OPEN FILE REPORT

Surficial Geology of the Nadaleen River Map-Area, Yukon Territory - Northwest Territories (106 C)

by

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ABSTRACT

Surficial mapping of the Nadaleen River map-area was conducted by airphoto interpretation. Extension of geomorphic features that have been published on adjacent map-areas supports the theory of a transection glacier system with source areas to the east and southeast during two or more Pleistocene glacial episodes. Constructional or depositional landform evidence for multiple glaciation is scant and most surficial features are related to the deglaciation of the Late Wisconsinan McConnell Advance and subsequent events. A more extensive and older (Reid ?) advance is recognized from glacial or deglacial erosional features on valley walls and uplands located above the limits of McConnell ice. A youngest multiple-pulse Neoglaciation displays fresh moraines and residual ice bodies in some north and east-facing cirques and alpine valleys.

Cirques, "U" shaped valleys and faceted spurs are the erosional glacial features of the area. Of the surficial landforms the vast array of rock glaciers, derived by several and a combination of multiple processes is paramount. The areal extent of the multi-terraced flood plain and fan deposits is continuous. Several large and recent rock slides and slumps of the 30-50 x 10^6 m^3 class as well as the overall presence of solifluction forms and expansive river icings necessitate careful planning on any contemplated construction projects. On the other hand, the mountainous physiography is cut by deep, low-gradient interconnecting valleys and is largely devoid of thick and expansive bog or muskeg terrain. These factors coupled with the abundance of surficial deposits suggest the area could be geologically favourable for development of selected transportation and utility corridors.

INTRODUCTION

Location, Historical Studies, Climate and Access

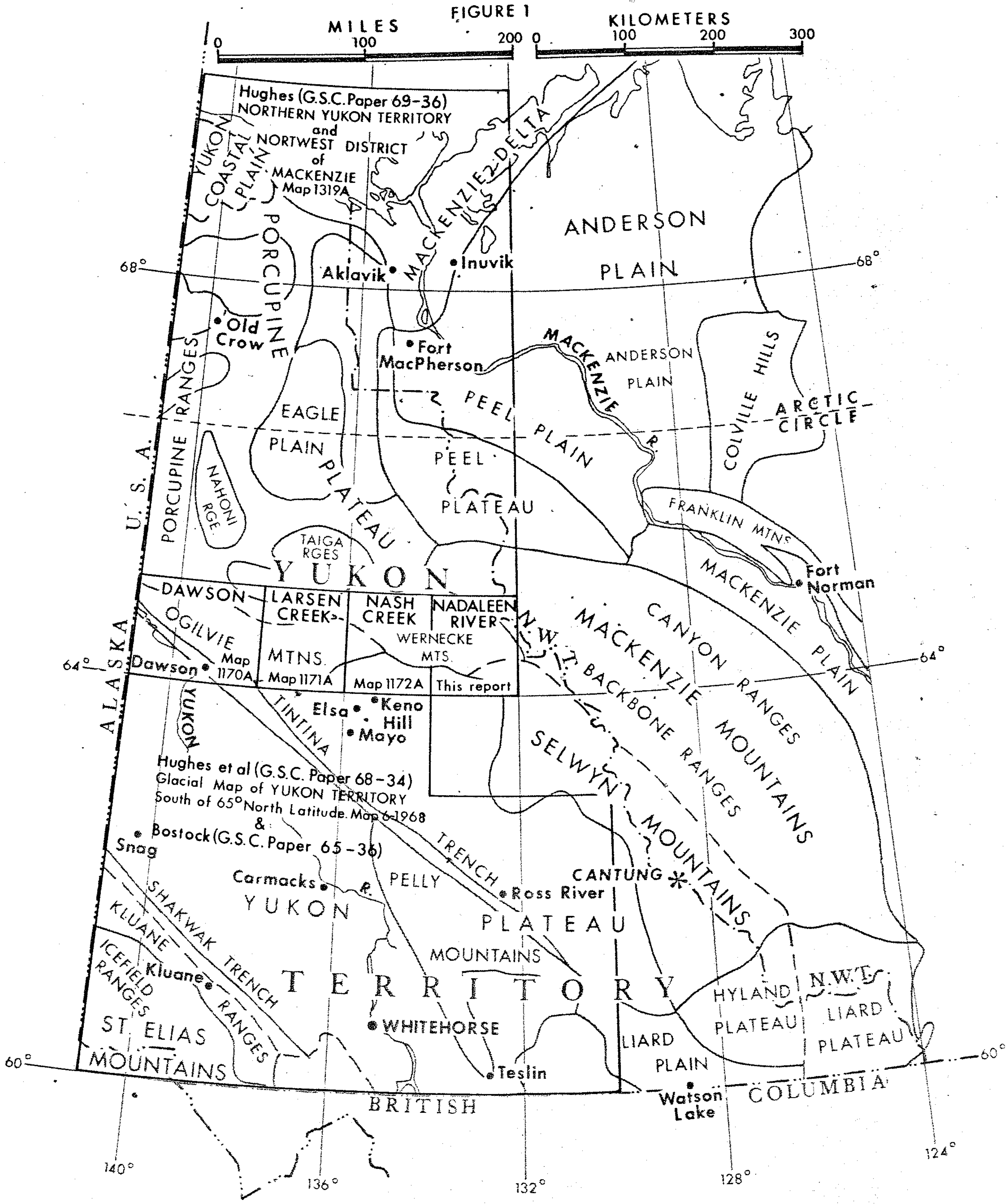
The Nadaleen River map-area lies in the central eastern Yukon Territory and a small portion of the Northwest Territories on the northern axis of the Selwyn Mountains. This region is bordered by the Mackenzie Mountains and Yukon Plateau to the east and south respectively (Figure 1). The first geological exploration to the area was carried out by Keele (1906) with visits to the lower Rackla and the upper Stewart River basins. These valleys outline the west and south margins of the map-area respectively. Keele noted the evidence of former westward movement of Pleistocene ice in the Stewart Valley; several layers of till (and hence, oscillatory or multiple glaciation), silt beds, deglacial gravels, and the upper and downvalley limits of ice in the main valleys. His reconstruction of the glacial history, presented in a general way, coincides with the glacial-deglacial sequence now recognized to be the McConnell or late Wisconsinan event; his analysis of the deglacial stage in particular is surprisingly identical to what was found in this study.

Further geological and periglacial observations were carried out by Wernecke (1932), apparently by aerial reconnaissance (Bostock, 1948), but the results are presumably unrecorded for the Nadaleen River map-area. Bostock (1948) classified the physiographic features in the Yukon and adjacent regions and surmised from air photos that the Pleistocene ice sheet was as high as 1525 m. (5000 feet) above mean sea level in the central part and as low as 1065 m. (3500 feet) on the north slope near the boundary of the map-area.

Wheeler (1954) carried out the first extensive ground investigation of the area and though the emphasis was on bedrock mapping and a search for the elusive hematite beds - reported as long-distant moving erratics by Keele (1906) and others. He managed a very good record of biologic, physiographic, glacial, deglacial, fluvial, periglacial and mass wasting observations. The upper limit of glaciation in major valleys was noted at 1740 m. (5700 feet) above mean sea level though cirque floors of recognized

RELATIONSHIP of NADALEEN RIVER MAP-AREA TO PHYSIOGRAPHY & ADJACENT REGIONAL STUDIES

FIGURE 1



• ADAPTED FROM G.S.C. MAP 1254A

higher elevation would raise this limit considerably in areas adjacent to the axis of mountainous massifs. On the north slope bordering the Snake River valley he noted an upper ice limit of 1370 m. (4500 feet) but these observations were considerably upstream from Bostock's (1948) general prognosis. Some of Wheeler's observations have been incorporated on the accompanying surficial map.

Blusson and Templeman-Kluit (1970) have remapped the bedrock geology of the area in entirety as one of four sheets covered by "Operation Stewart". This was primarily a ridge-top helicopter traverse and very few geomorphic features of valley bottoms were observed but those noted have been conveyed by personal communication onto the accompanying map. The overall geological setting is comprised of a series of Precambrian to Mississippian clastics and carbonates displayed in open upright folds, tilted fault blocks and complicating overthrusts. There are a few small scattered intrusions in the western half of the map-area but large plutons are notably absent. The bedrock geology will be displayed in an upcoming Open File Report(s) by Dr. Blusson (1974) of the Geological Survey of Canada.

