^{\circ}30'N$ ,  $136^{\circ}43'W$ ). Northward beyond the moraines the valley has been ice-free since the intermediate glaciation, and the stream is moderately incised. A—limit of last glaciation; B—valley unglaciated in last glaciation. (RCAF A13137-72)

Large alluvial fans have developed at the mouths of tributary streams in some of the main valleys. In certain valleys, such as the North Klondike south of the big bend, large fans are present only beyond the limit of the last glaciation. Within the limit of the last glaciation, fans are small and insignificant. The large fans have been accumulating since retreat of the ice of the intermediate glaciation. Presumably, they were once present in the upper parts of the same valleys, but were scoured out by ice erosion during the last glaciation.

In defining local limits of ice of the last glaciation, the relative sizes of fans can be applied as a criterion only within a very limited area, generally a single valley, after due allowance for difference in size of the tributary streams responsible for the fans. It is not safe to assume that a valley or part of a valley into which tributaries have built large alluvial fans is necessarily beyond the limit of the last glaciation. For example, several large fans, some of remarkably perfect form, occur in Wind River valley between Nash and Bear Creeks, although the limit of the last glaciation is about 10 miles downstream from Bear Creek. Thus, the size of a fan is governed not only by whether or not its site was glaciated in the last glaciation, but by many additional interrelated factors, among which are rock type, vegetation cover, steepness of slope, and climatic factors.

## Glaciations in the Western Region

### *Old Glaciation*

Virtually nothing is known of the pattern and extent of ice movement during the earliest glaciation, except that, locally at least, it was more extensive than during the two succeeding glaciations. Blackstone River leaves Taiga Valley to flow north in a narrow entrenched valley, which appears from airphotos to be unglaciated, so that during the more extensive glaciation the ice may have been diverted to the east and west along Taiga Valley. Erratics of syenite derived from the headwaters of Blackstone River are found beyond the inferred limits of the intermediate glaciation east of Chapman Lake in Taiga Valley and in Seela Pass to the west.

### *Intermediate Glaciation*

The pattern and extent of ice movement during the intermediate glaciation can be determined rather readily from airphotos and supporting evidence obtained on the ground. A valley glacier originating at the head of Blackstone River merged with one moving down the valley of East Blackstone River, and built the complex moraine near Chapman Lake. The glacier in the valley of the East Blackstone River originated in the divide between Tombstone and North Klondike Rivers; it moved northeastward to where North Klondike River turns sharply to the south; there the flow divided, part moving down North Klondike River, and part crossing North Fork Pass to flow down East Blackstone River. Boulders of light grey monzonite with large phenocrysts of zoned plagioclase, peculiar to dykes and sills found in the valley of North Klondike River above

the big bend, were distributed to the north and south by the divided flow. They occur on the east side of North Fork Pass to an elevation of at least 4,600 feet, some 250 feet above the present divide.

Ice moving southward down the valley of North Klondike River extended into Tintina Trench (Fig. 1) and was augmented by a glacier moving down the valley now occupied by Benson Creek. The approximate limit of the advance has been mapped by the extent of large erratic boulders of tough grey quartzite derived from the mountains on the west side of North Klondike River, by the position of meltwater channels, and by exposures of till in cuts and borrow pits along Flat Creek-Eagle Plains road<sup>1</sup>. If a moraine comparable to that at the junction of Blackstone and East Blackstone Rivers was built at the mouth of North Klondike River, it has since been destroyed by North Klondike and Klondike Rivers. Glaciers of comparable size and extent moved down all the large stream systems that head along the axis of Southern Ogilvie Ranges within the western region.

#### *Last Glaciation*

During the last glaciation, ice moved out of the headwaters of East Blackstone River into the northward continuation of North Fork Pass, where it diverged north and south to form a "hammer-head" shaped moraine, the southern loop of which now forms the divide in North Fork Pass. A contemporaneous glacier in upper North Klondike valley appears to have reached only to the big bend, where there is a weakly developed terminal moraine. Comparably restricted glaciers originated from many of the higher north-facing cirques of the western region.

