CONTINENTAL GLACIATION IN THE GLENLYON AREA PELLY RIVER DISTRICT, YUKON, CANADA

Thesis by

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ABSTRACT.

The Glenlyon area in central Yukon is bounded by 62° and 63° N and 134° and 136° W. It is part of the Yukon Plateau, a mature upland surface surmounted by isolated peaks and small ranges, and dissected by deep, young valleys. Features of glacial erosion and deposition are such that the direction of flow and the upper limit of the last glaciation can be determined from them.

Ice flowed into central Yukon from three sources, Selwyn Mountains to the east, Cassiar mountains to the southeast, and the Coast and St. Elias mountains to the south. Ice moved into the Glenlyon area from the first two of these sources and apparently the maximum stages of these two glacial advances were not synchronous, but Selwyn ice was active last. In this area, many higher mountains and hills projected above the ice surface as nunataks. In detail, topography altered the direction of ice flow, ice thickness and extent.

Evidence from adjacent parts of Yukon suggest two or possibly three glaciations but only the last has been recognized in the Glenlyon area although this could not have escaped glaciation in earlier stages. The large glaciers of central Yukon developed by windward building in contrast with the Cordilleran ice sheet in central British Columbia which developed on the lee of the Coast Range.

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INTRODUCTION

GENERAL STATEMENT

This study is preparatory for a more extensive field investigation to be made in the summer of 1951. Its objective is to assemble and integrate the information available from earlier fieldwork and from aerial photographs in such a way that the subsequent work can be carried out in the most fruitful manner. For this purpose, all available data on glacial geology in the Glenlyon area have been set down on the accompanying map (Plate 2), and significant features are described herein. Conclusions and inferences drawn from these data concern the number of glaciations in central Yukon, sources of the invading ice masses, age relations of ice from different sources, effects of topography upon ice flowage, nature of glacier recession, origin and significance of glacial erosional and depositional features, and possible light glaciers in central Yukon may throw on development of the North American ice sheets.

During the summers of 1949 and 1950 the writer, employed by the Geological Survey of Canada, mapped bedrock geology in the Glenlyon area on the scale of one inch to four miles. In the course of this work some features of glaciation were observed. Study of the glaciation has been facilitated and greatly supplemented by a detailed examination of aerial photographs (scale one inch to approximately 2500 feet). Owing to limitations of field coverage information on glacial features in much of the area has been derived from aerial photographs. Obviously,many of the conclusions based on observations from aerial photographs are subject to proof or disproof by future fieldwork,for,interpretation of features observed only in photographs may be erroneous. Although subsequent field work may change details, it will probably bear out information derived from photographs,for many glacial forms, easily seen in aerial photographs,are difficult or impossible to recognize or identify in the field.

LOCATION AND PHYSICAL SETTING

The Glenlyon area, approximately 4900 square miles, lies in central Yukon Territory, Canada. It is included between 62° and 63° degrees north latitude and 134 and 136 degrees west longitude (Plate 1).

Physiographically this region is within the Interior Mountain System of the Western Cordillera (Bostock 1948, Map 922A). More specifically it is part of the Yukon Plateaux. The area includes parts of Pelly Mountains, Tintina Valley, and Lewes, Stewart, and Macmillan Plateaux.

Pelly and Macmillan rivers drain the northern two-thirds of the Glenlyon area and Lewes and Little Salmon rivers drain the southern third. Pelly and Lewes rivers unite at Fort Selkirk to form Yukon River.

The present climate in central Yukon is semi-arid in terms of annual precipitation and sub-arctic in terms of mean annual temperature. In this environment, perennially frozen ground is common, but it is mainly restricted to slopes of northern and eastern exposure and to flat poorly drained areas. Spring thaw and runoff do not usually begin until about the first of May. Runoff continues throughout the summer at a reduced rate from thawing of the frozen ground after the snow has gone. Freeze-up begins, normally, in the latter part of October.

In spite of small total precipitation, ample moisture is available for vegetative growth in the short summer season. Forest growth is light but extensive and consists of black spruce and birch on northern and eastern slopes and white spruce with aspen on the drier southern and western slopes. Large stands of lodge-pole pine grow in some dry, flat areas. In unforested areas the cover is mainly arctic black birch, willow,and various grasses. Near timber-line (4500 feet) alpine balsam is common and above timber are heather, arctic black birch, willow,and other alpine plants.

TOPOGRAPHY AND PHYSIOGRAPHY.

GENERAL DESCRIPTION

The outstanding topographic feature is Glenlyon Range in the east central part of the area, southwest of Pelly River (Plate 2). Summit altitudes over much of this range exceed 6500 feet, and there are broad areas above 5000 feet. The peaks, with the exception of those at the north end, are jagged, rough, and invariably precipitous on the north and northeast where they rise above well-developed cirques. Floors of the large cirques are near 5000 feet above sea level. The south and southwestern slopes of the peaks are usually smooth and gentle except where intersected by deep glaciated troughs.

Tay Mountain and the area south of Little Salmon Lake and Magundy River are similar in many respects to Glenlyon Range. The remaining mountainous part of the area is typical Yukon Plateau terrain, a rolling upland of mature development with scattered peaks rising from it, and dissected by deep, young valleys. The general level of this westward sloping upland, is 4000 to 5000 feet altitude, 2000 to 3000 feet above the large rivers. Streams flowing in broad, mature valleys on the upland, plunge through narrow canyons to the larger streams below.

Tintina Valley is a great trough-like feature bearing roughly N50 W which extends from the head of Liard River into Alaska (Bostock 1948, pp. 60-62)(Plate 1). In the Glenlyon area it forms the valleys of the Little Kalzas River and part of Pelly River. It is apparently partly a structural and partly an erosional feature similar to Rocky Mountain Trench in British Columbia.

A flat, low area in the northwestern Glenlyon area between Macmillan River on the north and Ess, Tadru, and Tatlmain lakes on the south is here termed Pelly Basin. Only a few hills in the basin rise as much as 500 feet above a general level at 2000 feet altitude. The larger streams have cut valleys 300 to 400 feet below this level hence the overall relief is 900 feet.

LAND FORMS PRODUCED OR INFLUENCED BY CONTINENTAL GLACIATION

Erosional: All valleys within the Glenlyon area have been modified by glacial action to some extent. Many are deeply troughed with U-shaped transverse profiles and oversteepened sides. An excellent example is that part of Little Salmon Valley occupied by Magundy River and Little Salmon Lake. The single high valley wall of Macmillan River south of Kalzas Range is oversteepened by glacial erosion.

In glacially modified valleys truncated spurs, triangular facets, and hanging valleys are common. These features are particularly well developed on the northeast face of Glenlyon Range. The facets have been little modified by post-glacial erosion and only the larger tributaries have cut appreciable canyons in an effort to reestablish accordant junctions with the main streams.

Giant grooves have been carved upon the walls of many valleys by moving ice. These are commonly associated with rock benches, also attributed to glacial erosion. These two features, where abundant, give valley slopes a conspicuous horizontal-lined effect (Fig. 1).

In Pelly Basin and other flat areas are bedrock hillocks or roc-drumlins scoured and streamlined by glacial erosion (Fig. 2). These usually have a tail of drift extending out from the lee side forming typical crag-and-tail topography. Drumlins are also common in these areas, and all gradations can be found from roc-drumlins through crag-and-tail features to drumlins with no evidence of associated bedrock.