There are no meteorological stations in the map-area and the nearest long term records are those of Elsa (el. 914 m. above m. s. l.) on the northern fringe of the Stewart Plateau some 80 km. (50 miles) to the southwest. The weather record, given in Green (1971, 1972), is a good approximation of the conditions in the southwest quadrant because the valley elevations are similar; but, the more mountainous aspect of the remainder of the map-area would reveal significant localized climates. The mean annual temperature of Elsa is (-) 4.4°C. and the seasons are characterized by: exceedingly cold and dry winter, cool and dry spring, warm and moist summer, and a chilly and wet autumn. Wheeler's (1954) traverse encountered similar summer conditions. The map-area lies within the zone of discontinuous permafrost, but, according to Brown (1967), frozen ground is widespread and thicknesses of 137 m. (450 feet) have been reported near Elsa at the United Keno Hill Ltd. mining operations. The absence of permafrost would only be expected on southerly exposures and beneath large lake basins or river channels.

At present there is extensive summer exploration by mining companies but as of 1973 there were no permanent inhabitants in the area. There is a winter bulldozer trail along and on the flood plain and terraces of Gillespie Creek, Bonnet Plume River and an unnamed tributary to the northeast.

Supplies were toted on this trail to a mineral exploration venture located 16 km. (10 miles) east of Fairchild Lake in the heart of the Bonnet Plume Range. The camp has the only airstrip in the map-area though recent reports by mining companies suggest the eminent construction of an airport near the junction of Goz and Duo Creeks. There are a fair number of lakes and river channels suitable for STOL float planes or any style of ski equipped aircraft. Wheeler (1954) cautions on the use of horses in the region and with helicopters now based at Mayo this will be the most efficient transport until permanent developments appear in the region.

Physiography

The map-area lies principally in the Wernecke Mountains - a major subdivision of the Selwyn Mountain system that straddles the eastern Yukon boundary. The mountains are of rugged arctic-alpine character with the highest peak, Mt. MacDonald (2750 m.), lying in the headwaters of Corn Creek of the Bonnet Plume system. Relief of 1000 to 1500 meters or more is common throughout the area. The mountains have been broken down into three units as described: 1) the Rackla Range enclosed by the Bonnet Plume and Rackla River systems and characterized by a series of folded Precambrian dolomites and clastics with minor basic intrusives; 2) to the east, the Bonnet Plume Range bounded by the Bonnet Plume and Snake Rivers and underlain by mainly faulted Precambrian and Lower Paleozoic clastics and carbonates; and 3) the Nadaleen Range mountains to the southeast of the Rackla and Bonnet Plume basins and north of the Stewart River and Plateau, and composed of gritty quartzites and slates of Late Proterozoic age (Blusson and Templeman-Kluit, 1970). The structure of the Nadaleen Range is characterized by apparent tight east-west folds of an overthrust sheet. Small icefields and glacierets are common and periglacial features and processes are ubiquitous throughout the three ranges.

According to Bostock (1948, 1961) the Stewart Plateau, a subdivision of the vast Yukon Plateau lying to the southwest of the map-area, is a transitional upland-mountainous region bounded to the north by the East Rackla, Nadaleen and upper Stewart River valleys - or about 15% of the map-area. A variety of Upper Proterozoic, Lower Paleozoic and Mesozoic slates, quartzites and carbonates underlie this surface. Summits or ridge crests on the plateau almost reach 2000 metres above mean sea level in extreme cases, but icefields are not present and valley slopes are extensively covered with large spruce trees and woody shrubs - this region marking the northern limit of the boreal forest.

The northeast one-eighth of the map-area is covered by a small portion of the extensive Backbone Ranges of the Mackenzie Mountain system. Light-coloured carbonates and quartzites of Cambrian age situated in gentle northwest trending folds are characteristic in this quadrant of the map-area. Barren arctic-alpine relief is obvious though the summits reach only 2450 m. (8000 feet) above mean sea level. Icefields are about double the size of those in the neighboring Wernecke Mountains and one unusually long debris-covered glacier of significance (to be discussed in subsequent sections of this paper) are some of the important physiographic features in this range.

About two-thirds of the map-area lies within the Mackenzie drainage basin. The Arctic Red, Snake and Bonnet Plume Rivers are the major tributaries and all are characterized by uniform and fairly low gradients (1:350 in the lower reaches increasing to 1:100 upstream). The southerly exposure of the Wernecke Mountains and all of the Stewart Plateau are drained by the Yukon system by way of the Stewart River and the Rackla-Beaver and Nadaleen tributaries. Valley gradients in this system are very similar to those of the Bonnet Plume; several passes or through valleys between the two systems are only 150-250 m. (500-800 feet) above the main floors of either. Drainage courses prior to the onset of Pleistocene glaciation were probably considerably different from present ones, but are masked by glacial features. The only obvious pre-glacial capture appears to be the extension of the Nadaleen into the upper East Rackla system. However, during deglaciation the East Rackla re-captured these upper reaches only to lose it to the Nadaleen again when a dam of surficial deposits gave way to the re-establishment of the captured course. Wheeler (1954) outlines structural and lithologic controls on the development of river courses and evolution of the mountainous landscape for the map-area which will not be repeated herein.

Recent Quaternary Mapping - Multiple Glaciation

The analysis of the surficial geology of this area is a photo interpretative continuation of the surveys carried out to the west by Vernon and Hughes (1966) during "Operation Ogilvie" and subsequent field operations by the Geological Survey of Canada between 1961 and 1965. The survey area was then confined to the Southern Ogilvie Ranges and basins to the north, the Stewart Plateau, and the western tip of the Wernecke Mountains to the east (Fig. 1). This analysis revealed a multiple sequence of Pleistocene terminal moraines and their outlines along with related geomorphic features and surficial deposits were published on three maps (scale - 1:253,440). The easternmost coverage in that project, the Nash Creek map-area, is the western boundary of this study, and the westernmost map (Dawson) was re-examined along its eastern boundary by the writer in follow-up detailed studies (Ricker, 1968). The photo interpretative extension of geologic units, shown on the Nash Creek map-area, to the Nadaleen River is reasonably accurate though modifications of a few geologic units, as will be discussed, preclude direct comparison or projection. The area to the north of "Operation Ogilive" and the Nadaleen River area was mapped by Hughes et al (1972) on a smaller scale (1:500,000), but its overall framework is sufficient to act as a further control for this compilation. The chrono-sequences of moraines to the south and southeast of "Operation Ogilvie" and this study has been mapped by Bostock (1966) and added to and recompiled by Hughes et al (1969). From these studies it has been shown that regardless of the age of ice advance in the Pleistocene Epoch, glaciers to the west were localized and thin whereas those to the east were joined in a thick, continuous network or anastomosing array. The Wernecke Mountains marked one centre for the development of this interconnecting style of icefields and other centres lay to the southeast.

For the Wernecke Mountains, Vernon and Hughes (1966) visualize a system of transection and/or through glaciers which covered most and interconnected many valleys during several Pleistocene ice advances. These advances have been defined by Bostock (1966) from sequences of terminal moraines lying to the southwest of the map-area and formal names therein assigned will be used in this report. An older and more extensive advance known as the Reid Advance could be Early Wisconsinan in age and the source of this ice appears to have been in Nash Creek, Nadaleen River and map-areas to the southeast as predicted by Green (1971, 1972), Vernon and Hughes (1966), Bostock (1966) and several glacial map compilations listed in the references. A subsequent Late Wisconsinan episode, or McConnell Advance, also transected the drainage system within the map-area though nunatak and ice-free upland areas were more extensive and major trunk glaciers protruded from the mountain fronts to a lesser degree than in the Reid Advance. Recessional halts or minor readvances as noted by Keele (1906), during waning of the McConnell Advance are numerous in the map-area though are surprisingly rare in the adjacent Nash Creek area (Vernon and Hughes, 1966). After complete deglaciation and climatic amelioration a Neoglaciation developed a few sizeable valley glaciers which may have developed in an early and/or recent pulse(s). These various aged ice limits are shown on the accompanying map though major Wisconsinan end moraine systems lie to the north, west and southwest of the map-area as described in the following paragraph.

