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**University of Alberta**

# LATE CENOZOIC HISTORY OF MCQUESTEN MAP AREA, YUKON TERRITORY, WITH APPLICATIONS TO PLACER GOLD RESEARCH

by

Jeffrey David Bond ©

A thesis submitted to the Faculty of graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

Geomorphology

Department of Earth of Atmospheric Sciences

Edmonton, Alberta
Spring 1997

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## Abstract

The late Cenozoic history of McQuesten map area is characterized by progressively less extensive glaciations and deteriorating interglacial climates. The glaciations, from oldest to youngest, are the pre-Reid (a minimum of two early to mid Pleistocene glaciations), Reid (>200 ka), and McConnell (<29.6 ka BP). Pre-Reid interglacial reconstructions suggest a much warmer and more humid climate than today. The Koy-Yukon interglacial (200 ka) is considered to have a climate similar to a southern boreal forest and the first intact Diversion Creek paleosol, from this period, is documented in the McQuesten River valley. The Stewart neosol (Holocene) is widespread and poorly developed in comparison to past interglacial soils.

The distribution of surficial deposits, related to multiple glaciations, physiography, and fluvial order contrasts, may govern the distribution of placer gold occurrences in the study area. Placer deposits occur anomalously in areas outside the pre-Reid limit on Klondike Plateau, and on Stewart Plateau. Further exploration in McQuesten map area should reassess the placer potential of Klondike Plateau, within the pre-Reid ice limits.

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And now for something slightly different...

## Table of Contents

Pg

Chapter

1 INTRODUCTION........1
2 PREVIOUS RESEARCH........4
3 REGIONAL FRAMEWORK........7
    Physiography........7
    Geography........9
        Climate........9
        Drainage........12
        Permafrost and Soils........13
        Vegetation........17
    Bedrock and Tectonics........18
    Surficial Geology........21
    Glacial and Interglacial Geology........23

4 METHODOLOGY........28
    Surficial Geology........28
    Stratigraphy and Sedimentology........30
    Paleomagnetism........31
5 LATE CENOZOIC GEOLOGY OF MCQUESTEN MAP AREA........33
    Pre-Glacial Drainage........33
    Glacial and Interglacial Record........36
        Pre-ReidGlaciations........37
        Pre-Reid Interglaciations........48
        Reid Glaciation........53
        Koy-Yukon Interglacial........56
        McConnell Glaciation........71
        Holocene Interglacial........66

6 STRATIGRAPHY........69
        Flat Creek Section........79
        Stirling Bend Section........97
        Ash Bend Section........102
        New Crossing Section........109
        Vancouver Creek Section........113
        McConnell End Moraine Section........117

7 DISCUSSION/SUMMARY........122

8 APPLICATIONS........134
    Mining Exploration........134
    Placer Exploration........136

Natural Hazards....................................................................................138
Granular Deposits.................................................................................138

9 CONCLUSIONS.......................................................................................141

REFERENCES...............................................................................................144

Appendix I: Description of Surficial Geology Units...................................................153

Appendix II: Lithostratigraphic unit descriptions.........................................................161

## List of Tables

Table 1: Discharge of Stewart, McQuesten, and Little South Klondke Rivers............2

Table 2: Summary of soil morphologies from the Wounded Moose Paleosol................77

Table 3: Plant and Insect Macrofossils from Stirling Bend Unit 6..............................96

Table 4: The soil morphological features of paleosol at Vancouver Creek and the Diversion Creek paleosols.........................................................................116

## List of Figures

Figure 1: Physiography of Yukon Territory and location of McQuesten Map area (after Bostock 1970)....2

Figure 2: McQuesten map area....8

Figure 3: Topographic profile across McQuesten map area....10

Figure 4: Permafrost ditribution in Yukon Territory....14

Figure 5: Collapsed Open-Sytem Pingo....16

Figure 6: Geology of McQuesten Map area....19

Figure 7: Surficial Geology Map of McQuesten Map area....folder

Figure 8: Block Diagram of Pre-Reid Glaciation....24

Figure 9: Block Diagram of Reid Glaciation....25

Figure 10: Block Diagram of McConnell Glaciation....26

Figure 11: Glacial Limits in McQuesten Map area....27

Figure 12: Preglacial Drainage of Southern Yukon....34

Figure 13: Preglacial Drainage of McQuesten map area....35

Figure 14: Pre-Reid Ice Flow Patterns in McQuesten map area....39

Figure 15: Cryoplanation terraces and block fields on the White Mountains....40

Figure 16: Tors on the Willow Hills....41

Figure 17: Pre-Reid lateral moraine - Stereopair....42

Figure 18: Pre-Reid meltwater channel at the headwaters of Fory Mile Creek....44

Figure 19: Pre-Reid meltwater channel in Willow Lake valley....45

Figure 20: Pre-Reid meltwater channel dissecting the Willow Hills - Stereopair....46

Figure 21: Four phases of floodplain development in Tintina Trench - Stereopair...........49

Figure 22: Reid cirque on West Ridge...........50

Figure 23: Wounded Moose paleosol with sand wedge cast...........52

Figure 24: Reid Ice Flow Patterns in McQuesten map area...........54

Figure 25: Reid end moraine - Stereotriplet...........55

Figure 26: Reid age glaciofluvial terraces in the McQuesten River valley...........57

Figure 27: Aeolian ridges in Reverse Creek valley - Stereotriplet...........59

Figure 28: Vancouver Creek section and paleosol (Diversion Creek paleosol)...........60

Figure 29: McConnell Ice Flow Patterns in McQuesten map area...........62

Figure 30: McConnell end moraine - Stereopair...........63

Figure 31: McConnell glaciofluvial terrace on Stewart River...........64

Figure 32: McConnell glaciofluvial terrace in South McQuesten River valley ...........65

Figure 33: Ground Squirrel bones from Stirling Bend...........67

Figure 34: Location of Flat Creek section...........70

Figure 35: Flat Creek section sedimentology...........71

Figure 36: Composite photograph of units 1 - 4 at Flat Creek section...........72

Figure 37: Paleomagnetism diagrams from unit 1 at Flat Creek...........74

Figure 38: Paleomagnetism diagrams from Dawson (Froese collection)...........75

Figure 39: Stratigraphy of pre-Reid units relative to the paleomagnetic time scale...........76

Figure 40: Location of sections studied in McQuesten map area...........80

Figure 41: Stirling Bend section with stratigraphy...........81

Figure 42: Stirling Bend section sedimentology at 740 m...........82

Figure 42: Stirling Bend section sedimentology at 740 m....82

Figure 43: Units 1 and 2 at Stirling Bend....83

Figure 44: Paleomagnetism diagrams from unit 2 at Stirling Bend....85

Figure 45: Unit 3 at Stirling Bend....87

Figure 46: Stirling Bend sedimentology at 40 m....88

Figure 47: Unit 4 at Stirling Bend....89

Figure 48: Paleomagnetism diagram from unit 4 at Stirling Bend....91

Figure 49: Stirling Bend sedimentology at 240 m....92

Figure 50: Stirling Bend sedimentology at 640 m....94

Figure 51: Stirling Bend Organics (unit 6)....95

Figure 52: Paleomagnetism diagram from unit 6 at Stirling Bend....98

Figure 53: Units 4 and 7 at Stirling Bend....100

Figure 54: Ash Bend section on Stewart River....103

Figure 55: Ash Bend sedimentology....104

Figure 56: Mammoth tusk from Ash Bend....106

Figure 57: Sheep Creek tephra in Ash Bend organic deposit....108

Figure 58: New Crossing sedimentology....110

Figure 59: New Crossing section on Stewart River....111

Figure 60: Cobble sequence at top of Vancouver Creek section....115

Figure 61: McConnell End Moraine sedimentology....119

Figure 62: McConnell outwash and till at the end moraine section....120

Figure 63: Stratigraphic correlations diagram....123

Figure 64: Glacial Limits and Ice Flow Patterns for central Yukon ..... 125

Figure 65: Yukon stratigraphic correlations ..... 129

Figure 66: Stabilized slumps on Stewart Plateau near Scheelite Dome - Stereopair ..... 139