Tarns and mammilated outcrops mark the tops of ridges composed of coarsely jointed granitic rocks at the southeast end of Glenlyon Range. Here rock hillocks have roche moutonee form from which direction of ice flow can usually be inferred as in the instance of roc-drumlins.

Much of the bedrock is such that retention of small scale glacial markings is unlikely and only in a few places have markings been found. With two exceptions it is probable that all observed striated and polished rock surfaces have recently been exhumed from beneath drift.

Figure 1. Rock Grooves and Benches on Southwest Face of Glenlyon Range.

View looking north over Drury Lake. Ice moved to the left.

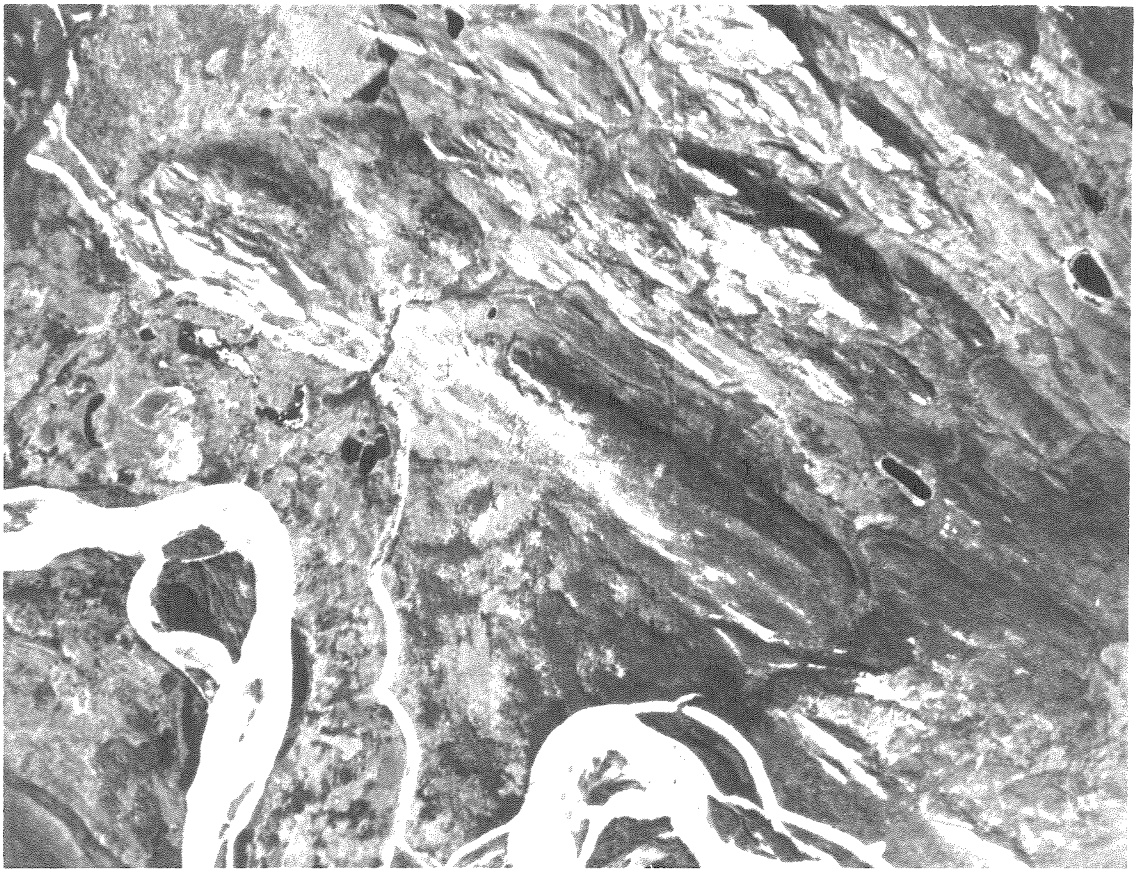

Figure 2. Roc-Drumlins

Scoured and shaped bedrock hillocks on north bank of Pelly River two miles east of the mouth of Tummel River. Ice moved from lower right to upper left. North is to the top. Scale: 1 inch 2500 feet.

Glacial streams produced considerable erosion and abandoned glacial stream channels are widespread throughout the Glenlyon area. Most conspicuous are marginal channels cut into bedrock on valley sides. Northeast of Drury Lake is a great array of abandoned channels all cut by streams flowing to the northwest. These apparently represent successive positions of marginal streams during recession of ice to the southeast. Near the west border of the area (62°21'N.) is a braided stream channel running about east-west (Fig. 3 and Plate 2). The small stream currently occupying this channel is greatly underfit. Because no similar braided streams are known in this part of the Yukon and because there is no apparent source for the large amount of water required to form such a channel, it is assumed that this is the site of a proglacial stream at the maximum stage of the last glaciation.

Depositional: Details of topography in the Glenlyon area are extensively modified by till and glacifluvial deposits. The nature of till and outwash deposits is discussed in the section on glacial geology and as their topographic expression is an integral part of their character, they are not discussed here. Drumlins and lateral or marginal moraines, particularly distinguished because of their topographic form, are discussed in this section.

Pelly Basin contains hundreds of till drumlins;some show

Figure 3. Pro-glacial Braided Stream Channel.

The channel marks the site of a pro-glacial stream that flowed to the west (left). Note the lateral moraine on the hill on the left. Scale: 1 inch = approximately 2500 feet.

a characteristic streamlined form but more are roughly symmetrical in long profile. It is not known to what extent they result from erosion or deposition. Material in the drumlins is relatively fresh and unweathered and seems to have been derived from the last glaciation. There is no evidence of an older, extensive till sheet from which drumlins might have been formed by erosion and it is most probable that they are depositional features of the last glaciation. In Pelly Basin and in a few other localities, drumlins show clearly the direction of ice movement and are the most conspicuous directional features (Fig. 4). With rock grooves and the shape of scoured bedrock hillocks they provide most of the information of the direction of ice flow on the accompanying map (Plate 2).

Lateral or marginal moraines were deposited on the flanks of mountains and ridges projecting through the glaciers as nunataks during and following the maximum of the last glacial advance (Fig. 5). Many moraines are so well preserved that they retain their original shape almost intact while others, particularly on steep slopes, have been partly or completely removed by erosion. Where well developed, lateral moraines form a small embankment on the slope and often enclose a shallow depression on the uphill side.

Lake Basins: Inference from photographs and limited knowledge derived from the field indicate that most of the large lakes are formed behind dams of glacial drift.