### Glaciations in the Eastern Region

In contrast to the independent radially outflowing glaciers of the western region, those of the eastern region were part of a vast transection glacier, which flowed generally northwestward regardless of the slope of the valleys. Although the transection glacier derived its ice mainly from east and southeast of the eastern region, as defined for present purposes, it was augmented by strong tributary glaciers originating in the ranges of the eastern region. As in the western region, three glacial advances are inferred, but whether deglaciation was complete between successive advances is not known.

#### *Old Glaciation(s)*

One or more old glaciations in the eastern region are indicated by scattered erratics lying at elevations well above the rather well-defined limit of the intermediate glaciation. Stratigraphic evidence of the old glaciation(s) is lacking within the mapped areas, but may be present to north and south where later glaciation was less intense.

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<sup>1</sup> Now designated as Dempster Highway.

### *Intermediate Glaciation*

During the intermediate glaciation, the valleys of the eastern region were occupied by a large transection glacier originating in more or less continuous ice-fields to the southeast, augmented by tributary glaciers originating within the eastern region. Part of the transection glacier occupied Wind River valley and extended northward beyond the limits of the map-areas; another part extended along Hart-Beaver valley (that is, the valley occupied by the northwesterly flowing part of Hart River, a southeasterly flowing part of Beaver River, and by Kathleen Lake) to the moraine complex at the junction of Hart and Middle Hart Rivers. Broad valleys crossing between Wind and Hart-Beaver valleys, and between the latter and the headwaters of East and South McQuesten Rivers, provided routes by which other parts of the transection glacier extended to undetermined limits to the south and west.

The ice surface of the transection glacier was highest in the southeast (4,700+ feet near Kathleen Lake) and sloped to the northwest, west, and southwest (about 4,000 feet near Elliott Lake and about 3,500 feet on the east side of Lynx Dome, lat.  $64^{\circ}05'$ , long.  $135^{\circ}40'$ ). Corresponding ice thicknesses are 2,200 feet at Kathleen Lake, 900 feet at the mouth of Bond Creek, 600 feet at Elliott Lake, and 1,000 feet on the east side of Lynx Dome. Indicated surface gradients over long stretches of the glacier range from 19 to 35 feet per mile.

### *Last Glaciation*

In the eastern region, the last glaciation was characterized by the restricted extent of the transection glacier, and by the failure of many glaciers in tributary valleys to join the main system. The latter characteristic is best displayed along Wind River north from latitude  $64^{\circ}25'$  to the limit of the last glaciation, which is marked by a terminal moraine just north of latitude  $65^{\circ}$ . Lateral moraines of the main glacier are particularly well defined at the mouths of tributary valleys, where they bulge into the mouths of the tributaries, in some places impounding small lakes. The terminal moraines of glaciers in these same tributary valleys are found several miles up in the valleys, indicating that the ice stopped short of joining the main glacier.

In Hart-Beaver valley the transection glacier reached only as far as longitude  $136^{\circ}05'$  and its southwestward distributaries were correspondingly restricted. For example, during the intermediate glaciation, ice moved southward out of Hart valley by way of Worm valley to join ice moving down the Middle Hart valley, but during the last glaciation ice extended only into the north end of Worm valley. There the ice impounded a small lake, which was filled with deltaic sand and gravel as meltwater discharged through Worm valley into Middle Hart valley.

The last ice-advance reached only to Lime Creek in the East McQuesten valley, and to near Steamboat Lake at the head of Eagle Creek, whereas in the intermediate glaciation the ice extended southwestward into North McQuesten

valley. Terminal moraines at Lake Creek and Steamboat Lake are 1,200 to 1,600 feet lower than the lateral moraines that mark the upper limits of ice of the intermediate glaciation. In South McQuesten valley a belt of moraines 2 miles south of Hanson Lakes marks the limit of the last advance.