## List of Maps

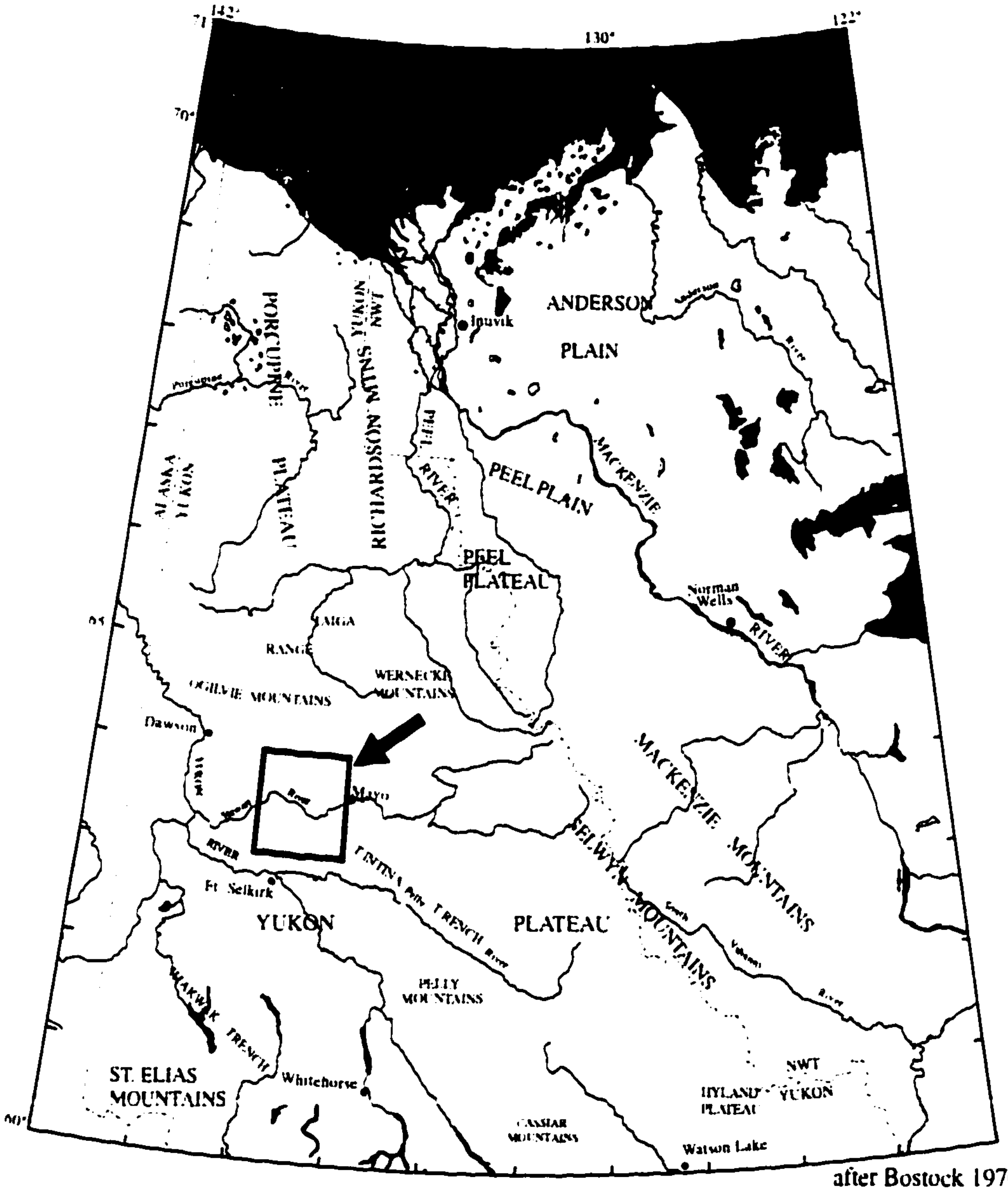
Surficial Geology, McQuesten (115P) ..... in folder

## CHAPTER 1

## INTRODUCTION

The last glaciation, in the Canadian Cordillera, was often the most extensive, resulting in erosion and reworking of older surficial sediments. Consequently, reconstructing late Cenozoic environments is often limited to events that have occurred during the last 30,000 years. Deposits from earlier glaciations and interglaciations are identified in section, however, such windows offer a limited regional view of paleoenvironmental history. In McQuesten map area, central Yukon, late Cenozoic glaciations were progressively less extensive, allowing older glacial deposits to be preserved (Figure 1). This presents an opportunity to compare glaciations and the morphological characteristics of landforms of different ages. In addition, a record of post depositional climatic weathering is preserved on the older surfaces, which offers insights concerning the nature of interglaciations (soil development) and glaciations (periglacial features) that followed.

Bostock identified multiple glacial surfaces in the McQuesten map area during bedrock mapping in the 1940s ( Bostock, 1966). His observations were confirmed by Hughes *et al.* (1969, 1972, 1983, and 1987). In central Yukon, these glaciations are now referred to as pre-Reid (oldest), Reid, and McConnell (youngest). Studies by Jackson (1989, 1990, 1994, and 1995) in the Pelly Mountains and Carmacks map area, and more recently by Duk-Rodkin and Barendregt (1997) and Froese *et al.* (1997) around Dawson, confirm an extensive late Cenozoic record for central Yukon.



after Bostock 1970

Figure 1: Physiography of Yukon Territory and location of McQuesten map area

Numerous paleosol investigations on Reid and pre-Reid surfaces in McQuesten map area have provided details regarding interglacial and glacial conditions. The paleosols are referred to as the Wounded Moose, Stirling Bend, and Diversion Creek paleosols and represent at least two interglacial periods (Foscolos *et al.* 1977; Rutter *et al.* 1978; Smith *et al.* 1986; and Tarnocai *et al.* 1985). Surficial geology investigations in McQuesten map area were initiated by Hughes and Duk-Rodkin in 1983. Their objectives were to describe glacial deposits and limits associated with multiple glaciations while mapping the surficial geology. Much of their mapping, however, was restricted to the Reid glacial limit. The pre-Reid glacial limit was intermittently mapped by Bostock (1966) and Hughes (1969), however, the overall extent of pre-Reid ice was not well documented. To fully document the late Cenozoic record in McQuesten map area, the composite stratigraphy of all glacial and interglacial units needs to be compiled, in addition to, the surficial geology and glacial limits.

This study has two objectives. Firstly, to document the late Cenozoic history contained in McQuesten map area (Figure 1). This will be approached through analysis of both the geomorphology and general sedimentology of each glaciation and interglaciation represented in the study area. This is based on regional surficial mapping and logging river and road cuts. The surficial mapping focuses on pre-Reid terrain. The second objective involves the application of glacial geology to mineral exploration in study area. Applications to both hard rock and placer gold exploration will be considered.

# CHAPTER 2

# PREVIOUS RESEARCH

In the summer of 1901, R.G. McConnell examined the geology along the lower reaches of Stewart River and Tintina Trench where he focused on bedrock and placer geology. McConnell made the first glacial descriptions in the area, noting the late Wisconsinan moraine in Stewart River valley, later named the McConnell glaciation.

In 1936, Bostock studied Carmacks map sheet and included numerous observations about glaciation. Bostock noted older deposits beyond the McConnell limit, providing the first evidence for multiple Pleistocene glaciations in Yukon. In 1948, while conducting geologic mapping in McQuesten map area, Bostock included evidence for at least two Pleistocene glaciations. Bostock (1948) also described the physiography of the Canadian Cordillera, referring to the Yukon Plateau, Stewart and Klondike plateaus, and Tintina valley. In 1966, Bostock defined limits for multiple glaciations during the Pleistocene in central Yukon. The glaciations from oldest to youngest were named the Nansen, Klaza, Reid and McConnell.

Hughes *et al.* (1969) compiled the glacial limits and flow patterns, south of 65° in Yukon. In this compilation, the Nansen and Klaza glaciations were grouped as the pre-Reid glaciations based on difficulties differentiating the older surfaces beyond the Reid limit. Hughes and Duk-Rodkin initiated surficial mapping of the McQuesten area in 1983; concentrating inside the Reid glacial limit.

Geologic research continued in the 1960s and 1970s in surrounding map areas.

McTaggart (1960) compiled the geology of Keno and Galena Hills, the most important lode deposits in the territory at the time, prospering in the development of silver, lead and zinc. A number of studies concerning the geology and geochemistry of the Keno Hill-Galena Hill areas were completed from the 1950s to the 1970s (Boyle 1955, 1965; Boyle *et al.* 1955; Gleeson and Boyle 1976). Surficial mapping was initiated in the Ogilvie Mountains during Operation Ogilvie (1961), when the Nash Creek, Larson Creek and Dawson map sheets were investigate (Vernon and Hughes 1966). Green (1971) studied the Mayo Lake, Scougale Creek, and McQuesten Lake map areas.