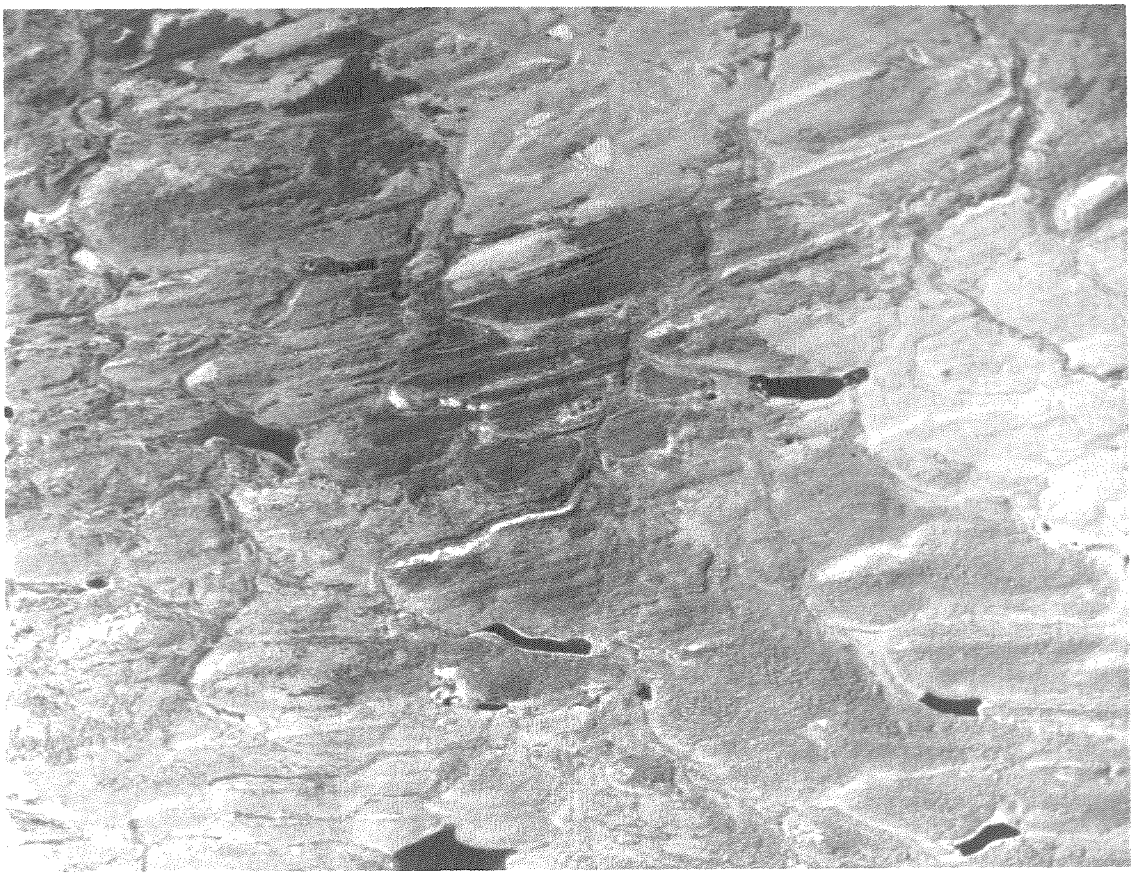

Figure 4. Drumlins

Drumlins, made by ice flowing from right to left near the divide between Pelly and Magundy rivers, east of the Glenlyon area. The shape of lakes and course of minor drainage is controlled by these forms. North is to the top. Scale: 1 inch = approximately 2500 feet.

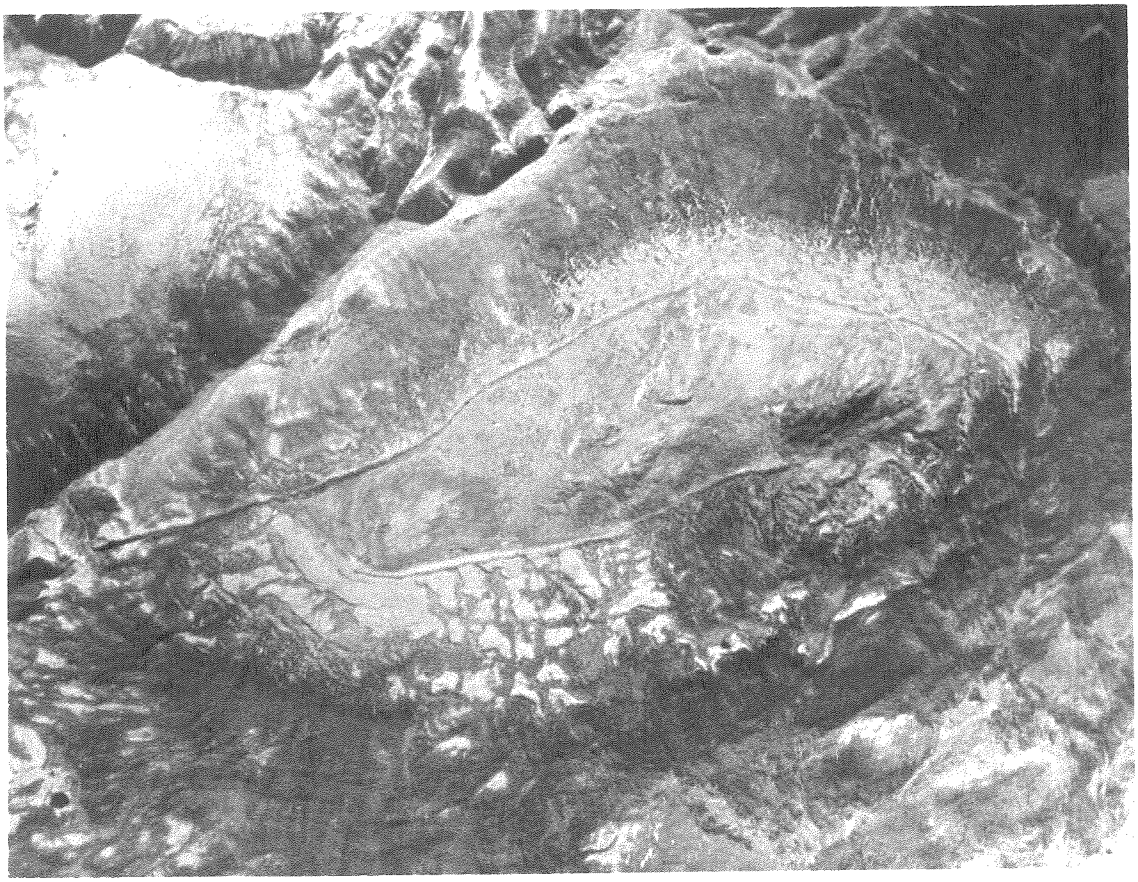

Figure 5. Lateral Moraine Encircling a Hill Top

The hill, at the maximum stage of the last glaciation, projected through the ice as a nunatak. Ice moved from right to left (roughly north). Scale: 1 inch = approximately 2500 feet.

Earn Lake is an excellent example. The lake is shallow throughout and no outcrops are known in the floor of Earn Valley. It is probable that such large lakes as Little Salmon, Drury, and Tatlmain are in basins with some bedrock closure.

Stream Diversions: Three examples of stream diversion caused by glaciation are noteworthy in the Glenlyon area where such features are common.

Dawson (1898, p. 126) described the diversion of Pelly River into a great bend beginning at the mouth of Harvey Creek and ending about eight miles west of the mouth of Earn River which he called "The Detour" (Fig. 6). The pre-glacial river followed an essentially straight course between these two points (A to B of Fig. 6). At present, Pelly River flows in a narrow valley cut into bedrock with no meanders or flood plain from Harvey Creek to about two miles above Earn River. The stream in most of this section flows rapidly. Above and below, the river has few or none of these characteristics. The last 10 miles of "The Detour" are cut into thick glacial drift and consequently the river has developed a broad flood plain, sweeping curves, and an even grade.