Anomalies in the various ages of ice advance occur with the geographic exposure. Neoglaciation extends primarily on the north and east slopes whereas older advances are far more extensive to the southwest of the ice centres. From the mapping of Hughes et al (1969, 1972) valley or outlet piedmont glaciers spilled out of the mountains onto the Yukon Plateau to the southwest but to the northwest the Late Wisconsinan McConnell Advance had carried only 40 km. (25 miles) downvalley beyond the Nadaleen map-area to termini still within the valley confines of rugged mountains. Some of the older Reid valley glaciers, however, on this north exposure merged with or were overridden by the west-moving Laurentide continental ice sheet in the Bonnet Plume Basin (a downvalley re-entrant located 65 km. north of the map-area), but the thickness of this valley glacier ice was much thinner than its counterparts on the southern slopes and Yukon Plateau.

Comparison of Nadaleen River Geologic Units to Adjacent Mapping

The Nadaleen River map-area straddles the various map projects just described. Unfortunately the map legends are not standardized and in order to allow a method of comparing them along boundaries common to this study area, the following solution was used:

(1) map units and symbols are labelled after the Vernon and Hughes' (1966) method with some modification, addition and re-arrangement as noted below; hence, the Nash Creek sheet (Map 1172A) should tie on the west boundary though sub-units may not necessarily be identical - some being changed to conform to the compiler's experience in the nearby Dawson area; and

(2) the symbols of some geologic features follows Hughes' et al (1972) Northwestern Yukon Territory and Northwestern District of Mackenzie sheet (Map 1319A) and eventually the enclosed map will be reproduced in colours according to that sheet. When comparing

the enclosed map to the adjacent Nash Creek sheet of Vernon and Hughes (1966) the following variations in geologic units should be noted.

Feature	Symbol on Nadaleen River Map		Symbol on Nash Creek Map
Glacial	Unit 1	=	Unit 1
terminal and recessional moraine	1a	=	1a
ground moraine	1b	=	1b
dead ice deposits	in 2c		1c
lateral and medial moraine	1c		-
Deglacial	Unit 2	=	Unit 2
terrace, kame pitted terrace, etc.	-		2a
non-pitted terrace	2a		-
hummocky or ridged deposits	in 1b or 1c		2b
pitted terraces kames, etc.	2b		in 2a
esker complexes	2c	=	2c
dead ice deposits	2c		in 1c
glacial lake deposits	2d		in 3d
Fluvatile - Subaerial	Unit 3	=	Unit 3
modern terraces	3a	=	3a
modern flood plains	3b	=	3b
alluvial fans	3c	=	3c
glacial lacustrine with thermokarst	in 2d		3d
Thermokarst (in Unit P=Periglacial)	Th		in 3d
paludal, modern lacustrine	3d		in 3d ?
talus slopes	3e		-

Units or features noted on the accompanying map but not shown on either published maps (1319A or 1172A) are presented to hopefully provide a guide to preliminary engineering analysis of any feasibility studies on contemplated construction projects.

GLACIATION AND GLACIAL LANDFORMS

Oldest Glaciation(s)

The oldest recognized glaciation (Early Wisconsinan (?) Reid Advance) existed as a vast transection system developed primarily along the eastern boundary of the map-area and into the neighboring Bonnet Plume (106 B) and Niddery Lake (105 P) sheets with major sources lying in the Backbone Ranges and several ranges of the Hess Mountains to the southeast. There was also a substantial input of local ice from cirques and valley glaciers in the Wernecke Mountains but farther to the south the contribution from the lower ranges of the Stewart Plateau was considerably less by comparison. The jurisdictional boundary separating the Territories was traversed by "through" glaciers and the same style of connection existed between the major drainage basins in the western portion of the study area. The upper ice surface descended to an elevation of about 1220 m.(4000 feet) above mean sea level as it exited from the map-area in several of these valleys to the north. Using elevations of a few faceted spurs and Wheeler's (1954) data on erratics and glacially modified ridge crests, it appears that the ice build up was greater in the Stewart drainage and only a few isolated nunataks protruded above a mountain ice sheet. West of the map-area in the Beaver-Rackla basin Vernon and Hughes (1966) established this ice surface at an elevation of at least 1430 m.(4700 feet) above mean sea level from which their gradient data suggest an elevation of at least 1525 m.(5000 feet) on the common map boundary to the Nash Creek - Nadaleen River map sheets. This projection is corroborated by a few of their erratic localities found at or slightly above this elevation adjacent to the map boundary. At Nadaleen Mountain and around Rackla Lake the ice surface was at least 200 m. higher but farther to the east the scant evidence of questionable quality suggests a levelling of the ice surface.

Depositional evidence of the Early Wisconsinan (or older) glaciation is no longer visible though a terminal ice limit can be inferred at the very northeast corner of the map-area. A few stratigraphic sections noted in the Stewart valley by Keele (1906) probably display pre-Late Wisconsinan sediment, but for the most part the succeeding ice advance obliterated most valley bottom evidence of older glaciations and their associated deglacial deposits. Thus, the recognition of the Early Wisconsinan or Reid Advance depends on the following described erosional features lying primarily in the northern one-half of the map-area.

Eroded faceted spurs superceded by a lower and fresher set(s) of spurs and/or "Schliffgrenze" (Muller, 1967) are the main evidence for delineating the oldest(?) glacial limit, and in a few cases elevated valley-sided meltwater channels above the Late Wisconsinan McConnell limit and castellated outcrops (tors) above the eroded spurs are further evidence. Whether these eroded spurs and tors are the product of one or more glaciations is not known but surrounding mapping have delineated two or more glacial episodes older than the McConnell Advance. It is not practical to attempt correlation of the upper limit to the downvalley Reid moraines because on the north slope these valley or trunk glaciers were meshed with or overridden by the Laurentide Ice Sheet (Hughes et al, 1972), and on the south slope, elevations of ridge crests to the southwest are too low to record the higher ice limits of the mountain ice sheet(s) (Bostock, 1966).

McConnell (Late Wisconsinan) Glaciation

The character of the last major ice advance as compared to the older glaciation(s) is more restricted though ice sources are similar. In the Stewart drainage system surfaces of a mountain ice sheet character gradually dropped from an elevation of 1525 m. (5000 feet) above mean sea level in the east and north to about 1300 m. ± 80 m. (4250 feet) on the west edge of the map-area (dependent on the valley considered). On the north slope and edge of the map-area the glaciation was reduced to a valley and trunk glacier type of system and the upper ice limits were about 900 m. (3000 feet) above mean sea level on the Snake and Bonnet Plume valleys and only a few tens of metres above the valley floors of the tributaries of the Arctic Red system. In the Bonnet Plume Valley near the northwest corner of the map-area a few tributary valleys (with "V"-shaped profiles) lacked an actively advancing outlet glacier - rather, ice from the Bonnet Plume spilled into these valleys and kame terraces and/or lake deposits were banked against the lobe of intruding ice in more or less the same situation described for some valleys in adjacent Nash Creek map-area by

Vernon and Hughes (1966). Upland areas throughout the region show either no evidence of the last Pleistocene glaciation, or ice restricted to local valleys - these small glaciers failing to reach the main valley trunk glacier beyond as shown by weakly to well developed terminal moraines or abrupt changes in the downvalley profile. In ambiguous cases the moraine in the upland valley could be either a recessional feature or a maximal ice position and hence, some glacier terminus limits on the map are subject to alternate interpretations. Elsewhere, the interconnection of glaciers from one major valley to the next is intact within the map-area. Mapping by Hughes et al (1972) to the north suggest that a major unnamed tributary of the Snake River (on the north boundary of the map-area near triangulation point 5931), during the Late Wisconsinan, was non-glaciated within the confines of the Nadaleen River map-area. The writer's review of the photos, however, suggests that their upvalley moraine of the McConnell limit is only a recessional feature of kames partially masked by recent fan activity and that ice actually descended downvalley into the map-area to coalesce with Snake River Valley ice.