Central Yukon, and specifically McQuesten map area, has been the focus of numerous pedological investigations aimed at differentiating glacial surfaces and understanding past climates (Rutter *et al.* 1978, Tarnocai *et al.* 1985; Smith *et al.* 1986; Tarnocai and Smith 1989; Tarnocai 1990; Tarnocai and Schweger 1991). Field excursions to central Yukon during the I.G.C. in 1972 and INQUA in 1987 included the McQuesten glacial surfaces and their associated paleosols.

Recent Quaternary research has been carried out by Morison (1983) on the placer deposits at Clear Creek and Fuller (1994) on the Stewart River terraces. The surficial geology and stratigraphy of the Carmacks map sheet was studied by Klassen *et al.* 1987, Ward (1989), and Jackson (1996). Jackson (1989) and Jackson *et al.* (1990 and 1996) studied subglacial volcanic deposits and magnetostratigraphy at Fort Selkirk on the Yukon River (Figure 1). The Fort Selkirk paleomagnetic data and tephra samples, separating pre-Reid sediments, provided the first dates on these older glaciations. The older pre-Reid glaciation at Fort Selkirk occurred between 1.60 Ma and 1.07 Ma (Jackson *et al.* 1996). The younger pre-Reid glaciation at Fort Selkirk occurred during the late Matuyama after 0.99 Ma (Jackson *et al.* 1996). Ward (1993) completed the Quaternary geology of Glenlyon map area and Giles (1993) studied the Quaternary sedimentology and stratigraphy of McConnell and Reid age sediments near Mayo. Jackson (1994) compiled the terrain inventory and Quaternary history of the Pelly River area, southeast of McQuesten map area. Duk-Rodkin (in preparation) completed the surficial geology of the Dawson map area and is currently revising glacial limits for Yukon Territory. Froese *et al.* (1997) is currently studying the stratigraphy and sedimentology of high level terraces along the Klondike River near Dawson.

# CHAPTER 3

# REGIONAL FRAMEWORK

## Physiography

McQuesten map area lies within the Yukon plateaus and consists mainly of three physiographic features: Stewart Plateau, Klondike Plateau, and Tintina Trench (Figure 2; Bostock 1966). Stewart plateau is a rolling upland surfaces ranging from 1067 m to 1829 m a.s.l. and is dissected by northeast-southwest valleys (Figure 2). Valley bottoms are less than 457 m a.s.l. The topography of the Stewart Plateau rises north towards the Ogilvie Mountains. On Stewart plateau, north of McQuesten River valley, local uplands (Syenite Range, West Ridge, East Ridge, and Red Mountain) exceed 1676 m and cirques are present at the headwaters of many drainages. Beyond the cirques, the drainages take on a V-shaped profile. Areas within recent glacial limits have broader valleys, whereas older glaciated terrain have steeper slopes and narrower valleys. South of McQuesten River, the Stewart Plateau is more continuous and has gentler summits. Block faulting has also contributed to the physiography between McQuesten River and Stewart River. The broad valleys south of McQuesten River are likely a product of tectonics, the late Tertiary paleodrainage, and glacial overdeepening.

Klondike Plateau, like Stewart plateau, represents an erosional surface that was raised and incised during the late Tertiary. The present surface is a broad upland with elevations ranging from 762 m to 1676 m. White Mountains, Willow Hills, and Ice

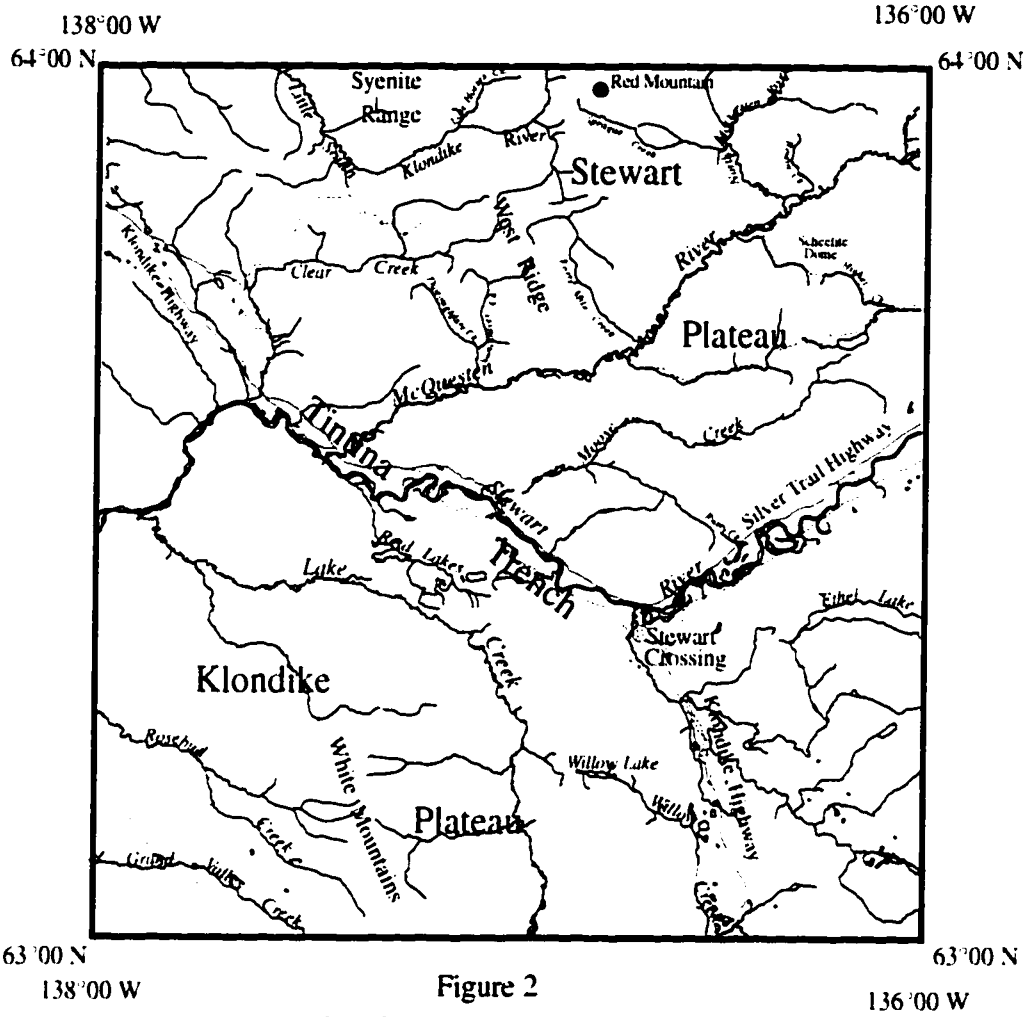
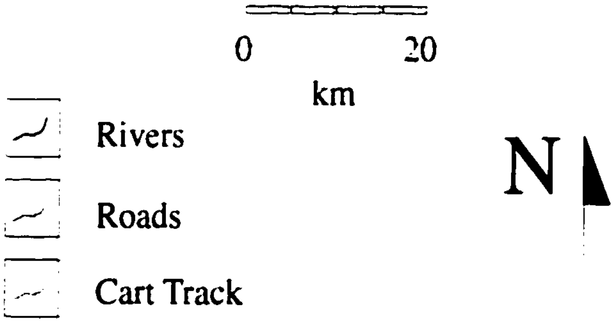


Figure 2
McQuesten Map Area
Yukon Territory



Chest Mountain are the major uplands on Klondike Plateau in McQuesten map area. The orientation of uplands and valleys is northwest-southeast, similar to the Tintina Trench. Valleys are broad and generally have low gradients. Drainages on Klondike plateau are locally derived and generally are low order streams.

Tintina Trench forms a broad valley between the Stewart and Klondike plateaus (Figure 2). The trench widens from 4 km in the southeast to 16 km in the northwest (Figure 2). This Pliocene graben formed along an early Tertiary strike-slip fault, which has undergone 450 km of dextral displacement (Templeman-Kluit 1980). Tintina Trench is the lowest topographic region in the map area, with an average elevation of approximately 457 m. The trench captures much of the drainage on Stewart Plateau and acted as a major conduit for glacial ice.

The change in physiography between Klondike and Stewart plateaus is shown on the topographic profile extending from Grand Valley Creek in the southwest to Red Mountain in the northeast (Figures 2 and 3). The Klondike Plateau is characterized by isolated highlands and deep, broad valleys with low gradients. In contrast, Stewart Plateau has steeper terrain with narrower drainages, hence greater relief.