Sections containing two tills are exposed in several localities, such as Wind River (near the divide to Rackla River), Bond Creek, Little Wind River, and the headwaters of Middle Hart River (west-central part of Nash Creek map-area). There is no weathering zone at the top of the lower till nor any intervening non-glacial deposits; the tills are distinguished mainly by a change in texture marking a difference in compaction. The significance of the two tills is uncertain, but because their differences are so minor it is unlikely that they are the products of separate glaciations.

A thick till of the last glaciation overlies a considerable thickness of gravel and sand on Wind River near McClusky Lake, which may be outwash from the retreating ice of the intermediate glaciation, or less likely, advance outwash of the last glaciation.

### Ice Retreat Following the Last Glaciation

Evidence suggests that the transection glacier of the eastern region retreated rapidly and continuously from its maximum extent. The main valleys are mostly free of features suggesting halts or readvances. However, areas of moraine topography at the divide between Wind and Rackla Rivers, and the divide between Hart and Beaver Rivers may indicate brief halts. These divides are points where ice-fronts that had been retreating upslope began retreating downslope; halts at these points may therefore have been controlled by topography rather than by a change of glacier regimen.

The scarcity of evidence for fluctuating retreat suggests that the regimen of the ice-fields feeding the trunk glaciers was decidedly negative, resulting in continuous and rapid retreat.

The trunk glacier in Wind River valley retreated upslope with the result that meltwater escaped freely to the north until the divide between Wind and Rackla Rivers was exposed. In the Hart-Beaver valley, retreat was southeastward across the Hart River and Beaver River divide, which was initially about 4 miles northwest of Elliott Lake. A glacial lake was impounded between the ice-front and the divide, at an elevation of just below 3,500 feet. Discharging meltwater cut a channel through the divide and shifted it 7 miles southeast to its present position. Retreat of the distributary glacier that had occupied the valley of upper Beaver River and East McQuesten River, permitted discharge across the divide between the two streams at below 3,000 feet elevation, and the lake level dropped accordingly. Still later an arm of this lake occupied the valley that contains Scougale Creek and the headwaters of South McQuesten River. Its outlet was across the moraine-belt to the south of Hanson Lakes, at less than 2,500 feet elevation.

Another extensive glacial lake with an outlet at the west end of Ladue Lake, occupied Keno-Ladue valley. The lower reaches of Rackla valley, and a section of Keno-Ladue valley south of the map-areas, contain thick silt deposits carried into this lake by meltwater streams.

The levels, in some cases multiple levels, of the glacial lakes are marked by deltaic deposits of sand and gravel formed where streams entered the lakes. Only vague suggestions of shoreline features can be found, either on airphotos or on the ground, indicating short duration of the lakes and rapid retreat of the ice.

In the western region, many of the individual valley glaciers advanced to their maximum positions, built terminal moraines, and then retreated without fluctuation. Many others, however, experienced halts and perhaps minor re-advances during the general retreat, which are marked by moraine loops inside the outermost terminal moraines. The presence of such retreatal moraines in the western region, as opposed to their near absence in the eastern region, may be the result of more sensitive response of the small individual glaciers to very local changes in glacier regimen.

### Pleistocene Chronology

A bottom sample from a bog occupying a depression in the terminal moraine of the last glaciation in North Fork Pass (eastern Dawson map-area) yielded a radiocarbon age of  $7510 \pm 100$  years (GSC-50; Dyck and Fyles, 1963, p. 8). Several similar depressions within the same moraine have no organic accumulation in them yet, indicating that long periods can elapse before bog accumulation commences. The radiocarbon age permits, but does not demand, tentative correlation of the last glaciation of the area with that of the Alaska Range, central Alaska, which culminated a little more than 10,000 years ago (Wahrhaftig, 1959, p. 428). Subsequent activity of rock glaciers (see following), followed still later by activity of debris-covered glaciers and rock glaciers, may be correlated with two stages of rock glacier activity in the Alaska Range, which Wahrhaftig and Cox assign to the interval 1,000 B.C. to A.D., and a 600 to 1,000 year interval ending early in the twentieth century.