The diversion of Pelly River occurred after recession of the ice front to the southeast and was caused by a thick deposit of outwash and a mass of stagnant ice in the old

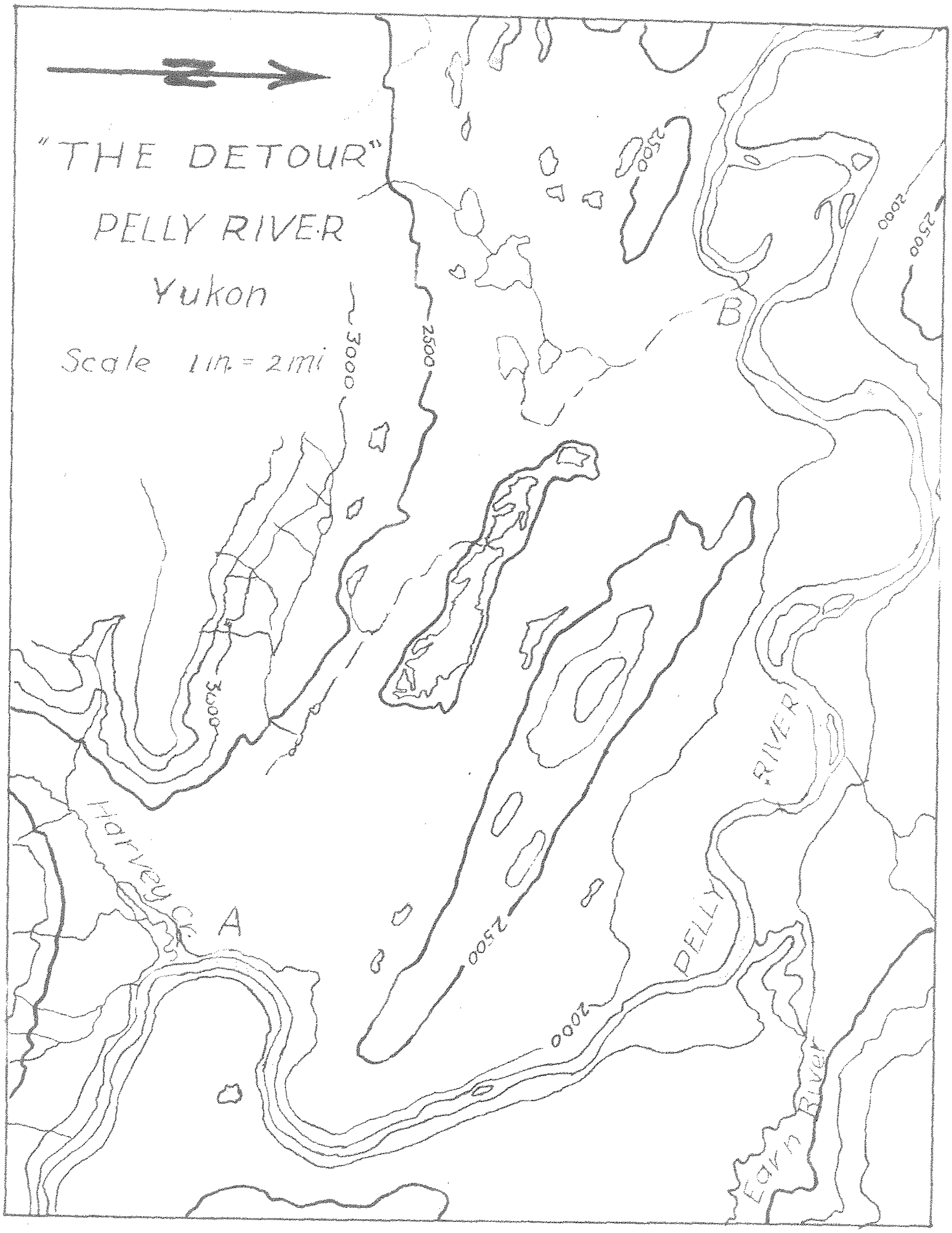

Figure 6. Map of "The Detour" on Pelly River.

The pre-glacial channel was from A to B.

course below Harvey Creek. Under these circumstances the river found a lower outlet to the east by way of "The Detour"

A second example of stream diversion influenced by glacial activity is afforded by Harvey Creek(Fig. 7).

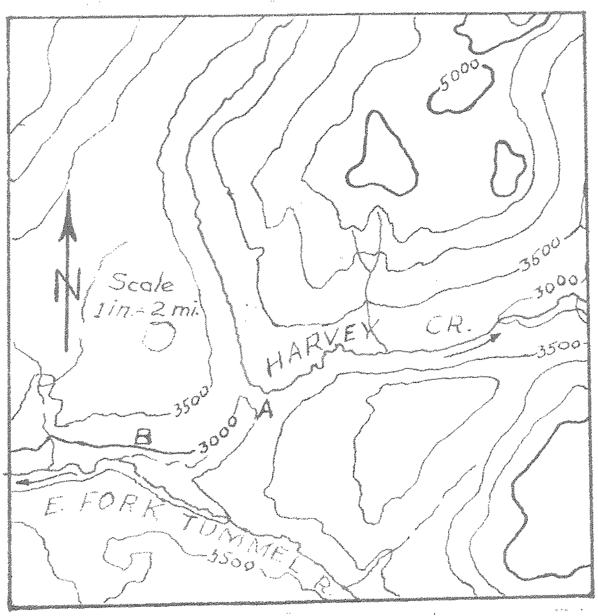

Figure 7. Map of Part of
Harvey Creek and
Tummel River.
Harvey Creek captured its headwaters in post-glacial period. Elbow of capture is at A, abandoned channel is from A to B.

In this case the diversion is indirectly connected with glaciation and involves stream capture. Two features suggest that Harvey Creek has captured its present headwaters from a branch of Tummel River (above point A, Fig. 7): (1) the right-angle bend in Harvey Creek where its course changes from southward to eastward (at A), and (2) the deep, abandoned, pool-filled gorge extending from this bend to the east fork of Tummel River (A to B, Fig. 7). A gravel-covered ridge at A prevents the stream from flowing into the abandoned canyon, the floor of which is lower than the present bed of Harvey Creek (note 3000 foot contour). The floor of the abandoned canyon joins Tummel River with perfect accordance, and, because it cuts through glacial drift and into bedrock, it is clearly a post glacial feature. On the inside of the bend, Harvey Creek is cutting into bedrock, and it is possible that bedrock underlies the gravel-covered ridge at a shallow depth. The resistance of this ridge to down cutting by the stream formerly flowing to Tummel River is one of the principal reasons why the capture ultimately occurred. Harvey Creek was able to lower the divide at its head more rapidly and eventually effected diversion of the stream that flowed across the resistant ridge.

The valley of Harvey Creek is a vastly overdeepened and oversteepened trough with walls 2000 to 2500 feet high resulting from glacial erosion. The stream, even at its present size, could hardly have cut such a gorge, hence it seems reasonable to assume that glacial erosion greatly lowered the former divide between Harvey Creek and its present headwaters, and thus facilitated the capture.

A third example of stream diversion is found on Little Salmon river. The valley of this river is broad and straight between Pelly and Lewes rivers but, nine miles from its mouth, the Salmon River leaves this broad valley (at A in Fig. 8), and flows through a narrow defile called the lower canyon by Cockfield (1928, p. 3).