A terminal moraine (see map) on the floor of a major tributary valley of the Arctic Red system is inferred to indicate a stadial climax position of Late Wisconsinan ice. This moraine, combined with morainal features upvalley into the cirque zone, is the reference datum for the chronosequence of moraines mapped elsewhere in the study area. Downstream from this moraine, scarped fans and incised valley floors and the mapping of Hughes (1972) suggest the McConnell age assignment as defined by criteria of Vernon and Hughes (1966). Unfortunately, this is the only major moraine of recognized maximal stadial position in the map-area; others are 40 km (25 miles) beyond the map-area to the north and much greater distances to the west and southwest - previously noted upland moraines being excluded.

Erosional Features

Utilizing geomorphic evidence established by Vernon and Hughes (1966) for determining the age of final cirque development, about 80% of the cirques in the map-area were with active glaciers during the McConnell Advance (including those with ice at present). A few of these may have been passively filled by ice inundation from an adjacent valley glacier (e.g. Corn Creek area) because their headwalls display either a dendritic drainage pattern or a series of tor-like features. The percentage of cirques occupied by only older Reid Advance glaciers is higher to the west and north in adjacent map-areas; this augments another line of evidence to support the theory of the development of the transection glacier system to the southeast. The failure to (re-)generate ice in a particular cirque or basin is controlled partly by orientation (Wheeler, 1954) and partly by a minimum threshold elevations of the basin and of the enclosing peak or ridge. Hence, during the Late Wisconsinan Advance ice-free cirques were scattered throughout most of the map-area with southward orientations on peaks below 2100 m (7000 feet) above mean sea level being typical.

Cirques with active Late Wisconsinan ice lie as low as 1220 m (4000 feet), but the relationship of elevation to exposure, lithology and other parameters has not been studied for this report.

Erosional features of the valley bottom, attributable to glacial processes, include a myriad of rock drumlins, crag and tail, stoss and lee, grooves and other related directional features. Nearly all of these indicate ice movement to have been coincident to downvalley gradient and trend. The upland development of such features appears to be scant. The combination of directional features and the "Schliffgrenze" together with fresh faceted spurs provide a reliable indicator of the upper limit of the McConnell Advance except where obviously superceded by a crisply-displayed Neoglacial feature of very limited areal extent in a few cirques and alpine valleys.

Depositional Features

With the exception of a few Neoglacial moraines nearly all glacial deposits are a product of the McConnell Advance or its recessional pulses. Wheeler (1954) gives "drift" thicknesses of up to 45 m (150 feet) in major valleys and records 15 to 23 m (50-75 feet) in the North Rackla and Hematite valleys, 9 to 15 m (30 to 50 feet) at Goz Lakes, and a complete absence in some valleys northwest of the Snake River area. Unit 1a designates terminal and end moraines or frontal recessional ridged features comprised mainly of till. These forms have rounded crests and are quite subdued in appearance though washboard or corrugated moraine at a recessional terminus (e.g. Nadaleen Valley system) is an associated and glaringly obvious ground moraine feature (Unit 1b). Ground moraine, Unit 1b, covers most broad valley floors as a thick deposit but is a discontinuous and thinly mixed veneer on valley slopes or floors of narrower tributary valleys. Drumlins are locally present in groups on some broad valley floors though hummocky moraine is found in others. On gentle valley slopes subsequent glacio-fluvial runoff has often rilled the till surfaces into a scale-like or shingle appearance which could represent the modification of drumlins in some cases. Other hummocky expressions are related to underlying bedrock discontinuities and to admixtures of englacial or supraglacial debris during deglaciation. Thus, Unit 1b can be quite variable in textural composition and there has been no attempt to sort out subsequent additions of minor deposits for this small scale of mapping. Unit 1c refers to lateral and medial moraines that are located remote from the terminal moraine systems and are large enough to be mapped as a distinct depositional entity - otherwise a heavy series of dots are used on the map. These smaller lateral features could be kames or other infillings because their reverse slope feature are seldomly preserved or visible on old valley wall forms.

Neoglaciation

According to the review of Terasmae (1968), about 3000 years B.P. the climate cooled to allow a new accumulation of ice in cirques. Most ice-fields, cirque glacierets and small valley glaciers in existence today may be the result of a more recent climatic pulse termed the "Little Ice Age" or Late Neoglacial event beginning about 600 years B.P. Though somewhat tenuous, lichenometry by Gray (1971), on talus block veneered ice surfaces near Gillespie Lake, suggests their origin between 1000 and 4000 years B.P. Gray's calibration was carried out on 65-70 year old placer tailings near Dawson and the extrapolation suffers not only from an insufficient time span, but also from edaphic and ecotonal differences between the areas considered. Downvalley from a few of these fresh moraines there are more sets of ridges with a not-so-fresh appearance, but with a much bolder relief than those of Late Wisconsinan recessional features. These moraines are probably Early Neoglacial in age or are a slightly older 5000-9000 year old advance as defined in several localities of Alaska (Péwé et al, 1965). Where no upvalley glacieret or ice-cored moraine exists, and yet the feature under scrutiny is with sharp relief, the subphase of Neoglacial development (N) is not assessed. Neoglacial landforms, with the exception of one to be mentioned extraordinary case, are always developed within 1 to 2 kms. of their cirque source. In the case of the exceptional valley of the Arctic Red River system, referred below in the "type" chronosequence, a debris covered valley glacier is of 10-11 km. in length and is slowly stagnating except for superposed or onlapping additions of ice from one cirque at the valley head. The significance of this glacier will be discussed in the following paragraphs.

Chronology of Morainal Sequences

The designation of morainal ages on this map is based on the following premises: 1) the progressive downvalley increase in age of moraines (Ricker, 1968), 2) observations on morainal limits and their relative ages outside but adjacent to the map-area as reported by previously mentioned workers, and 3) key radiocarbon dates on deposits mapped in the surrounding areas. With respect to these three criteria the key area for establishing a chronosequence should be the Stewart Valley but unfortunately Wisconsinan moraines are far distant removed from the map-area. There are good radiocarbon dates in the Snake River valley but, due to mergence of the Early Wisconsinan ice with Laurentide ice, the missing morainal sequence coupled with the distant downvalley position of the McConnell terminus also precludes direct correlation to glacial sequences in the map-area. In order to compress the distance-versus-time factor, the tributary of the Arctic Red valley will be used because there is evidence of many ice front positions within a short distance and there is also the fortuitous preservation of the long and stagnating valley glacier which gives additional clues on the younger end of the time scale. In the following discussion circumstantial geomorphic evidence is used to establish the age of the major moraine as the Late Wisconsinan datum equivalent to the McConnell moraine of the forementioned Snake Valley.

The "type valley", Arctic Red system, for the chronology lies on the northeast side of the jurisdictional territorial boundary in the Backbone Ranges on the approximate coordinates of 64°55'N by 132°00-20' W and the upper stretches of the system showing the key Neoglacial features is centered on 64°44' N by 132°23' W.

The assumed Late Wisconsinan (McConnell) moraine lies at the mouth of the main valley and an upstream tributary entrance harbors enclosing Early Postglacial glaciofluvial deposits which depict a temporary halt in glacier retreat. Farther upstream the long, debris-covered valley glacier probably represents a post-Hypsithermal birth of a new ice advance because it is doubtful that it would have survived the previous climatic optimum despite the recent(?) detachment from some probable infeeding cirques. However, a three lobed rock glacier is advancing out of another of these cirques and it appears to be overriding the valley glacier - the uppermost lobe of the rock glacier has a fresher appearance. Wahrhaftig and Cox (1959) credit advancing rock glaciers in the Alaska Range to a multiphased Late Neoglacial event and Terasmae's (1968) regional climatic analysis suggest that such a correlation could be applicable to this region though Gray's (1971) lichenometric evidence would suggest a long, sustained, to the present, Early Neoglacial advance. However, the writer prefers the former hypothesis in view of the sequence of deposits shown here.