Marl from frost-heaved palsa at the northwestern end of Hart Lake (in the central part of Nash Creek map-area) yielded radiocarbon ages of  $12,900 \pm 150$  years (GSC-67, carbonate fraction) and  $12,140 \pm 140$  years (GSC-67-2, organic residue) (Dyck and Fyles, 1963, p. 28). The pollen assemblage from the marl lacks black spruce, white spruce, and fir, and contains very little pine, elements that are well represented in surface samples from the site, which is slightly above tree-line. The dominant element of the assemblage is birch (presumably dwarf birch), with minor willow and alder, indicating that the climate was less favourable than at present for growth of spruce (unpub. rept. of Palynology Laboratory, Geol. Surv. Can.; R. J. Mott, Jan. 12, 1962). The palynological evidence is compatible with the view that marl formation began shortly after retreat

of ice from the moraine that impounds Hart Lake. The moraine is assigned to the last glaciation. If this assignment is correct, then locally at least the last glaciation culminated prior to about 12,900 years ago. An alternative possibility to be borne in mind is that the glacial sequence is more complex than the present reconnaissance study has shown. Exact simultaneity of advances and retreats of individual glaciers in the western region, or of all parts of the transection glacier in the eastern region, is hardly to be expected.

Cirques and valleys glaciated in the last glaciation are relatively unmodified as compared with those unglaciated since the intermediate glaciation, which indicates that the time since the end of the intermediate glaciation is substantially longer than the time since the last. However, present information does not warrant speculation either as to the absolute age of the intermediate glaciation, or as to its age relative to the sequence in the Alaska Range.

## ROCK GLACIERS AND DEBRIS-COVERED GLACIERS

Rock glaciers and debris-covered glaciers occupy many of the cirques in the higher mountains of the area, especially the Wernecke Mountains. The reconnaissance nature of the present study permitted only brief examination of a few examples, and most of those shown on the accompanying surficial geology maps were identified from airphotos.

All three forms of rock glaciers described by Wahrhaftig and Cox (1959, p. 387) from the Alaska Range, namely, lobate, tongue-shaped, and spatulate, occur in the field area (Pls. IV, VI, VII, and VIII). The characteristics given by Wahrhaftig and Cox apply to the rock glaciers of the mapped area (with one exception to be noted later) and the reader is referred to their descriptions.

Both active and inactive rock glaciers have been recognized in the area through the criteria given by Wahrhaftig and Cox (1959, p. 435). The inactive rock glaciers are mostly completely covered with lichens, turf, or even trees, and their fronts are rounded in profile; the fronts of active rock glaciers are barren of vegetation and have straight profiles, which intersect the upper surfaces at sharp angles. Inactive rock glaciers (mainly of the lobate type) head at elevations as low as 3,500 feet; most of the active ones head at elevations above 6,000 feet.

### Debris-Covered Glaciers

Debris-covered glaciers were first identified on the ground during examination of rock glaciers. A study of these known debris-covered glaciers on airphotos revealed that they have several geomorphic features distinguishing them from rock glaciers. However, they have the same general shape as rock glaciers and many similar characteristics (Pls. IV, VII, and VIII). They have steep fronts (up to 40 degrees) with heights to 200 feet or more, and steep embankment-like sides. All head in cirques with steep north-facing headwalls. At the foot of the headwall there may be névé and ice with little or no debris cover; more commonly there is a spoon-shaped depression, which is elongated downstream. The bottoms of these depressions are in places 10 feet or more below the debris-covered glacier that extends downstream from the depression. Some depressions are floored by apparently clean ice. Longitudinal furrows (Wahrhaftig and Cox, 1959, p. 392) extend down-valley along both sides of the debris-covered glacier, and die out before reaching the snout. Also present in many of the debris-covered glaciers are meandering furrows, which on airphotos appear like those described by Wahrhaftig and Cox (1959, p. 392) "tightly meandering incised trench(es) extending lengthwise down

the rock glacier, commonly near the middle", and are found on the ground to be "irregular lines of coalescing conical pits, each pit 20-100 feet across". Short straight furrows have also been observed, especially near the glacier snouts, to which they are radial.