## Geography

### *Climate*

Yukon is located in the Cordilleran climatic region and is broadly characterized by a sub-arctic continental climate, with long cold winters and short warm summers

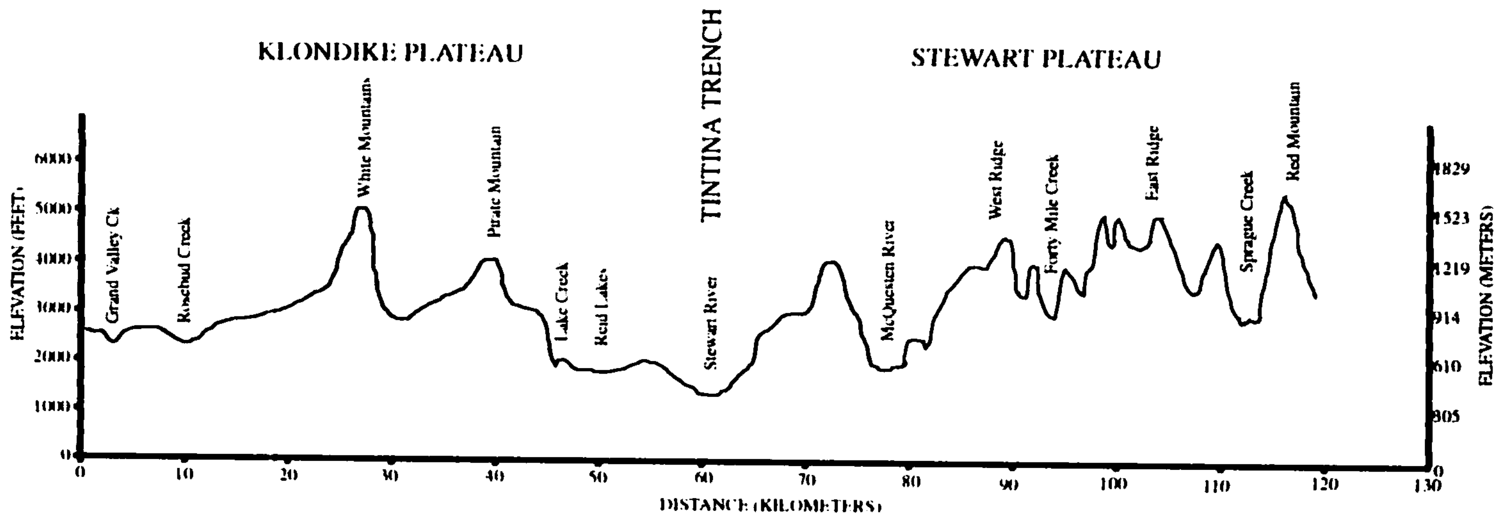


Figure 3: Topographic Profile across McQuesten map area. Profile extends from the southwest corner to the northeast corner.

(Wahl *et al.* 1987). Yukon climatic parameters have a high mean annual range of temperature, and the central Yukon basin is the most continental region in the territory.

In Mayo, the highest temperature ever recorded was 36.1° Celsius and the lowest temperature recorded was -62.2° Celsius (Wahl *et al.* 1987). Temperature variation within a single month can also be highly variable. Mayo shows a February temperature range of more than 74° Celsius from 12.2° Celsius to -62.2° Celsius between years (Wahl *et al.* 1987).

The primary source of storms affecting Yukon is in the Gulf of Alaska. Most precipitation falls on the St. Elias-Coast Mountains causing a rain shadow in southern and central Yukon. Annual precipitation ranges between 300 mm and 400 mm in central Yukon with most falling in the summer (Wahl *et al.* 1987). Central Yukon is considered a semi-arid climate, however, relative precipitation can be highly variable. In Mayo, July precipitation has ranged from 9 mm to 108 mm.

Winds tend to be light with a high percentage of calm conditions in winter due to persistent anticyclones (Wahl *et al.* 1987). The mean annual wind speed at Mayo is 5.8 km/hr, compared to Whitehorse which has a mean annual wind speed of 14.1 km/hr. Anticyclones affect Yukon in the winter months and are most extreme above the deep Yukon valleys. The resulting inversions trap arctic air in low lying areas which maintains cold temperatures. At higher elevations, above the inversion, animals such as caribou and moose respond to this temperature difference and migrate to higher elevations during extreme cold periods (Wahl *et al.* 1987).

***Drainage***

McQuesten map area is part of the Yukon River drainage basin. Stewart River flows through the middle of the study area and is the largest drainage incorporating 85% of the area (Figure 2). The remaining 15% is Klondike River drainage to the north. Other important drainages include McQuesten River, Little South Klondike River and Lake Creek (Figure 2). Drainages on the Stewart plateau are part of major systems that drain the Selwyn and Ogilvie Mountains and are typically larger than drainages on the Klondike plateau.

The mean monthly discharge ($m^3$/second) of three major drainages in the map area is outlined in Table 1:

**Table 1**

Stewart River (at Stewart Crossing):

| Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 62.7 | 53.7 | 50.0 | 56.1 | 61.5 | 1720.0 | 914.0 | 601.0 | 489.0 | 260.0 | 121.0 | 84.8 |

-mean yearly discharge of 415 $m^3$/second

McQuesten River (at mouth):

| Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.1 | 6.9 | 6.76 | 10.2 | 116.0 | 107.0 | 49.4 | 37.3 | 39.2 | 29.0 | 16.5 | 10.4 |

-mean yearly discharge of 35.9 $m^3$/second

Little South Klondike River:

| Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.3 | 1.1 | 1.1 | 1.6 | 25.1 | 21.6 | 8.0 | 8.7 | 7.5 | 4.0 | 2.4 | 1.7 |