From the Arctic Red system the McConnell ice limits were carried west by photogrammetric extension of the "Schliffgrenze" and faceted spurs into the Snake River Valley and into its network of feeder alpine valleys where other debris-coved glaciers and fresh moraines exist. The Snake system was correlated to the Bonnet Plume system in the same manner where gradients appear to line up with McConnell moraines mapped to the northwest by Hughes et al (1972). However, carrying of these limits onto the south slope to the Nadaleen, Rackla or Stewart valleys is sketchy because edaphic and ecotonal changes have altered the appearance of the "Schliffgrenze". To add some control to the meagre data on glacial limits in this sector sequence of adjacent moraines to the west and southwest, as illustrated by Vernon and Hughes (1966) and Bostock (1966), were extended into the map-area to aid in the differentiation of Early Postglaical recessional features from maximal stadial ice front features of the McConnell Advance. This, however, does not guarantee an age synchroneity of the last maximal advance on north and south slopes of the mountainous ranges dividing this map-area because radiocarbon dating of the key moraines on each side is still defined by very broad limits as will be discussed.

Absolute age dating of the morainal systems lies on surrounding projected or correlative evidence of a few dated deposits and the various interpretations of this data are given in Ricker (1968). The following table reveals the data which is applicable, more or less, to this map-area:

TABLE 1. Selected Radiocarbon Dates in the Central Yukon

Event-Geoclimatic Unit	Absolute Age (yrs. B.P.)	Evidence	Source of Data
Reid Ice Adv. (E. Wisc.)	>42,900	Wood above till near type locality in Stewart Valley	Hughes in Lowdon and Blake (1968)
McConnell Ice Adv. (L. Wisc.)	<31,000 to >9750	Wood below outwash of McConnell moraine, silty peat above the outwash; Snake River Valley, 40 km north of map-area	Hughes in Dyck et al (1965), and Lowdon and Blake (1968)
Early Postglacial Adv. or recessional standstills	15,000 to 7500	Pollen diagrams for northern Cordillera	Terasmae (1968) and Ricker (1968)
Hysithermal Interval (Holocene)	7500 to 4000	as above	as above
Early Neoglacial Adv. (Holocene)	<3300 to >1520 (?) (800-4000 yr B.P.)	Wood fragments in till on north slope of St. Elias Mtns.; (lichenometry near Gillespie Lake and Dawson)	Rampton in Lowdon and Blake (1970) Terasmae (1968); (Gray, 1971)
Late Neoglacial Adv. (Holocene) (="Little Ice Age")	II 1520 to 440(?)	Wood fragment in and above till (as above)	Rampton; as above
	I 480 to pres.(?)	Peat below till (as above)	Rampton; as above

The oldest published minimal date for a positively identified McConnell Moraine is 13, 870 years B.P. from a basal zone of a bog on the "Foxy Moraine" near the North Fork Pass region of the Dawson map-area to the west (Ricker, 1968) and there are suggestions of minor readvances or stand stills after this time from surrounding drill holes on other moraines in the same district. For the Neoglaciation there are no applicable local absolute dates and the lichenometric data of Gray (1971) has previously discussed problems. Hence, there could be variances in the age of intervals of glacier fluctuation in particularly the Late Neoglacial phases listed above, but the same style of Neoglacial sequence is present in much of Alaska's mountainous areas (Péwé et al, 1965).

DEGLACIATION AND ASSOCIATED DEPOSITS

Age of Deposits or Features

Products of deglaciation are developed primarily in major valleys as a result of the wastage of the McConnell ice advance. There are, however, a few exceptions. Lateral and overflow meltwater channels lie above the limits of McConnell ice and are assumed to have been developed during the deglaciation of the Early Wisconsinan Reid episode. One such channel has helped to cut a deep box canyon through a dissected upland (a pediment?) located on the northeast corner of the map-area and fortuitously the same channel was reactivated during the subsequent McConnell episode. A few alpine valleys and cirques are floored with fresh veneers of outwash, ablation moraine and other features attributable to the waning phases of the Neoglacial episode.

Sequence and History of Deglaciation

During deglaciation of the McConnell "ice sheet" the following wastage process appears to have taken place: 1) downwasting of stagnating ice coupled with and followed by horizontal retreat, and 2) disintegration of residual dead ice blocks on the low divides between valleys - especially those straddling the Stewart and Bonnet Plume basins. That is, ice was removed from many of the upland areas before valleys became free of glaciers.

High-level ice-marginal meltwater channels are scattered in distribution, and projection from one such feature to the next does not suggest steep intervening ice gradients though overflow channels interconnecting one valley to the next illustrate greater rates of downwasting in some as compared to their neighbors. However, at lower valley wall elevations more continuously developed (or preserved) lateral channels and kame terraces show a greater inclination and on occasion lead to a former zone of ice frontal deposition. These frontal deposits probably represent temporal cessations in ice retreat (heavy black dashed outline on map) but minor re-advance (heavy and unmarked black continuous outline) can be inferred by end morainal characteristics at some mouths of alpine valleys tributary to major valleys and at a prominent morainal system in a low-level and broad valley in a tributary of the Nadaleen system near

Mt. Mervyn. These are perhaps a weak expression of the so-called "valley glacier phase" of the Late Wisconsinan climatic episode as recognized or inferred in many other portions of the Canadian Cordillera and Alaska.

In the Stewart Valley, Bostock (1968) outlines an uncorrelated post McConnell advance about 90 km.(55 miles) downstream from the southern map boundary at the Stewart River exit and 65 km.(40 miles) upstream from the McConnell moraine of climax position. Continuing northeastward from the uncorrelated feature into the non-mapped Lanzing sheet (adjoins Nadaleen River on the south) the Stewart Valley is an unknown as far as the deglacial events are concerned. Farther up valley into this map-area, and into especially the Nadaleen tributary, there are a sequence of 4 to 5 recessional halts. In the adjacent Rackla Valley 5 or 6 similar recessional standstills are identified.

Meltwater discharged initially from the Bonnet Plume valley into the Nadaleen Valley but as the ice downwasted an interplay of ice-dammed lakes developed at lower elevations with discharges being carried to the northwest in the Bonnet Plume. Upvalley, but west of the Goz Creek valley entrance, the Bonnet Plume Valley was blocked with residual ice which backed up an ice dammed lake therein to the northwest, as shown by raised deltas, shoreline terrace complexes and possible obscure strandlines. Several terrace levels at the mouth of Kohse Creek are associated with this event. Farther downvalley to the north of the Pinguicula Creek entrance, unnamed tributary valleys were ice free and, hence, lake ponded before the disappearance of ice in the adjacent Bonnet Plume master valley. Pinguicula Creek itself carried meltwater from a stagnating ice lobe in Corn Creek valley because ice in the Bonnet Plume at that point blocked the out flow of meltwater.

Stagnating valley glacier(s) protruded from unnamed valleys into the Snake master valley near the north boundary of the map-area. As a result, a large long and fairly stable lake was backed up to the southeast on the Snake Valley floor. Lacustrine silt benches, multi-level raised deltas and associated strand levels are supporting and extensive evidence but the lake appears to have been confined to the main valley while ice remained in the majority of the tributary valleys.

Retreat of ice in the side valleys heralded the beginning of the dead ice phase and several large ice masses were stranded in the position of today's lake basins located on the Stewart-Bonnet Plume drainage divide. Just south of Bonnet Plume Lake landforms suggest a sequence of inward peripheral slumping of glacial debris as the ice block diminished in size. Similar dead ice deposits indicate an analogous origin of Duo Lakes and Rackla Lake, though the latter is complicated by an up-valley ice lake that drained initially to the east into the Bonnet Plume and later towards the ice blocks at Rackla Lake.

The net effects of the McConnell deglaciation are: valley bottoms pocked with small lakes; deranged river systems on especially the low divides between the major valleys; localized areas of extensively rilled valley slopes; and, tributary valley mouths choked with outwash and terraced deposits. There were no major drainage readjustments created by the last major deglaciation other than the see-saw battle between the East Rackla and Nadaleen rivers, but prior to McConnell Glaciation there is a lack of compelling evidence to suggest what major changes had occurred. Low level interconnecting through valleys, however, suggest drainage changes contrary to the pattern of flow today.