The transverse ridges and furrows that occur on most rock glaciers of the present area and in the Alaska Range, and which indeed are the characteristic features of rock glaciers, are lacking on debris-covered glaciers (Pls. IV, VI, VII, VIII). Faint ridges that are roughly parallel with the outline of the glacier, and hence are transverse at the glacier snout, are visible on airphotos of most of these features, but are noticeably less conspicuous than the transverse ridges and furrows of the rock glaciers. On the other hand, the meandering furrows and collapse pits characteristic of the debris-covered glaciers are not known from typical rock glaciers of the present area, although they have been reported

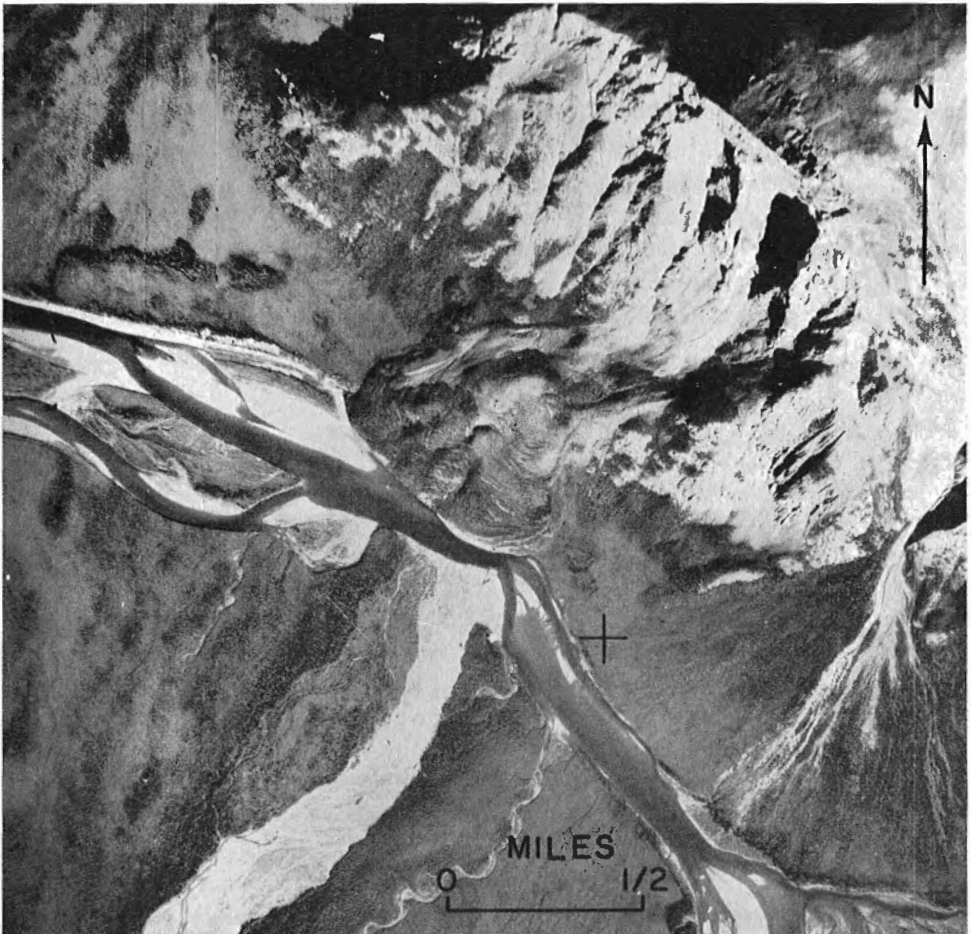


PLATE VI. A stabilized, sparsely forested spatulate rock glacier, Bonnet Plume River, extreme northeast part of Nash Creek map-area. Elevation at the snout of the rock glacier is about 2,000 feet.