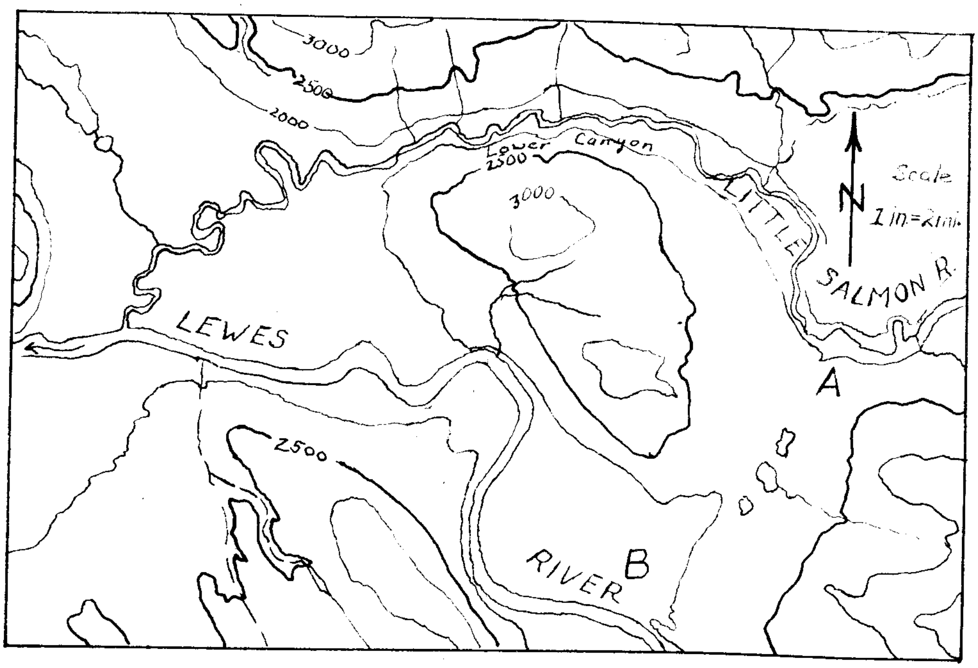

Figure 8. Map of Lower Little Salmon River.
The pre-glacial channel was from A to B.

From point A through the abandoned valley to Lewes River at B is just four miles over which ~~of~~ the old valley is covered by thick glacial outwash in which kettle holes are conspicuous. It seems probable that the lower canyon formed when ice blocked the valley between A and B. As the ice front retreated to the south, outwash deposits were sufficient to prevent the river from resuming its former course, particularly as it became entrenched into these deposits at A.

GLACIAL GEOLOGY

INTRODUCTION

Evidence of only one glaciation (or glacial stage) has been found in the Glenlyon area although at least two glaciations are identified in the Carmacks area to the west and a little north of the Mayo area adjoining to the north. A boulder clay containing deeply weathered boulders and overlain by auriferous gravels near Nansen Creek and isolated erratics near Fort Selkirk, both in the Carmacks area, are interpreted by Bostock (1936 pp. 9-10 and p. 48) as representing two separate glaciations, both older than the last advance. Bostock (1948, p. 64) found deeply weathered granitic boulders overlain by hard fresh stream gravels of similar type in Dublin Gulch, just north of the Mayo area. This locality was not covered by ice of the last glaciation and he attributed the weathered boulders to an older ice advance. The one glaciation identified in the Glenlyon area appears to be the last major advance during which ice covered all but the highest hill tops and reached its outer limit at about 25 miles to the west as shown by Bostock (1936, Map 340A: 1948 Map 922A) (Plate 1).

GLACIAL DRIFT

<u>Till</u>: Till or boulder clay (Dawson, 1898 p. 125, and p. 129; McConnell, 1902, p. 35) is the most widespread

glacial deposit within the Glenlyon area. Although it contains some large boulders, till is, in general, not coarse, and is closely associated with sands, gravels, and silts in Pelly and Macmillan River Valleys. Till is well exposed in cut banks along Pelly River and rests upon bed-rock in some places and upon stratified and sorted deposits in others. Some Pelly River exposures show horizons of till separated by gravels and sands, but this relation is so local it probably represents a minor readvance of the ice rather than two distinct glaciations.

Till is rarely exposed along lower Macmillan River because it is overlain by 200 feet of poorly stratified, somewhat plastic, and fairly cohesive clay. In several places great slide-masses of clay project into the stream and in one place nearly dammed it. McConnell (1902, p.36) be-lieved this clay was deposited in a lake formed by an ice dam at the mouth of Macmillan River but this origin seems unlikely because such a dam would flood Little Kalzas Valley and part of the low land between Pelly and Macmillan Rivers where evidence for such a lake is lacking. The origin of the clay is not known at present.

Outwash: The glacial outwash consists of stratified sands, gravels, and silts. Particles in the gravels are dominantly pebbles and rarely reach cobble size.

Outwash is most abundant in the western and particularly the west central part of the area but thick outwash deposits occur in all the large river valleys. A few examples are cited.

Glacifluvial material composes terraces 200 to 300 feet above Pelly River. On the east fork of Tummel River over 500 feet of stratified sands and gravels were observed. Cross-bedding and the dominantly granitic material indicate a source to the east. South and southeast of the junction of the main and west forks of Tummel River is a steep north-facing bank (Plate 2 and Fig. 9). In the valley of the West Fork the upper surface of the bank slopes gently south. This surface is pitted by kettle holes as is the flat at the bottom of the steep north face. These relations suggest that the bank is an ice contact feature formed by deposition against the face of an ice mass lying to the north. The bank represents a recessional stage in the glacial history.

In some parts of the Glenlyon area huge masses of stagnant ice were surrounded by outwash deposits as for example in the valley of Tatchun Lake in the southwest part of the area. Details of the topography here are very irregular and the lake shore is intricately embayed (Fig. 10).

DIRECTION OF MOVEMENT OF THE LAST ICE ADVANCE

During the last great advance ice flowed from the east, southeast, and south into central Yukon (Plate 1). Ice