Description of Deglacial Deposits

Deposits of deglaciation have not been rigidly divided into time rock or facies groups representing the sequential phases of deglaciation because of the inherent complexities which need detailed field work to unravel. Many of these sub-units listed below have been rearranged from the work of Vernon and Hughes (1966) or described in the introduction of this report.

Unit 2a represents planar features of gravel and sand deposited without *in situ* ice but are adjacent or distant from the waning ice sheet or valley glacier. Outwash terraces representing the original valley train (or deposits of different origin but reworked by glacial meltwater) and a few deltas are the chief members of the sub-unit with the former being a very common deposit in many major valleys. Wheeler (1954) reports 30 m. (100 feet) escarpments on the terraces of the North Rackla, Bonnet Plume and Snake valleys and describes the texture as poorly sorted gravel and sand.

Unit 2b consists of either ice marginal deposits or deposits with ice *in situ*, but generally maintain an overall planar form. The features are modified by kettled surfaces or cusped margins and are made up of gravel, sand and minor sequences or blocks of till. Proximal pitted outwash, isolated kames or hillocks, pitted deltas and terraces (of diverse origins) are the principle features in the sub-unit and such features are only well developed in a few locations along major valleys, but are more continuous in tributary valleys.

Deposits of irregular form derived usually by subglacial (but fluvial), englacial and supraglacial origin characterize Unit 2c. Many of these represent products of the late stagnating and/or dead ice facies. Notable features include: crevasse deposits (Rackla basin, Duo Lakes), slump and slide or hummocky or ablation deposits (Bonnet Plume Lake) and eskers and associated complexes thereof (Corn Creek). Though such forms are prominent their distribution in the map-area is sparse.

Glacial lake deposits (silt, fine sand and shore line gravel complexes), Unit 2d, are usually detected by the presence of minor slump scarps in the Stewart and Bonnet Plume valleys, but this criteria does not materialize for the deposits of the Snake Valley. It is probable that some undifferentiated portion of Unit 2 mapped elsewhere would include lacustrine deposits as well. Vernon and Hughes (1966) show an obvious delta system in the Rackla valley on the adjacent Nash Creek sheet which can not be corroborated with evidence of silt terraces in this area where part of the lake must have occurred. Therefore, it is likely that glacial lakes were extensive elsewhere in the map-area for which the evidence is now obscure. Forementioned ice-free tributary valleys of the Bonnet Plume basin are likely locales for such temporal features.

Rill deposits, associated with ice removal, are a likely veneer on the floors of most melt water channels and are too small to be delineated separately on the map. Other thin sheets of similar origin make up a part of Unit 2, non-subdivided, especially where mapped on overlying ground moraine deposits of Unit 1b.

For engineering purposes, deposits of Units 2a, 2b, and 2c are ideal for fill and foundations. The elongate terraces of 2a or 2b are ideal route locations though a few of the lower terraces along the Bonnet Plume are devoid of vegetation and appear to be subjected to either infrequent but extraordinarily high flood levels or unique ground icings brought about by subsurface rise of the water table. Construction on or downslope from silt terraces of Unit 2d should be avoided because the ground ice and inherent thawing conditions in the discontinuous permafrost zone make them prone to massive or minor slumping and unequal and continual subsidence of the thaw-sink type of process.

RECENT DEPOSITS OF NON-GLACIAL ORIGIN

Deposits of the Fluvial and Subaerial Environment

Low flat terraces of gravel (Unit 3a) lie between higher outwash terraces and the present flood plain (Unit 3b) in scattered localities on major valley floors. The terraces are probable post McConnell deglaciation in age of construction, and generally have a mantle of forest or shrub on their surfaces. Their elevation of at least a few metres above the flood plain almost precludes the possibility of inundation in the 50 year flood run-off cycle and river icings upon them are usually absent. Those terraces subjected to repeated flooding are included with the almost-barren flood plain (Unit 3b); remnants of river icings (aufeis) of up to 2 metres in thickness (Wheeler, 1954) appear on a few aerial photographs but were rather extensive during Wheeler's traverse in 1953. Other details of the flood plain have not been subdivided in this study though oxbow lakes, point par deposits, back swamps, modern delta fronts and other classic features of major river morphology are readily apparent on the photographs.

Alluvial fans (Unit 3c) are a predominate geomorphic feature in the northern Cordillera and this area is no exception. Frontal escarpments are usually wanting or relatively low and this implies a post-McConnell age of development (Vernon and Hughes, 1966). Fans have played a major role in the diversion of headwaters streams on low divides and are a major damming agent in the modern development of small and large lake basins (e.g. Pinguicula Lake, Fairchild Lake, etc.). Paludal and bog deposits of recent origin (Unit 3d), as opposed to glacial origin (Unit 2d), are often developed in morainic depressions, on the flood plain (especially the East Rackla River), and between fans or against fans butting against other features of higher relief. Streams regimens are low in valleys harbouring coalescing fans (e.g. Arctic Red River tributaries), and thus little flood plain, but the regimens can be high for those of the opposite set of conditions (e.g. Snake River). Regardless of the regimen, however, most major stream tributaries debouch a large fan into master valleys which suggests, at present, an equilibrium condition between the supply of the tributary and forces in the carrying capacity of the master river.

Other engineering ramifications of the above described deposits are the obvious use of the terraces, flood plain and fans as sources of construction aggregates and as an ideal surface for winter tote roads. One such road in the northwest corner of the map-area used extensive stretches of the Bonnet Plume flood plain as a means of route supply to a mining exploration venture. However, braided drainage areas in most valleys are the potential areas of icings and summer or permanent routes involving stream beds or river crossings will have to be carefully planned to avoid this hazard. Furthermore, in order to minimize transport-corridor washouts on fans, it is desirable to lay out routes near their apex of even those on the "underfit" valley floors.

Deposits of the Terrestrial Environment

An excellent appraisal of the significance of various mass wasting processes on the rate and manner of denudation of the northern Wernecke Mountains is given by Gray (1971). The following should be regarded as complimentary notes.

Extensive sheets of talus (Unit 3e) and individual talus cones are ubiquitous in alpine valleys, cirques and are not uncommon on especially north facing slopes of major valleys. Terminal protalus flatirons are a common secondary development and lobed, or swell and swale, profile on the surface of some is an additional precursor to the eventual development of lobate rock glaciers as suggested by Ricker (1968) and Gray (1968, 1969b, 1971); this will be discussed on subsequent pages. Talus cones are glaringly prolific in some cirques and those shown in the composite cirque east of Goz Pass are worthy of mention. Gray (1970, 1971) estimated a mean 3 to 17.3 cm. per millenium of rock face retreat (variable as to lithology) to account for the volume of talus cones located near Gillespie Lake in the adjacent Nash River map-sheet.

The map-area lies in a significant land slide region. At least four rock slides of major proportions (25-50 x $10^6 m^3$) have breached the modern flood plain lying below their zones of release and adjacent slopes are likely sites of renewed disruption. Wheeler (1954) described the slide that temporarily blocked the Bonnet Plume River on the eastern map boundary. The source of this slide is high on the valley wall in limestones with the slide plane parallel to the bedding plane on a limb of an asymmetrical and faulted anticlinal-synclinal pair of folds. House-sized debris completely overshot the river and rebounded off the opposite valley slope suggesting a rock-fall type of avalanche similar to the Hope and Frank slides of the southern Canadian Cordillera. The Bonnet Plume River was temporarily dammed but the spillway has since been re-entrenched and a terrace system now exists in the debris above valley base level. Another major rock slide located in the very centre of the map-area (east of spot el. 6955) illustrates another bedding plane release. Here, an alpine cirque underlain by a sequence of shale, dolomite, and quartzite was "beheaded" down to a slide plane surface that strikes subparallel but is steeper than the surface slope. Two unusual pits at the base of the release zone, in bedrock, have been scooped out and added to the debris which travelled 3 to 5 km. down a tributary valley. The debris deflected off an opposing slope after reaching a main valley and continued on a new course, down gradient, before finally coming to a halt. Again a stream was blocked but enough time has lapsed to permit a re-opening of a channel through the extensive but thin debris zone.