(RCAF 12260-285)

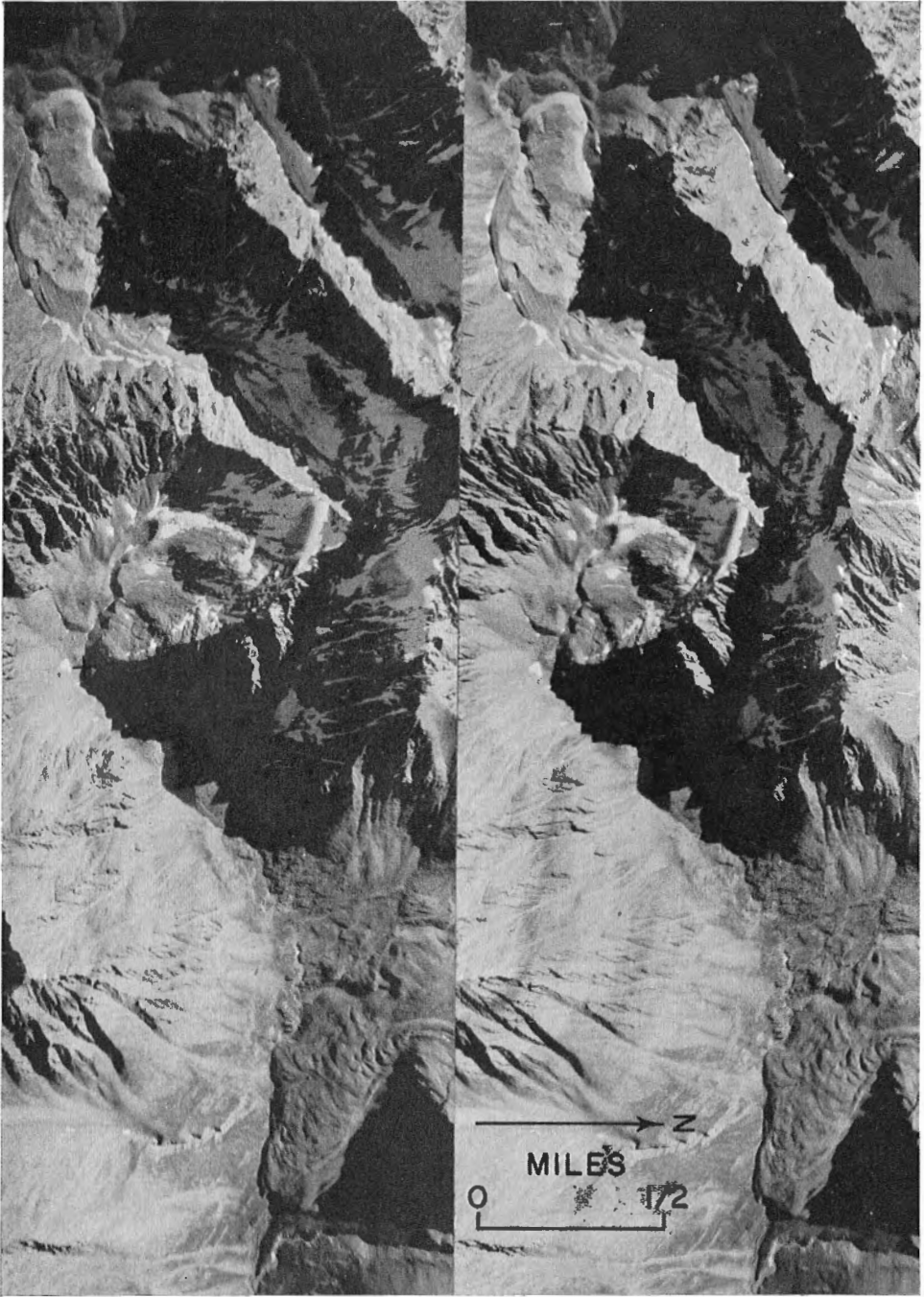


PLATE VII. A debris-covered glacier, almost bisected by a collapse pit (top); lobate rock glaciers (middle); and a spatulate rock glacier (bottom); east of Nash Creek map-area ( $64^{\circ}48'N$ ,  $133^{\circ}57'W$ ).  
(RCAF A12260-294, 295)