-mean yearly discharge of 7.04 $m^3$/second

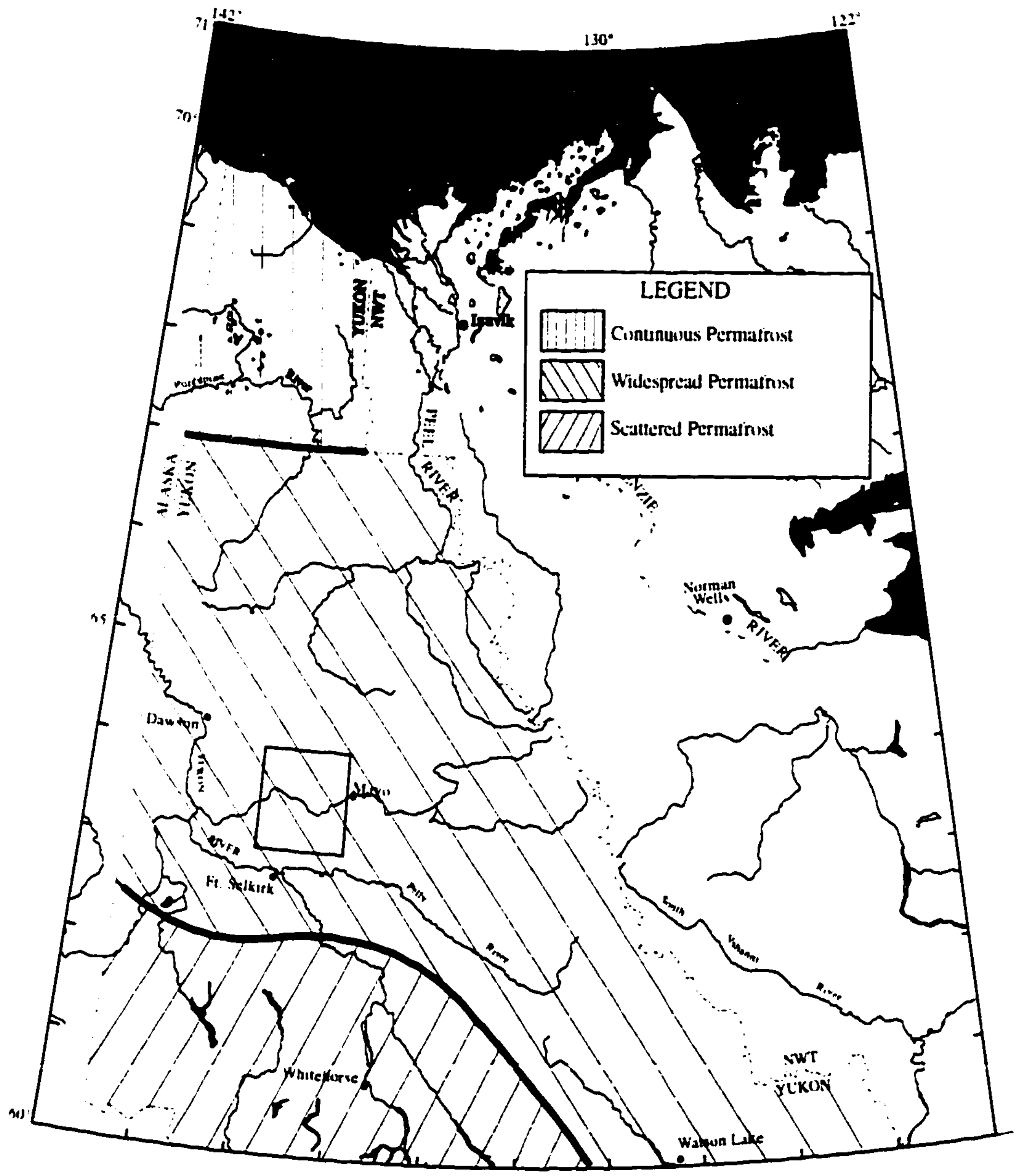
Inland Waters Directorate 1991

Maximum discharge in Stewart River is delayed to June and July because its drainage basin is larger, more distant, and includes terrain of higher elevation with snow in the Selwyn Mountains. Peak discharge occurs in May and June for the McQuesten and Little South Klondike drainages because the snow pack and ground ice, within these drainages, is susceptible to earlier melting than is much of the Stewart River drainage.

River morphology in McQuesten map area includes transitions between scroll-like meanders and confined meanders. On Stewart River, within the limit of the last glaciation, meanders appear confined between thick accumulations of glacigenic sediments. Beyond the McConnell limit, the floodplain is wider and the Stewart River takes on scroll or serpentine meanders. In Tintina Trench, Stewart River appears to vary between confined and scroll meanders and becomes a confined meander system upon leaving the trench and entering Klondike plateau. Numerous drainage anomalies occur in the study area and include those redirected by former glaciers. Some of the more prominent anomalies include the diversion of Robbed Creek into the Pirate Creek drainage; the diversion of Reverse Creek into Moose Creek; the Stewart River diversion away from Tintina Trench and onto the Klondike Plateau and the diversion of Minto Creek into the Mayo River (Figure 2).

### *Permafrost and Soils*

Yukon Territory spans the scattered, widespread, and continuous permafrost zones (Figure 4; Brown, 1978). The regional distribution of permafrost is largely controlled



(after Brown 1978)

Figure 4: Permafrost distribution in Yukon Territory

by latitude and climate. Whereas local permafrost variations are controlled by surface sediments, soil moisture, aspect, and snow depth (Burn 1987). McQuesten map area lies within the limits of widespread or discontinuous permafrost (Figure 4). Permafrost is found on north-facing slopes, on highlands above 1372 m a.s.l., and in poorly drained mesic valley bottoms. Features such as sorted polygons and solifluction indicate permafrost conditions at high-elevations. Xeric south-facing slopes are generally permafrost-free up to 1371 m a.s.l. Outwash terraces along Stewart River and Tintina Trench are generally dry, well drained, and permafrost-free. Fine grained deposits on outwash terraces, represented by organic deposits or fenlands, may contain permafrost.

Permafrost conditions in lowlands are sometimes evident by the formation of pingos. Hughes (1969a) identified over 460 open-system pingos in central Yukon in glaciated and unglaciated terrain. Most pingos developed in unglaciated terrain or on pre-Reid age surfaces. In McQuesten map area, sporadic open-system pingos occur within both the Reid and pre-Reid limits (Figure 5).

A brunisolic soil, also referred to as the Stewart Neosol, is the dominant soil in the study area. Solum thickness ranges from 37 to 49 cm; it contains limited pedogenic weathering and little to no illuviated clay or other soil structures (Tarnocai *et al.* 1985). Soils on north facing slopes at high elevations, however, exhibit cryosolic characteristics (Tarnocai 1987).

Figure 5: Collapsed open-system pingo near the North McQuesten River. Pingos are a good indicator of ground ice, but overall are infrequent on glaciated terrain. The hydraulic flow that created the pingo is from a slope to the left of the photograph. A second pingo is present in the background.

### *Vegetation*

McQuesten map area lies within the boreal northern Cordillera and subalpine northern Cordillera ecoclimatic provinces and within the Klondike River, Pelly River, and Mayo Lake-Ross River ecoregions (Ecoregions Working Group 1989; Oswald and Senyk 1977). The region is dominated by a northern mixed deciduous and coniferous forest. Black spruce (*Picea mariana*), sedges, and sphagnum tussocks are common on poorly drained sites in valley bottoms (Oswald and Senyk 1977). White spruce (*Picea glauca*), aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), and less commonly lodgepole pine (*Pinus contorta*) dominate well-drained areas in valley bottoms. Lodgepole pine and aspen are common on eolian deposits. A combination of aspen, grasses, and white spruce are common on south-facing slopes. Boreal species such as black spruce, white spruce and paper birch dominate north-facing slopes. Subalpine regions consist of willows, shrub birch, and alpine firs (*Abies lasiocarpa*) at treeline (1372 m a.s.l.). Minor variations in treeline occur with aspect and surficial materials. Ericaceous shrubs, willows, shrub birch, lichens, and mosses are common in alpine regions. Feathermoss, willows, shrub birch, and ericaceous shrubs are common in the under story of coniferous stands. A sagewort grassland with several forbs are found in the under story of aspen stands on steep south-facing slopes (Oswald and Senyk 1977). Alder (*Alnus* sp.) and willows are locally common along drainages. Aspen, balsam poplar (*Populus balsamifera*), willow, and fireweed (*Epilobium angustifolium*) are associated with disturbed sites.

## Bedrock and Tectonics

The geology of the study area includes three main facies: North American strata, Yukon-Tanana Terrane, and post-accreted intrusive strata (Gabrielse et al. 1977, Templeman-Kluit 1979 and Wheeler and McFreely 1991; Figure 6). The Tintina Trench separates North American strata from Yukon-Tanana Terrane forming a prominent regional physiographic lineament (Figure 6). Tintina Trench is a Pliocene graben that formed along a mid to late Cretaceous strike-slip fault. Strata along Tintina fault are regionally offset by as much as 450 km (Templeman-Kluit 1979; Figure 6). More recent mapping (1:50,000) was undertaken in the northern part of the area in conjunction with geologic mapping (1:250,000) of the Mayo area to the east (Murphy *et al.* 1993; Murphy and Heon 1994, 1995; Roots and Murphy 1992). Emond (1985, 1986, and 1992) investigated aspects of the geology, mineralogy, and geochemistry of tin and tungsten veins, breccias, and skarns, in addition to felsic intrusions in the McQuesten River area.

### *North American Strata*

North American strata, northeast of Tintina fault, consist of sedimentary and volcanic rocks deposited along the margin of ancestral North America in the Selwyn Basin. Selwyn Basin developed through intermittent attenuation and rifting of