In the headwaters of Corn Creek there are two fresh rock slides. One was an airborne event because collapse of an arrête in one cirque basin caused debris to overshoot a rock glacier and a low saddle of the next arrête beyond, to land on the floor of the adjacent cirque. The majority of the debris, however, poured out of the mouth of the source cirque into the major valley beyond. The debris zones are very blocky and with high porosity as suggested by the presence of a dammed lake. The water surface is much below the non-channeled surface of the debris thus indicating subsurface drainage through the interstices. The rupture zone appears to be on a bedding plane in pelitic rocks. About 10 km. (6 miles) to the northwest of this slide the northwest flanks of Mt. MacDonald display another major slope failure which involves the complete removal of an arrête separating two cirques. A bedding plane slip in a sequence of shales, carbonates and quartzite appears to be the cause of collapse. Adjacent arrêtes of the same geologic setting are similarly poised. The valley below has been completely engulfed and there are ponds on the extensive debris surface. The valley lies above timerline and has not been glaciated since the McConnell Advance. Post slide gullying on the scarp suggests an event of Early Post Glacial timing.

A major rock slump lies near the northeast corner of the map-area on a tributary of the Arctic Red River drainage system. Surface corrugations on this mass suggest slow movement at present though other parts of the slide have stabilized as shown by a superposed drainage pattern. Again, the rupture surface appears to be parallel to bedding and adjacent slopes would be future suspect dislocation zones. The active component in this slide is unusual because in other nearby regions the debris of landslides, if moving slowly, would be transformed into rock glaciers (e.g. Tazin Range, Rackla Lake) but such glaciers are now dormant. Similar phenomena have been recorded to the west of this area in the Dawson map-sheet by Ricker (1968) and Gray (1968, 1971).

The foregoing descriptions and discussion have considered land slides involving dislocation of bedrock. There are, however, a few slides confined to movement of only surficial deposits; both types of slides are differentiated on the accompanying map.

A large slide developed in a talus zone near Duo Lakes exhibits large boulders carried down into the valley floor suggesting a process characteristic of an alluvione (mudspate). Wheeler (1954) reports a large mudslide adjacent to Rackla Pass and smaller debris slides are evident elsewhere in the map-area. Surficial deposits, especially those of laminated silt components are prone to slumps and one large rupture in such materials is evident just south of the map-area on the elevated floor of the Stewart River Valley.

The terrestrial geologic processes have many engineering considerations. Talus could make an excellent source of subgrade fill but Gray (1971) cautions of the frozen subsurface conditions in some which would entail expensive thawing procedures. This can be avoided by selecting non-vegetated areas favourable to solar radiation. Unless a protective berm or retainer wall is contemplated the placement of road or utilities should be kept well away from the toe of these features. Obviously, all studies on transportation and utility coriders in this map-area will have to assess in the field the various potentials for slides before preliminary designs are drawn up on the project. Failures on bedding planes appear to be a major instability in the region, but other causes or factors are likely to exist in the bedrock as well. Side valley outbursts of debris or mud as described and gelifluction of ground ice-bearing,unconsolidated, fine grain, sedimentary deposits on valley floors are other major hazards.

Deposits of the Eolian Environment

Loess sheets (Unit 4) are a typical development during and following deglaciation in the northern Cordillera. Ricker (1968) noted numerous veneers of such material in the Dawson map-sheet but the deposits were usually sporadic in extent and strongly reworked by solifluction thus masking easy recognition on aerial photos. Similar veneers can be expected on the Nadaleen River sheet and substantial thicknesses appear to be recognizable in the Arctic Red River basin on wide flood plains and adjacent broad areas of ground moraine. Sand dunes are not recognizable within the map-area.

PERIGLACIAL PHENOMENA

Landforms developed by periglacial processes are mapped to varying degrees of attention because of the diverse scale of features involved. Felsenmeer, nivation hollows and benches, patterned ground (pg), thermokarst or collapse pits (Th), palsa or string bogs and other hummocky or frost heaved features of massive or segregated ground ice require low level photography on a scale of 1:30,000 or larger in order to permit consistent readable delineation. The scale of photography used in this project is 1:50,000 and only in ideal circumstances can minor features be observed. Some are indicated on the accompanying map along with an almost complete delineation of the spectacular larger features.

Minor Slope Features

Solifluction of varying intensity has affected most slopes in the map-area. This thin veneer of surface disruption has been ignored in the mapping; yet one assumes, automatically, that is is present. Local areas of channelled soil flowage, slopes of intensive modification, or aprons of debris without an obvious large input by stream action ("solifluction fans") are denoted by map Unit P. North, northwest, and especially west-facing slopes are garnished with lobed solifluction features in which there has been no attempt to classify in the detail of this mapping. Ricker (1968) and Gray (1968, 1970) have studied these lobes, to the west of the map-area, in more detail with the latter investigator measuring significant amounts of yearly movement on a few. Wheeler (1954) noted the abundance of nivation landforms on the north and east slopes, and extensive felsenmeer above the 1740 m. (5700 feet) contour on cherty and slaty bedrock areas.

Construction projects on valley wall slopes are not recommended, and careful on-site examination of solifluction features is mandatory for all planning where the use of this environment cannot be avoided.

Valley Bottom Features

Thermokarst activity of lake shores located on morainal topography is evident but not as glaringly displayed as in the map-areas to the west.

Patterned ground (Sub-unit pg) as manifested by ice wedge polygons could be delineated in only a few upland valleys, but is surprisingly obscure on major valley bottoms. Bogs of the palsa and/or string type are not extensive and occur on the flood palin or morainal areas as entities usually too small to be mapped; some are included with Unit 3 (undifferentiated).

Pingo-like features, of non proven origin, are found in three major valleys: Bonnet Plume River flood plain near Fairchild Lake, Stewart River flood plain just south of the map boundary by only a few hundred metres, and perhaps in the Arctic Red basin near or within the former limits of the large McConnell moraine that is now the flood plain located a few hundred metres east of the map boundary. All of these pingos lack the diagnostic cratered summit, but Hughes (1969) noted about one third of the known pingos in the central Yukon to be also lacking this feature. The identification of the pingo in the Arctic Red system is in greater doubt because of a resemblance to surrounding morainal topography, but its location on the active flood plain is not conducive to preservation if it was a moraine. According to Hughes (1969), the distribution of pingos is sparse in the eastern Yukon because the overriding Late Wisconsinan Advance has somehow upset the ground temperature equilibrium that is necessary for their development. His distribution maps in the 1969 report show only a few pingos on the edge of this age of glaciated terrain and these are at Mayo (Fig. 1); for some unknown reason one in the Beaver-Rackla locality, 35 km. to the west of this study area, shown by Vernon and Hughes (1966, Map 1172A), is excluded in the 1969 report. The new localities, herein reported, are also within the limits of the McConnell Advance, but they have the topographic and geologic setting necessary for the evolution of the closed system type which, according to Hughes (1969), is a rarity in the central Yukon.

Rock Glaciers, Debris Covered Glaciers, Ice Cored Moraines, Glacierets and Other Transitional Forms

Vernon and Hughes (1966) have discussed the two types of rock-ladened glaciers that are common to the Ogilvie and Wernecke Mountains to the west of the map-area. Their mapping shows the number of these glaciers (s. lat.) to increase to the east which is certainly verified by this map compilation. Classic rock glaciers (s. stricto) are developed by the later or secondary invasion of moisture into porous rock rubble, followed by in situ ice transformation, and thereby creating a potential "plastic" media to promote down slope creep in a manner similar to typical ice glaciers. Rock glaciers with ice derived by glacial processes are the usual other form; they are usually developed through one or both of the following processes though other variables are known to exist. Glacier ice of normal or primary origin, can subsequently or simultaneously be modified by the copious additions of surface rock debris on an annual and sometimes cataclysmic basis. Or, during movement of a small but stagnating glacier in a sheltered area, the ice volume is reduced by evaporation, sublimation and mechanical disintegration, while debris is incorporated along shear planes and other surfaces through subglacial and englacial sources. In either process the ice is a primary event and hence, the terminology: rock-ladened glaciers, debris covered glaciers, dying glaciers, debris-loaded glaciers, buried glaciers, relict glaciers, etc. Roots (1954) noted both types in the Omineca Mountains of British Columbia and after careful study suggested that the distinction between felsenmeer, talus ridges, secondary and primary rock glaciers is clear without overlap or intergradation. Gray (1971) made in the Nash Creek map-area an extensive study of both kinds of these glaciers and found that in surficial appearance, the rock glacier of primary ice origin can have the replicate features of a secondary ice or classical type in form, size and distribution, despite the criteria used by Vernon and Hughes (1966) to differentiate the two. Hence, Gray prefers to abandon the old classification in favour of valley-wall and cirque-floor glacier types and noting that the latter are usually of the primary glacier ice origin. However, in order to keep the mapping consistent with the Vernon and Hughes (1966) publication, the writer used their criteria in an attempt to distinguish, not totally successful, the various types, using their Plate VII[1] and VIII (rock glaciers north of Gillespie Lake in the Nadaleen River map-area) as the working model. In addition, the activity status of the secondary ice-derived rock glaciers was determined by utilizing the criteria of Wahrhaftig and Cox (1959). Where the type or activity could not be determined the undifferentiated rock glacier (RG) has been so designated on the map.