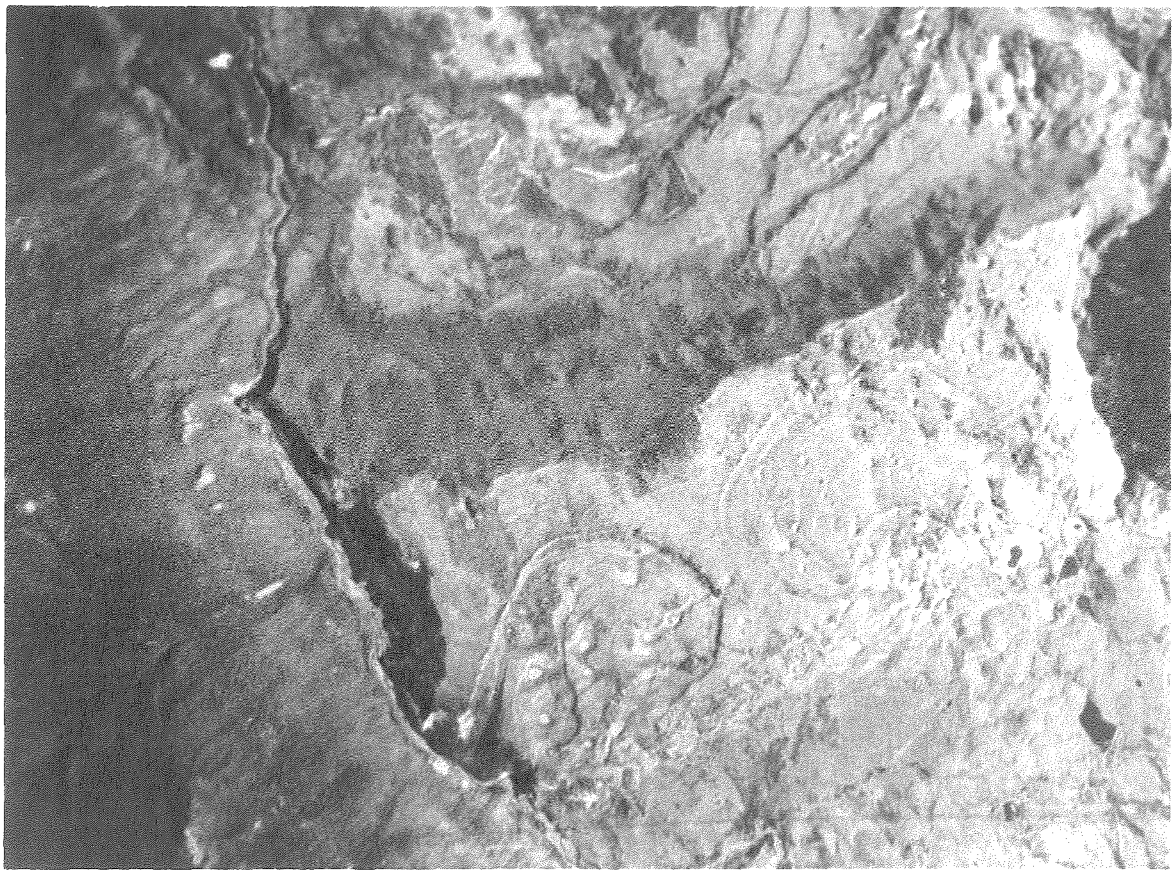

Figure 9. Ice Contact Bank.

The west fork of Tummel River cuts bank on left (see Plate 2) and flows north(top). The pitted upper surface of the bank slopes gently south. Scale: 1 inch = approximately 2500 feet.

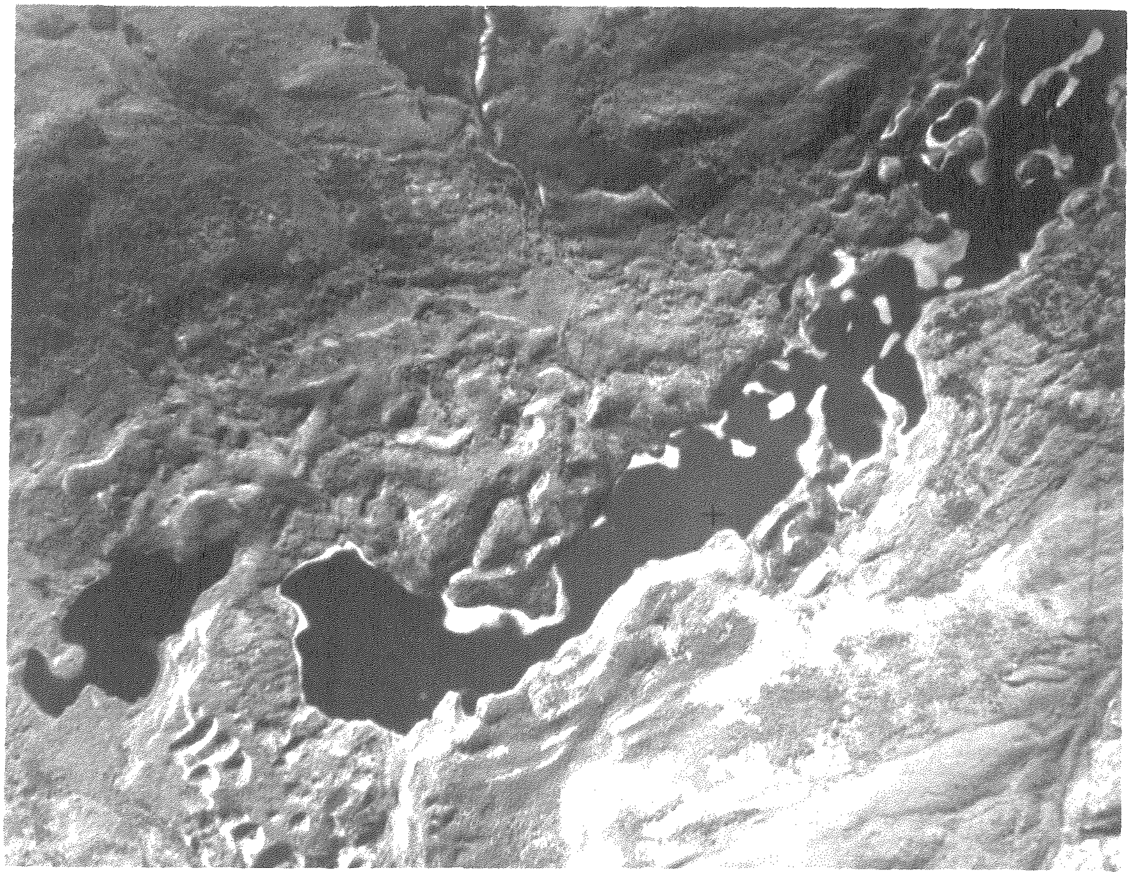

Figure 10. Heavily Pitted Outwash, Tatchun Lake.

A large mass of stagnant ice lay in this valley. North is to the right. Scale: 1 inch approximately 2500 feet.

from the east flowed north of 62 15'N, and was separated by Pelly Mountains from that moving from the southeast through and west of Big Salmon Range. Ice from the south drained out of the Coast and St. Elias mountains.[1]

The closest apparent source of ice flowing into the Glenlyon area from the east is Selwyn Mountains on the MacKenzie-Yukon drainage divide 200 miles to the east of the border of the unglaciated area (100 miles from the east boundary of the Glenlyon area). Ice from the southeast may have originated in the Cassiar Range in Northern British Columbia, also 200 miles from the glacier limit. Ice from Selwyn Mountains will henceforth be referred to as Selwyn ice and that from Cassiar Range as Cassiar ice.

In detail the regional trend of glacier flow was profoundly altered by local topography. This is clearly shown in the Glenlyon area where glaciers were not thick enough to cover the higher mountains, and the main valleys formed the major channels of ice flow. The direction of movement always had a westward component and in certain cases ice flowed up valleys that normally drain eastward.

In the southeast part of the Glenlyon area Selwyn ice moved northwest down Pelly River Valley to the low divide

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1 Data derived from published maps of the Geological Survey of Canada.

to Magundy River where it split, part flowing west around the south end of Glenlyon Range and part continuing on down Pelly River. From Magundy River Valley the ice flowed northwest up Drury Valley, west down Little Salmon Valley, and southwest over the steep valley wall (Plate 2). The easternmost evidence of Cassiar ice is seen west of 134 45'W. on the south boundary of the Glenlyon area from whence it flowed northwest across Little Salmon River Valley and was there augmented by Selwyn ice flowing west from the Pelly.

For about 20 miles north of Little Salmon Valley ice flowed northwest up tributaries and over divides to Pelly River drainage. This was caused by two factors; the northwest pressure of ice moving down Lewes River and the inability of ice from Pelly River to move westward through the high Glenlyon Range thus leaving the area open for occupation by ice from Little Salmon Valley.

Glenlyon Range constitutes a major obstacle which forced ice moving in and east of Pelly River Valley to flow northwest. At the northwest end of the range the glacier was able to turn westward and spread out in an expanded bulb over the flat Pelly Basin. It spread south, southwest, and west from the northwest end of the mountains but was unable to move northward because ice from Earn and Macmillan rivers occupied the northern part of the basin.

The main flow of ice down Macmillan River, however, passed north of Kalzas Range. Tintina Valley, Pelly River Valley, and Tatlmain Lake Valley provided the main channels of ice flowing westward out of the Glenlyon area.