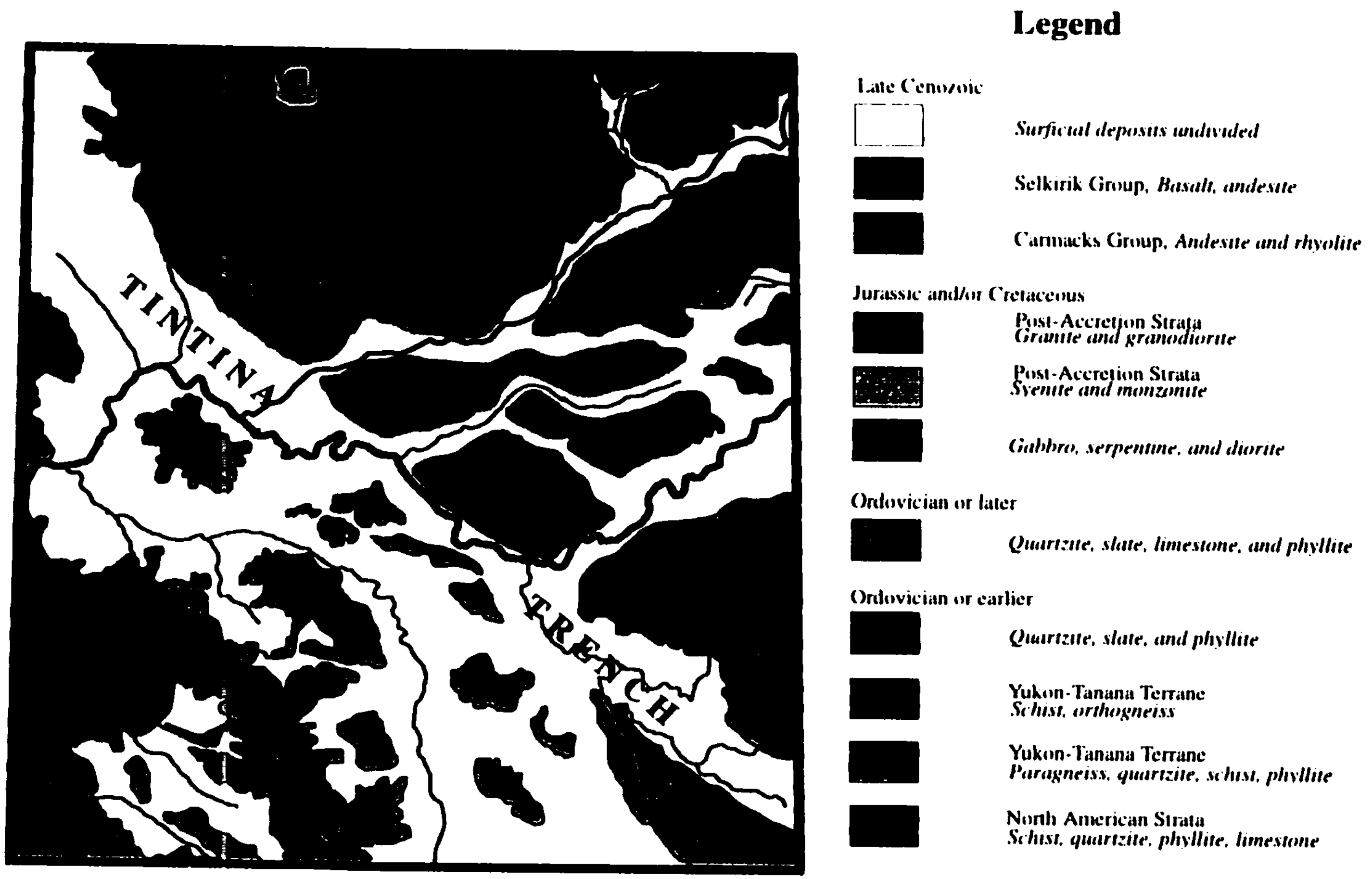


Figure 6: Geology of McQuesten map area (after Bostock 1963)

transitional continental crust near the western margin of North America (Murphy and Heon 1993). Subsequent clastic sedimentation into Selwyn Basin occurred from the Hadrynian to the Permian (Murphy and Heon 1993, Murphy *et al.* 1993, and Ward 1993). These rocks were deformed, and in places metamorphosed, during subduction of the oceanic plate beneath the basin in the Jura-Cretaceous, producing the thrust faults and folds of the Selwyn Fold Belt. Rocks of North American affinity in McQuesten map area consist of Upper Proterozoic to Lower Cambrian Hyland Group psammite, phyllite, carbonate, and meta-clastic rocks, and clastic strata from the Ordovician-Lower Devonian Road River Group and the Devonian to Early Mississippian Earn Group (Figure 6; Bostock 1964; Emond 1992; Murphy and Heon 1993).

### *Yukon-Tanana Terrane*

Yukon-Tanana Terrane can be divided into two components: Teslin-Taylor Mountain terrane and Nisling terrane, separated on the basis of metamorphic cooling ages and apparent structural position (Hansen 1990). Teslin-Taylor Mountain terrane is an accreted terrane that was emplaced upon Nisling terrane (metamorphosed North American continental crust) during an early Mesozoic subduction complex (Templeman-Kluit 1979; Hansen 1990). Teslin-Taylor Mountain rocks comprise the main assemblage within the Klondike Plateau in McQuesten map area. Yukon-Tanana terrane consists of metamorphosed and deformed sedimentary, volcanic, and plutonic rocks that include Proterozoic ortho and paragneiss, schist, quartzite, and phyllite (Bostock 1964; Hansen 1990).

### *Post-Accretion Strata*

Post-accretion strata include rocks emplaced following accretion of strata of oceanic and island arc affinities (exotic terranes). These are common throughout the map area and include mid-Cretaceous and Tertiary felsic intrusive rocks occurring as metre-scale dykes to stocks up to several km$^2$ (Figure 6) (Murphy and Heon 1993). Felsic intrusive rocks consist primarily of granite, monzonite, granodiorite, and syenite. (Bostock, 1964; Ward, 1993).

## Surficial Geology

The distribution of surficial deposits in the study area is largely controlled by physiography. Deposits can be subdivided into three groups including: alluvium, till/moraine, and colluvium. Alluvium includes both modern floodplains and relic alluvium or glaciofluvial terraces. Alluvium consists of stratified and crudely to well sorted sand and gravel with minor silt and cobbles. Generally these deposits are confined to lowlands. Some of the more prominent locations include Stewart River valley, Tintina Trench, McQuesten River valley, Lake Creek valley, and Willow Creek valley (Figure 7, see insert). The best preservation of glaciofluvial deposits occurs in lowlands unaffected by reworking by large modern streams (e.g. Willow and Lake

Creeks; Figure 7).

The distribution of till/moraines, like alluvium, is predominantly found in the lowlands (Figure 7). Moraines consist of unsorted clay, silt, sand, and gravel with minor cobbles and originate as deposits derived directly from glaciers. Till blankets (>1m thick) are found in the valley bottoms and lower valley sides, whereas till veneers (<1 m thick) occur on valley sides and on the summits of uplands below 1219 m a.s.l. Till veneers often consist of sparsely distributed glacial erratics on a colluvial surface. This is particularly common in the northern part of the map sheet where slopes are steeper causing more rapid mass movement. Till blankets at higher elevations may be found on plateaus or in meltwater channels in drainage divides. Moraine and glaciofluvial deposits of pre-Reid age in Tintina Trench and Lake Creek valley may be referred to as Drift deposits. This designation is assigned to deposits that resemble outwash or till, however, can not be differentiated due to limited surface expression related to erosion of the landforms (Figure 7).

Colluvium is the most widespread surficial deposit in uplands of the Cordillera. Colluvium consists of weathered bedrock and or redeposited till. Permafrost promotes gelifluction, frost creep, and mass movement of the surface layer into colluvial deposits. Mass wasting or landslides are concentrated in the northern part of Stewart Plateau (Figure 7).

## Glacial and Interglacial Geology

Multiple glaciations have affected Yukon Territory during the Pleistocene. Icefields in the St. Elias, Pelly, Cassiar, and Selwyn mountains combined to flow onto the interior plateaus of central Yukon (Figure 1).

Pre-Reid glaciations include undifferentiated advances of early to middle Pleistocene age (Figure 8). These contrast with well defined Reid and McConnell glaciations (the last two glaciations) in the central Yukon (Figure 9, 10, and 11). Soil development during pre-Reid interglaciations is recorded by the Wounded Moose paleosol (Tarnocai *et al.*, 1985). The post Reid interglaciation (Koy-Yukon) is recorded by the Diversion Creek paleosol. The Holocene soil is referred to as the Stewart neosol (Rutter *et al.*, 1978). Each soil has characteristics that can be used as a relative age indicator. Pre-Reid glacigenic deposits cover about 60% of McQuesten map area, whereas Reid and McConnell deposits cover about 38% and 2% of the map, respectively (Figure 11).