Gray (1968, 1969b, 1971) and Ricker (1968), in nearby study areas, discovered a gradational series of talus cones to protalus flatirons to lobate rock glaciers of secondary ice. The compilation of these features for

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1 The north arrow on Plate VII (<u>in</u> Vernon and Hughes, 1966) is reversed in error.

the Nadaleen River sheet was confronted with a continual, difficult, and arbitrary decision to be made on the distinction of each kind of feature in this gradational series. On this aspect Wahrhaftig and Cox (1959) describe the sequential development of rock glaciers in the above mentioned series. Ricker (1968) and Gray (1968, 1971) also noted the development of rock glaciers on old landslide debris zones in the Dawson map-area, and in the current study a few of these combinations are mapped. Foster and Holmes (1965) describe a transitional rock glacier in the Alaska Range which appears to be of primary and secondary ice origin which would be contrary to Roots' (1954) theory. Ricker, (1968) reviewed all the known methods of rock glacier evolution and after application to those features of the Dawson area, developed a proposal that a continuim of gradational and similultaneous action of some of these different processes can contribute to the development of a rock glacier of complex multiple origins. Gray (1971) in follow-up detailed studies, arrived at much the same conclusion as well for those rock glaciers in the Nash Creek map-area.

Within the Nadaleen River map-area the following combination and sequences of "glacier" are present:

1) active, dormant and re-activated lobate (often too small to be mapped), tongue-shaped (widespread) and spatulate (very large but rare) rock glacier with ice of secondary derivation;
2) active rock glaciers of the above forms overriding the upper zones of a debris covered glacier (primary ice) - e.g. NW of Reptile Creek;
3) debris covered glaciers (primary ice) overriding rock glaciers of secondary ice as reported in Vernon and Hughes (1966) - e.g. Tazin Range, south of Bonnet Plume Lake in the Nadaleen Range;
4) coalescence of lobate rock glaciers (secondary ice) with primary ice derived rock glaciers - e.g. 12 km. SW of Bonnet Plume Lake;
5) valley glaciers of relatively debris-free ice with an almost or completely detached end moraine - e.g. Corn Creek headwaters;
6) moraines in case #5 (above) with ice cores or interstitial ice which appear to be moving down slope away from the up-valley glacierets with intervening distances now as much as 2000 to 2300 metres in separation [1] - e.g. near landslide on Bonnet Plume

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1 Dr. Blusson (pers. comm.) has observed a similar circumstance about 20 km. east of Cantung (Fig. 1).

River, headwaters of Corn Creek, Reptile Creek, Algae Mountain;

7) valley glacier or cirque glacieret without moraine of any type e.g. headwaters of Corn Creek, north of Reptile Creek.

8) ubiquitous distribution of the series of talus to protalus to lobate rock glaciers of secondary ice;

9) rock glaciers of secondary ice origin in landslide debris areas e.g. Rackla Lake, Stewart Valley;

10) debris lobes, planar on upper surfaces in a few, either without diagnostic characteristics or sometimes with conflicting characteristics, thus preventing identification of the type of glacier or the process(es) responsible for their evolution; these are marked "RG" on the map as are those glaciers hidden on the shaded portions of the photographs - e.g. Goz Pass area.

Of the rock glaciers of secondary ice derivation, the majority appear to be active at present (using the criteria of Wahrhaftig and Cox, 1959); though those at lower elevations, on a southerly exposure, are more likely to be inactive. According to Wahrhaftig and Cox (1959) inactive rock glaciers are of Early Neoglacial development or older, whereas the higher elevated active forms have grown with the onset of the "Little Ice Age" or Late Neoglacial event. Gray (1969a, 1971) recorded movements of a few centimetres per year for a few rock glaciers (of secondary ice type) in the adjacent map-area and concluded that such a slow rate of movement could be accommodated only if the presently active features were evolved in Early Neoglacial times. Lichenometry by Gray, as previously discussed, was also used as a supporting tool to project this time span.

Glaciers of primary ice, whether debris-loaded or not, also appear to have a variety of regimens despite their usual northerly and easterly exposures. Some are waning judging by the nearly detached and downwasted relationship to their high terminal moraine or by the development of huge surface pits (300 m. in diameter) or zones of firn-free ice now located much below fresh trim lines. Others of the extensive debris covered type have no downstream moraine and are actively overriding other land forms. However, in a few cirques very fresh hummocky terrain (Unit 2c) suggest the recent disappearance, in total, of a debris covered glacier. Rates of movement of debris covered glaciers are greater than those of the other end member in the rock glacier series because of their two to three fold higher proportion of ice. Local velocity measurements are few.

Gray (1971) measured a maximum surface rate of 11 cm/yr for one glacier near Dawson but Hughes (1966) and Blusson (1968) recorded an overall advance of about a metre or more per year (while a superposed kinematic wave moved at a rate of several fold greater) on a similar style of debris covered glacier located at Canada Tungsten Mine Ltd., some 300 km. (190 miles) southeast of the map-area. Rates for those of the Alaska Range are intermediate to the above cited examples (Wahrftig and Cox, 1959) and the writer suspects that this will be the case for those within the Nadaleen River map-area.

Of several unusual features worth noting about rock glaciers in this study, the most outstanding examples of either type are found fully engulfing the floors of cirques in the northeast corner of the map-area. Tarns have been developed along their edges in a manner similar to ice dammed lakes. In the previously mentioned "type" chronology area, the Arctic Red tributary valley, the long, debris-covered, valley glacier is currently detached from two of its three source areas in a composite cirque. Various crevasse patterns are visible on the surface despite the masking debris load. Another glacier located at the mouth of Reptile Creek is completely "pitted" from ridge top to valley floor as if an icefall crevasse pattern has been modified by the debris cover and has in turn developed an unusual ablation pattern.

Rock glaciers (s.lat.) warrant a consideration with regard to the development of transportation and utility routes. Obviously routes should not be anchored on a glacier regardless of the state of present activity, and those developments located below valley draped tongues of such could be eventually engulfed, though the exceptionally slow rate of movement allows for ample time to carry out remedial measures - even if the damming of a river becomes a distinct threat. As a precaution, rock glaciers of obstruction potential should be monitored for velocities throughout the duration of the life of the facility being considered.

MIXED AND UNDIFFERENTIATED DEPOSITS

Map Unit Ud denotes surficial deposits of colluvial, mass wasting and other origins which mantle and mask the character of the underlying deposits. The unit can also include exposures of minor amounts of any of the deposits noted in the legend but are not differentiated due to map scale considerations. Undoubtedly, expansive but thin veneers of ground moraine have been mapped under this unit because near surface bedrock or secondary erosional processes have masked their typical air photo characteristics - the boundary between map Units "Ud" and 1b or 3e (talus) is an arbitrary decision and in many cases the uniformity of definition from valley to valley cannot be guaranteed on the accompanying map. Wheeler (1954) recorded an upper "drift limit" of 1430 m. (4700 feet) above mean sea level for Goz Valley; according to the present interpretation, much of this "drift" is of mixed origin and could be extended to elevations of 1700 m. (5700 feet).

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