PLATE VIII. A typical debris-covered glacier with well-developed meandering furrows (bottom), and a debris-covered glacier superimposed on a rock glacier (top); 1.5 miles southwest of Gillespie Lake, northeast Nash Creek map-area. (RCAF A12283-142, 143)

from rock glaciers of the Alaska Range. This raises the question of whether the series of 'rock glaciers' studied by Wahrhaftig and Cox might not include debris-covered glaciers.

The debris cover over the ice of the glaciers, as exposed in the walls of meandering furrows, is as much as 10 or more feet thick and the underlying ice contains debris concentrated in layers parallel with the glacier surface, as well as scattered through the body of the ice.

The ice underlying the debris cover was seen on several glaciers. In one glacier near Gillespie Lake (Nash Creek map-area), seen only from the air, an estimated 50 to 100 feet of ice is exposed in a stream channel below the thin cover of debris. The most closely studied exposure is in a glacier some 6 miles northwest of Hart Lake (Nash Creek map-area). The surface of this glacier is covered by a layer of debris from 6 inches to 5 feet thick, consisting of a chaotic jumble of blocks and boulders as much as 10 or more feet long. Conical pits floored with ice and filled with water and roughly conical piles of debris are both present on the surface. Ice and névé partly fill the depression at the head of the glacier and the hollow between the side of the glacier and the cirque wall. Small ridges in the depression mark former (seasonal?) ice levels; at present the ice is at least 20 feet below the upper ridges. A meltwater stream, following a meandering furrow, drains the depression. Near the glacier snout the furrow is 50 feet wide and 20 feet deep (Pl. IX). The meltwater flows in a narrow channel cut obliquely



P.V. 3, 4-61

PLATE IX. Ice exposed in the wall of a furrow in a debris-covered glacier, 6 miles west of Hart Lake, central part of Nash Creek map-area. The ice, which contains minor amounts of debris, is partly masked by debris slumping from the surface.

downward in the floor of the furrow. In all, some 35 feet of ice is visible below the debris cover. Ice with presumably seasonal layers of rock debris is exposed in a similar furrow in a debris-covered glacier in the vicinity of Tombstone Mountain (east-central part of Dawson map-area).

That the entire thickness of debris-covered glaciers, as well as the observable upper layers, consists mainly of ice, can be inferred from an example just east of Nash Creek map-area. The glacier, studied from airphotos only, heads in a north-east-facing cirque that drains into a tributary of Bonnet Plume River. It is about 5,300 feet long, 1,800 feet wide, and has a steep snout estimated to be 200 feet high. The most conspicuous feature of the glacier is a huge roughly circular pit with scalloped outline, with maximum diameter of 1,600 feet, midway between the head and snout of the glacier, and virtually dividing it in two (Pl. VII). The steep walls descend 150 feet or more to a pit floor, which is covered with a patternless jumble of morainic debris. A meandering furrow extends from a spoon-shaped depression at the head of the glacier to the upstream edge of the pit; another meandering furrow with depth varying up to 50 feet or more, extends diagonally from the downstream edge of the pit northwestward to the side of the glacier. The pit is drained, indicating subglacial drainage, possibly along a course marked by the furrow. The pit clearly resulted from melting out of ice within the glacier, probably by unusual enlargement of one or more pits of the type that together form meandering furrows. Thus, of the total thickness of the glacier, ice comprised somewhat more than 150 feet. If the thickness of the glacier in the pit area was originally 200 feet, as at the steep snout, then ice formed 75 per cent or more of the total thickness. (Values for the height of the snout and the depth of the pit were determined photogrammetrically, and may be in error, but the ratio of the two values should nevertheless be close to the true value.)