THE MAXIMUM STAGE OF THE LAST ICE ADVANCE

Introduction: Topography has a profound effect on direction of flow within an advancing ice sheet when relief and ice thickness are in the same order of magnitude, and it also influences tremendously the thickness of ice and hence helps control the areal extent of glaciers.

The upper limit attained by ice of the last glaciation can be determined in the Glenlyon area because the ice did not completely submerge the land. Under this circumstance the upper limit of glacial erosion and deposition on mountain sides marks the highest extent of the ice.

Of the various criteria used lateral moraines, above which there is no evidence of glacial activity, most clearly mark the upper limit of glaciation. Lateral moraines do not occur on steep hillsides nor are they always found where they might be expected. In such places no maximum limit can be determined accurately, but a minimum limit can usually be approximated between obviously glaciated slopes and apparently unglaciated slopes.

No pronounced end moraines have been observed in the Glenlyon area; the terminal positions of the glaciers are inferred from evidence of their thickness; considerations of topographic effects, and the position of outwash deposits. The lower parts of the area were all glaciated but ice came from two directions. Cassiar ice covered most of the southwest part of the area and flowed northwest into Pelly Basin. Selwyn ice flowed southwest to the southern margin of the basin hence it appears that the areas covered by the two ice masses overlap and that each had a terminus or margin within the Glenlyon area (Plate 2).

Selwyn Ice: Along the east border of the Glenlyon area Selwyn ice reached a maximum altitude of close to 6000 feet thus it was between 3500 and 4000 feet thick in the larger valleys (Plate 1). As the glaciers flowed around Glenlyon Range, up Drury Lake Valley from the southeast and into Pelly Basin from the northeast, they thinned rapidly and near the northwest end of the range the surface was at 4800 feet giving a maximum thickness of approximately 2800 feet. Ice that flowed westward out of the area in Pelly River Valley was about 1800 feet thick. A long moraine west of Tadru Lake marks the margin of Selwyn ice that moved southwest across Pelly Basin. This moraine averages 3000 feet altitude hence the maximum thickness of the ice was about 1000 feet in this area.

Cassiar Ice: In the southwest part of the Glenlyon area Cassiar ice left many lateral moraines. South of

Little Salmon Lake the ice was between 2500 and 3000 feet thick at the maximum stage. East of the north end of Tatchun Lake it was 2000 feet thick, and southwest of Tadru Lake the ice surface was at 3000 feet altitude, 500 to 700 feet above the lowest elevation in that locality.

No evidence of the terminal position of Cassiar ice has been observed in Pelly Basin where it might be expected. The inferred terminus of Cassiar ice is north of the southern limit of Selwyn ice which moved southwest across Pelly Basin. It seems probable that Selwyn ice attained a maximum or maintained a maximum after recession of Cassiar ice to the southeast.

Some features in Little Salmon River Valley also indicate that Selwyn ice was active after Cassiar ice had receded. Along the valley sides are lateral moraines below the level of features produced by Cassiar ice moving transversely across the valley. About four miles south of the west end of Little Salmon Lake a moraine around a small hill is lower on the south than on the north end (Plate 2). It is probable that the moraine was formed by ice moving south around the hill. These features presumably could be formed only by Selwyn ice flowing from the east into Little Salmon Valley after recession of Cassiar ice.

Relation to other Data: A few miles west of the lowest moraines in the Glenlyon area assumed to represent the upper limit of the last glaciation (3000 feet on the west border at 62 30'N.), Bostock (1936, Map 340 A) shows the glacial limit at 4000 feet altitude. Farther north, on Ptarmigan Mountain, he shows the limit at 4500 feet. This is just a few miles west of well-marked lateral moraines below 3500 feet in the Glenlyon area. In view of the consistent gradient indicated by moraines within the Glenlyon area, the writer believes that the higher points in the Carmacks area must represent an older glaciation. It is obvious that field work is required to settle this question. It may be stated, however, that determinations of the upper limit of glaciation in the Glenlyon area are in close agreement with those in the Mayo area to the north (Bostock, 1947, Map 890 A).

In his rapid reconnaissance of Macmillan and lower Pelly rivers McConnell (1902 p.34) put the upper limit of glaciation in Macmillan Range near the junction of the two rivers at 3700 feet. He also placed the westward extent of the last glaciation some 20 miles farther east in Pelly River Valley than did Bostock (1936, Map 340A). It is possible that McConnell, who observed the fresh and obvious evidence of glaciation in the Macmillan River Valley, missed less distinct evidence farther west and that Bostock saw little or none of the fresh evidence to the east. Again it seems that two different glaciations best explain the discrepency.

Gradient of the Ice Surface: Because of marked effects by topography on the thickness of the ice sheet no definite and inclusive statement may be made concerning the gradient of the ice surface during the maximum glacial stage. Lines, crudely sketched through points where ice reached the same elevation, roughly contour the former ice surface. These lines show a gradient close to 50 feet per mile. They are nearly perpendicular to the various features indicating direction of flow as true contours on a glacier surface should be. How the contours should be joined across the zone of overlap of the Selwyn and Cassiar ice masses in Pelly Basin is a matter of speculation. They seem to cross smoothly but there is little evidence as to what their exact position should be.

EFFECTS OF TOPOGRAPHY ON ICE FLOW

In some aspects, glacier flow is analagous to flow of a rapid stream. A boulder projecting from such a stream causes the water to rise on the upstream side and be depressed downstream and similar features are formed adjacent to a mountain mass projecting from a glacier. Where a stream flows rapidly past closely spaced projections of the bank the water level between the projections will be lower than at the ends of the projections. Similarly, where glaciers flow past projecting spurs, the surface is depressed in the interspur areas. Such effects of topography on glacier flow occurred in the Glenlyon area.

A long and nearly continuous lateral moraine encircles the hills about 14 miles west and 5 miles north of the west end of Little Salmon Lake. It is lower on the lee side than on the stoss side and its elevation on spurs projecting about perpendicular to the direction of ice flow is higher than in the interspur valleys (Plate 2).

Ice thins rapidly when it flows from a narrow, confined channel onto a broad, open expanse from which there are many outlets aggregating a greater cross-sectional area than the inlet. Ice thinned in this way where it flowed from Pelly River Valley onto the floor of Pelly Basin.

Another case of glacier thinning caused by topography occurs where a valley glacier is forced to flow up hill and over a divide. This situation occurs most commonly when a lateral projection from a large trunk glacier flows up a tributary valley. The ice must be thick enough at the beginning of the up-grade to produce a flow over the divide equal to the input. This is somewhat analagous to a stream that forms a lake in order that it may surmount an obstacle. From theoretical considerations, it appears that thinning of an ice stream in this way reduced the thickness between the beginning and end of the up-grade by about twice the difference in altitude of the two points (Fig. 11).

This holds for cases in which the vertical interval is in the order of one third the thickness of the ice at the beginning of the slope and the horizontal distance of the up-grade is perhaps 20 to 100 times the vertical interval. Thinning of this type must have occurred where ice flowed northwest up tributaries of Little Salmon River.