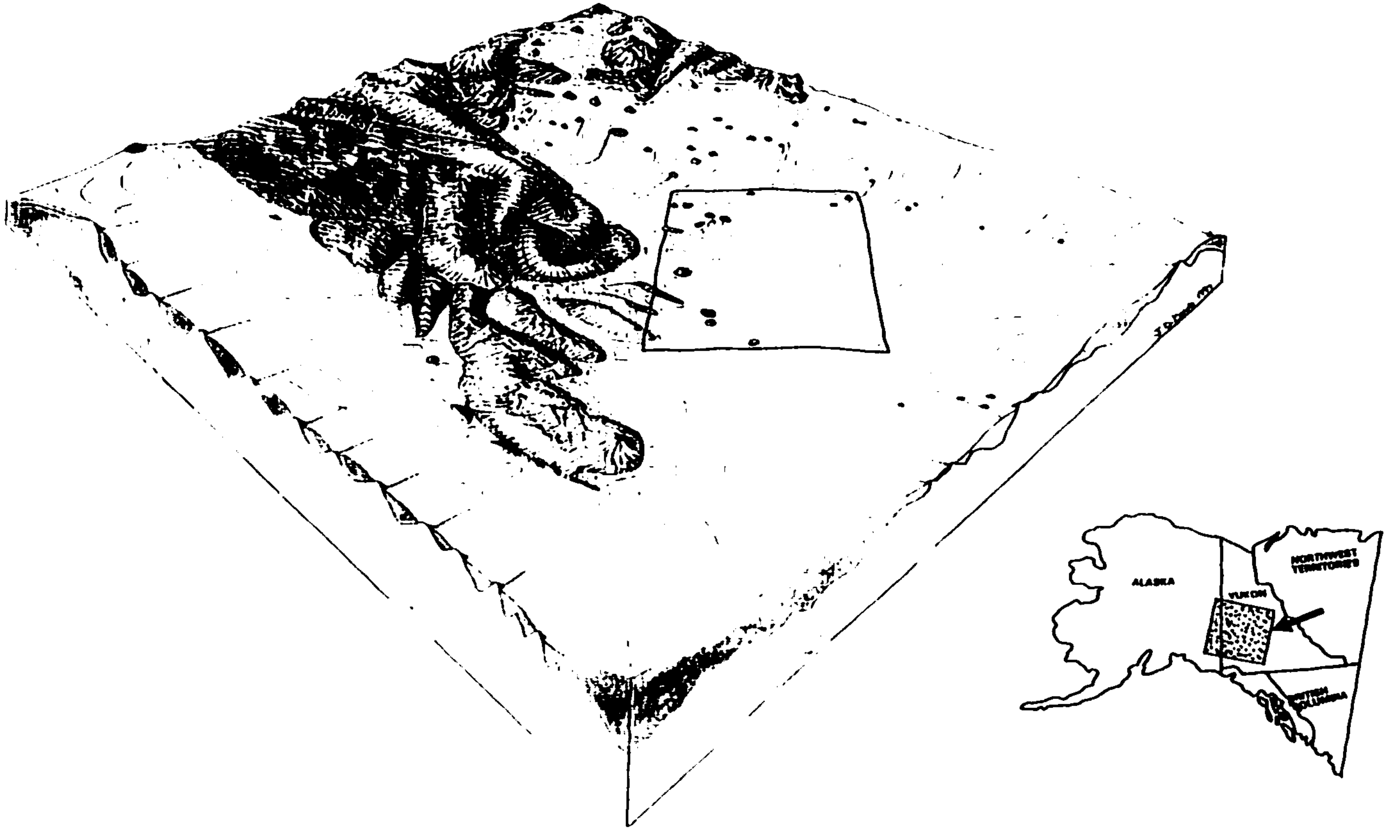


Figure 8: View to the north of the Pre-Reid glaciation in central Yukon. The Yukon plateaus were inundated by ice originating in the coast range, Pelly, Selwyn, and Ogilvie mountains. McQuesten map area was almost completely glaciated, except for nunataks along the western border of the map. The inset map show the area depicted in the block diagram.

(Glacial limits by Bostock 1966; Duk-Rodkin in prep.; This study)

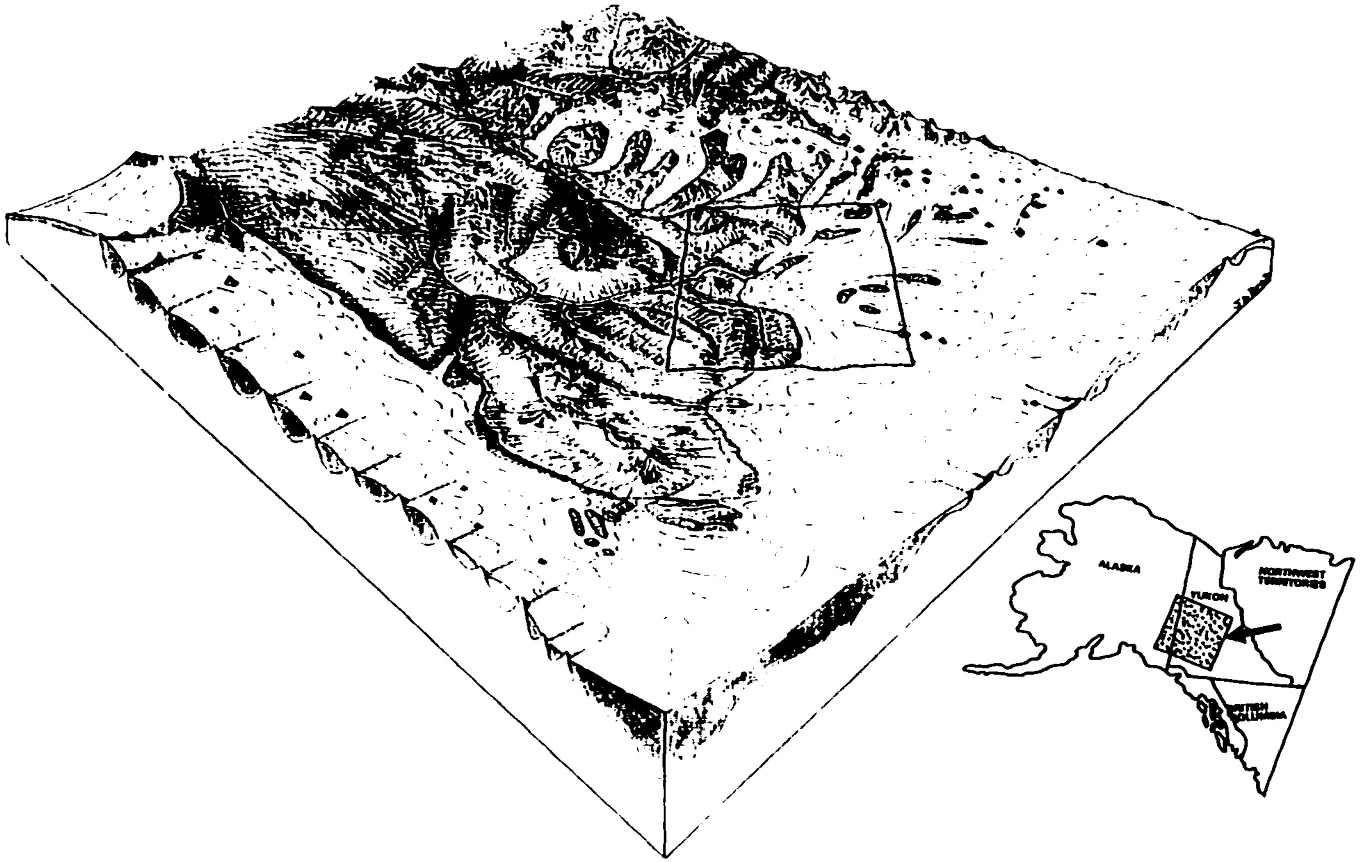


Figure 9: View to the north of the Yukon plateaus during the Reid glaciation. The extent of ice is much less in central Yukon. Reid ice emanated into McQuesten map area from the east and southeast, and terminated in Tintina Trench.

(Glacial limits by Bostock 1966; Duk-Rodkin in prep.; This study)