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# INDEX

	PAGE		PAGE
arêtes .....	6, 7	mass wasting .....	6
Bear Creek .....	4, 11	McClusky Lake .....	14
Beaver River, Beaver valley.....	5, 13, 14	McQuesten Lake .....	2
Benson Creek.....	12	Middle Hart River, Middle Hart valley	13, 14
Blackstone River.....	1, 3, 11, 12	monadnocks .....	4
Bond Creek.....	13, 14	moraines .....	6, 7, 8, 10, 12, 13, 14, 15, 16
Bonnet Plume River.....	18, 22	Mott, R. J. ....	15
Caldwell Lake .....	4, 5	Nash Creek .....	11
cave-in lakes .....	2	névé .....	17, 21
Chapman Lake .....	11	nivation .....	6
cirques .....	6, 7, 9, 12, 16, 17	North Fork Pass .....	11, 12, 15
Clark Lakes .....	2	North Klondike River, North Klondike valley .....	1, 11, 12
dead-ice deposits .....	1, 2	Ogilvie Ranges	
Dempster Highway .....	4, 12	Central Ogilvie Ranges .....	3
Eagle Creek .....	13	Southern Ogilvie Ranges .....	1, 3, 4, 12
East Blackstone River .....	6, 11, 12	Ogilvie River .....	8
East McQuesten River .....	13, 14	patterned ground .....	4
Elliot Lake .....	13, 14	palsa bogs .....	4, 15
fans, alluvial .....	7, 11	palynology .....	15
Flat Creek Beds .....	4	peat .....	4
Flat Creek–Eagle Plains road .....	12	permafrost .....	4
fluviatile deposits .....	2	pingos .....	4, Pl. II
furrows,		pits, collapse .....	18, 19, 21, 22
longitudinal .....	17	Rackla River, Rackla valley .....	14, 15
meandering .....	17, 20, 21, 22	radiocarbon dates .....	15
straight .....	18	ridges, transverse .....	18
Gillespie Lake .....	20, 21	Rock Creek .....	3, 4
glacial deposits .....	1	Rocky Mountain Trench .....	3
glacial erratics .....	6, 11, 12	Scougale Creek .....	14
glacial lakes .....	14, 15	Secla Pass .....	11
glaciers		shorelines .....	15
debris-covered glaciers .....	7, 9, 15, 17-22	solifluction lobes .....	4
rock glaciers .....	7, 9, 15, 17-22	South McQuesten River .....	13, 14
transection glaciers .....	12, 13, 14, 16	Steamboat Lake .....	13, 14
glacio-fluvial deposits, outwash .....	2, 14	Stewart Plateau .....	2, 3, 4
ground ice .....	4	Taiga Valley .....	3, 11
Hanson Lakes .....	14	talus .....	7
Hart–Beaver valley .....	13	tarns .....	7, 9
Hart Lake .....	15, 21	thaw lakes .....	2
Hart River, Hart valley .....	3, 10, 13, 14	thermokarst topography .....	2
ice-wedges .....	4	till .....	1, 7, 12, 14
Kathleen Lake .....	5, 13	Tintina Trench .....	3, 4, 12
Keno–Ladue River, Keno–Ladue valley	2, 15	Tombstone Mountain .....	3, 22
Klondike Plateau .....	3, 4	Tombstone River .....	11
Klondike River .....	4, 12	Wernecke Mountains .....	2, 3, 4
Ladue Lake .....	15	Wind River, Wind River valley...4, 11, 13, 14	
Lake Creek .....	14	Worm valley .....	13
Lime Creek .....	13	Yukon Plateau .....	4
Little Wind River .....	9, 14	Yukon River .....	3
Lynx Dome .....	13		
marl .....	15		



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