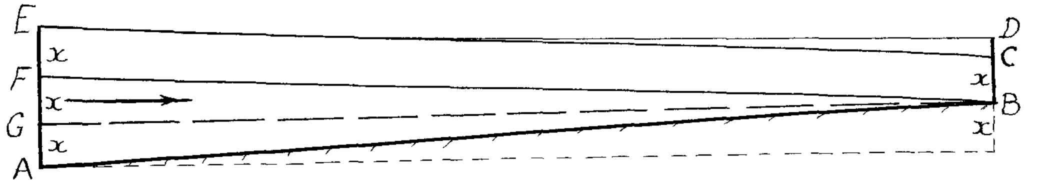

Figure 11. Cross Section of Glacier Flowing Up-slope and Over a Divide.

A represents beginning of slope, B the divide. Lines ED, EC and FB represent various theoretical positions of the glacier surface. x is the vertical interval between A and B. Distance AB is 20 to 100 times x.

The obvious effects of erosion by this ice moving uphill support the concept of extrusion or obstructed extrusion flow, for it is difficult to see how erosion could be accomplished if active ice overrides a basal, stagnant layer. A volume of ice represented by triangle ABG (Fig. 11) must be lifted in order to flow over the divide at B. If we assume the thickness of ice at the beginning of the slope to be 2x (i.e. AF) and that there is no friction then the surface of the ice must decline along the line FB in order that sufficient energy be expended to lift the volume represented by ABG. When the thickness of the ice is 3x (AE) at A the surface must describe a curve approximated by the line ED. When there is more ice above the line GB than is required to lift the volume of ice below, then the surface need not have as steep a gradient as before and the gradient may become less as the divide is approached. Since erosion probably occurs along line AB, the attending friction requires that the surface slope more steeply than the line ED. If friction and the degree of slope each cause the gradient of the ice to be steepened so that the surface declines by 1/2x for each between A and B, then the ice will be thinned by 2x between A and B. The positions of lateral moraines in some valleys in the Glenlyon area suggest that thinning of this magnitude occurs in nature.

NATURE OF THE GLACIER RECESSION

As the glaciers receded and thinned large ice masses became isolated when topographic divides were exposed. Also thinning appears to have been so uneven that masses of ice were isolated where normal recession would be expected. Large scale stagnation is demonstrated by intensely pitted outwash deposits (Fig. 10). Apart from several instances of large scale stagnations, the ice retreated normally up Pelly and Lewes river valleys.

RELATION TO NORTH AMERICAN ICE SHEETS.

Within the present scope of this work it is impossible to establish any certain relations between glaciation in central Yukon and in the mid-continent. It is probable that the age of the most recent glaciation is Wisconsin but beyond that nothing further in chronological correlation can be attempted. Evidence of two and possibly three glaciations in central Yukon seems fairly definite and it is hoped that further field work will cast more light on the glacial sequence.

The most extensive glaciers in central Yukon (Selwyn and Cassiar) developed essentially by a process of windward building. They were much larger than lee-side glaciers that came from the Coast and St. Elias mountains. In this respect these glaciers apparently developed differently than the Cordilleran ice sheet farther south which, according to Armstrong and Tipper (1948, pp. 305-307), drained east from Coast Range into central British Columbia. In northern

British Columbia Watson and Mathews (1944, p. 36) found evidence indicating that Cassiar Range was the centre of the Cordilleran ice sheet from which the ice moved west and southwest. Hedley and Holland (1944, p. 31) concluded that ice also flowed to the east from Cassiar Range, and the evidence presented here suggests that Cassiar ice also flowed north and northwest into central Yukon. It could not move far northeastward because of Pelly Mountains and the pressure of ice flowing west from Selwyn Mountains.

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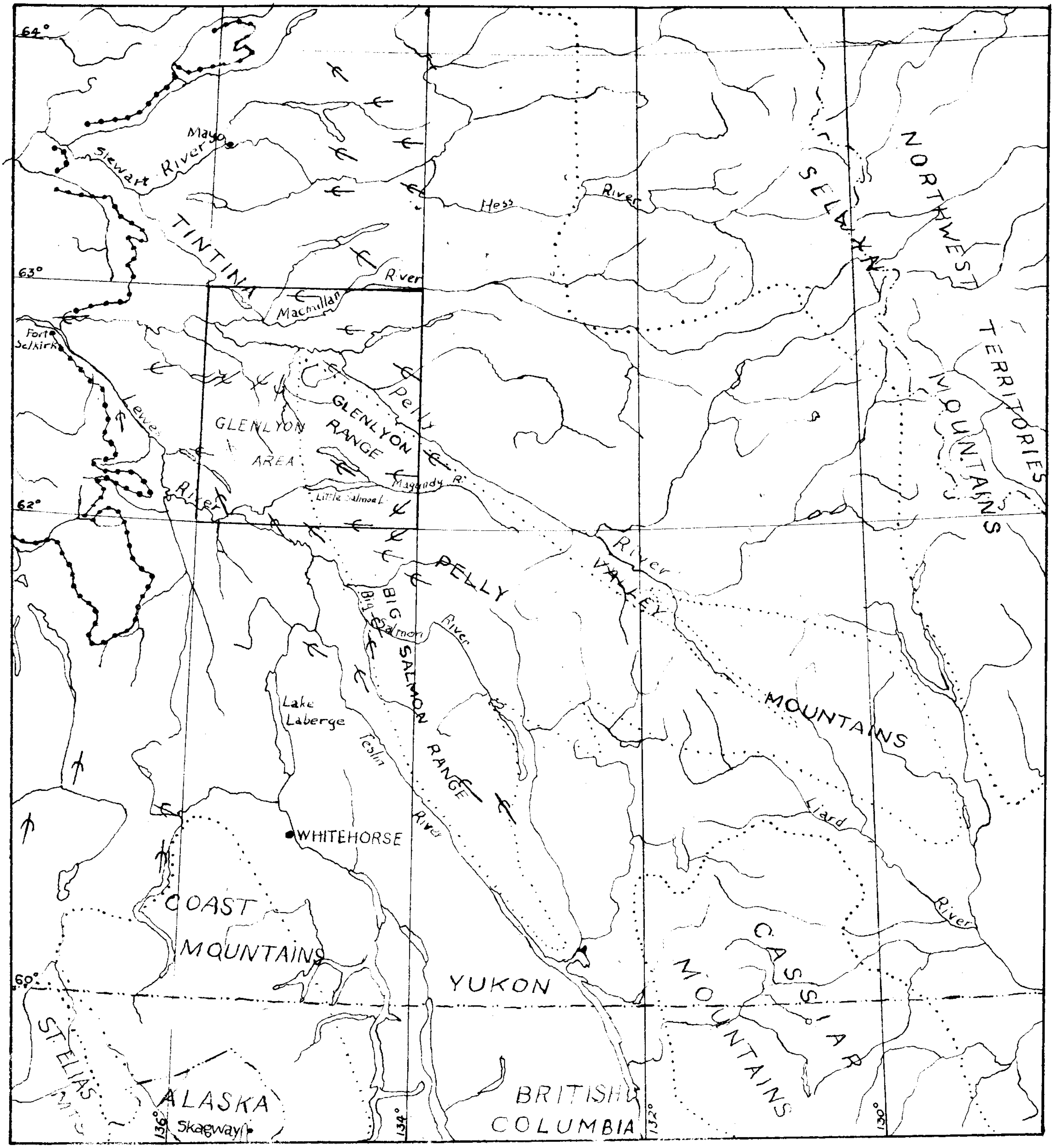
PLATE I



PART OF SOUTHERN AND CENTRAL YUKON

Scale : 1 inch = 40 miles

Glacial Directional Features

Glacier Limit (after Bostock)

Margin of Mountain Area