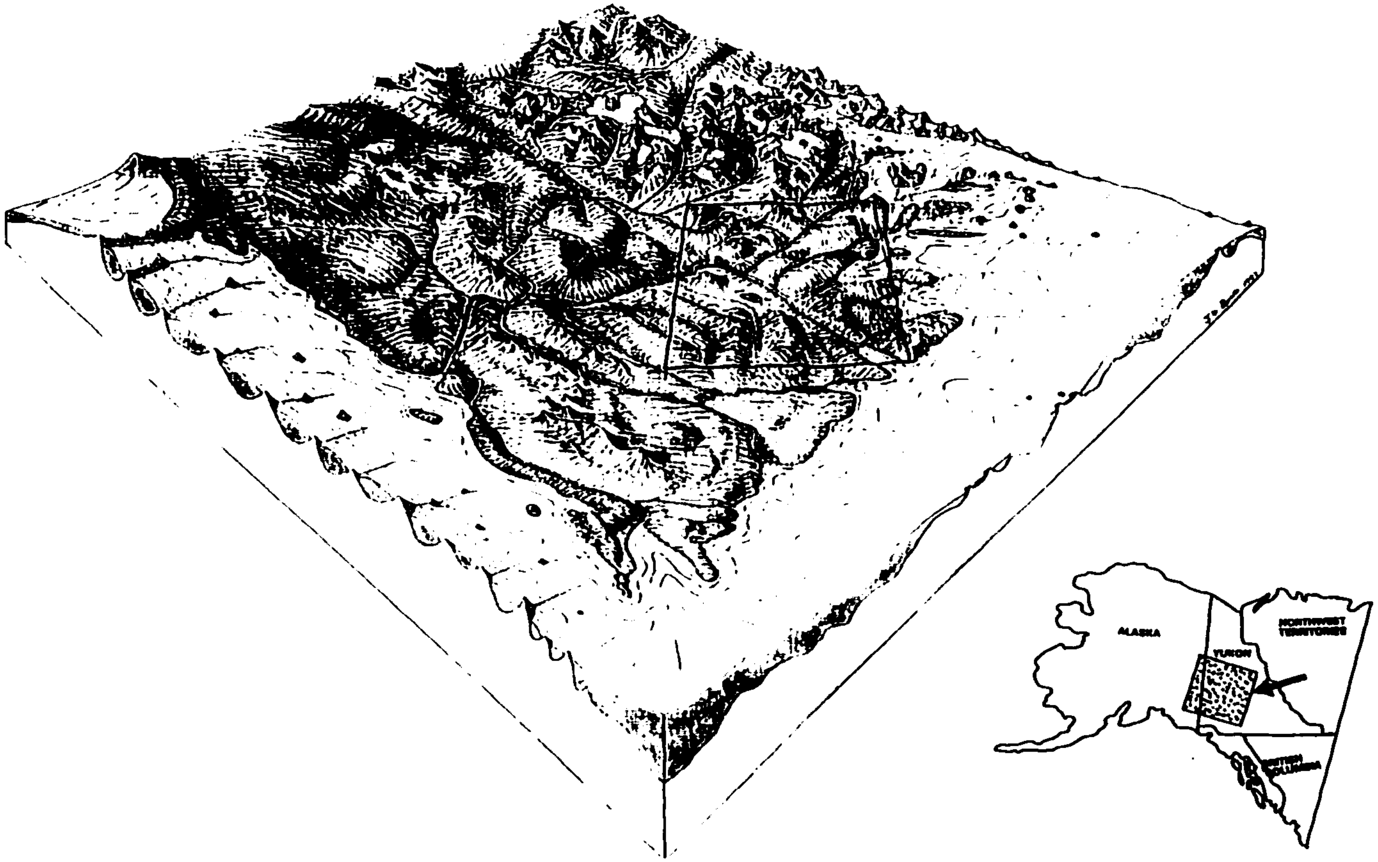


Figure 10: View of the McConnell glaciation in central Yukon. Notice the less extensive glaciers east of McQuesten map area and also to the northwest in the Ogilvie Mountains. In the study area Reid and pre-Reid surfaces were preserved beyond the McConnell limit.

(Glacial limits by Bostock 1966; Duk-Rodkin in prep.; This study)

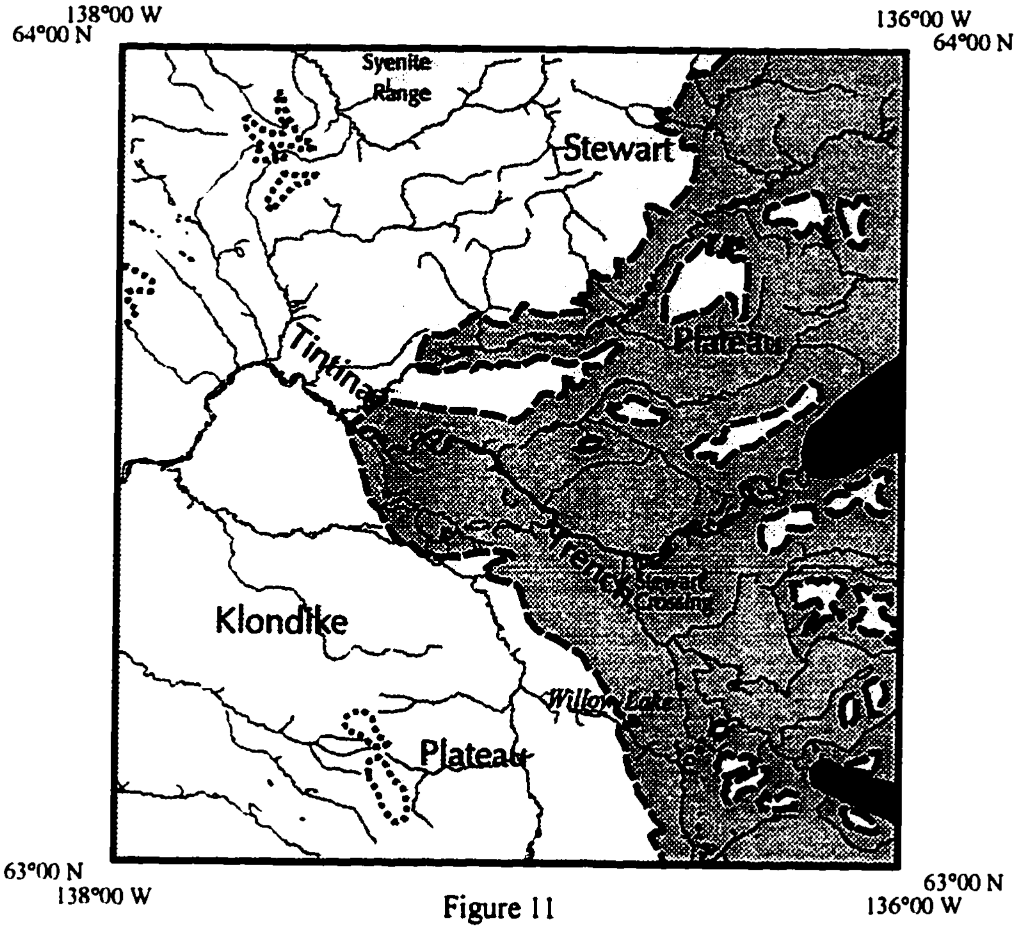


Figure 11
Glacial Limits in McQuesten Map Area
Yukon Territory

0 20
km

■ McConnell Glacial Limit

▨ Reid Glacial Limit

⬚ Pre-Reid Glacial Limit

⁘ Unglaciated

N

# CHAPTER 4

# METHODOLOGY

The methods employed in this study were surficial mapping, stratigraphy and sedimentology, and paleomagnetism.

## Surficial Geology

The surficial geology of McQuesten map area is a continuation of a previous mapping project by Hughes and Duk-Rodkin in 1983. Approximately 50% of the mapping was completed in 1983 and 1988 with the majority of it restricted to the Reid glacial limit. This project focused on mapping outside the Reid glacial limit, compiled the legend, and prepared the map for final drafting. Digitizing and final drafting was completed by S.J. Hinds at the Geological Survey of Canada.

The interpretation of the surficial geology was completed using air photographs. Ground truthing was limited to areas accessible by truck or foot and helicopter travel was limited to one trip from Mayo to the White Mountains in the southwest of the map. Numerous helicopter surveys were completed in the summer of 1995 with Kennecott Canada during their mining exploration program. Surveys in 1995 were concentrated on the Stewart Plateau and to the Stewart River valley N.E. of Tintina Trench.

Surficial mapping was completed in accordance with the Terrain Science Division, Geological Survey of Canada. The following is a list of map units that were employed. For a complete description of map units see appendix I and the map.

**QUATERNARY**

**Holocene**

*Organic Deposits*

Fenland

*Alluvial Deposits*

Alluvial plain, terrace, fan, and complex

*Colluvial Deposits*

Colluvium veneer, blanket, and complex

*Eolian Deposits*

Eolian veneer, blanket, and ridges

**PLEISTOCENE**

**Late Pleistocene (Late Wisconsinan - McConnell Glaciation)**

*Glaciofluvial Deposits*

Glaciofluvial plain, terrace, and complex

*Glacial Deposits*

Moraine (Till) veneer, blanket, and complex

**Middle Pleistocene (Illinoisan - Reid Glaciation)**

*Glaciofluvial Deposits*

Glaciofluvial plain, terrace, and complex

*Glaciolacustrine Deposits*

Glaciolacustrine plain, and blanket

*Glacial Deposits*

Moraine (Till) plain, veneer, blanket, and complex

**Pliocene - Early Pleistocene (Pre-Reid Glaciation)**

*Glaciofluvial Deposits*

Glaciofluvial plain, terrace, terrace veneer, and complex

*Glaciolacustrine Deposits*

Glaciolacustrine blanket

*Glacial Deposits*

Moraine (Till) plain, veneer, blanket, hummocky, and complex

*Drift Deposits*

Drift plain

**Pliocene - Pleistocene Undifferentiated**

*Colluvial Deposits*

Mass Wasting

Cryoplanation terrace

**PRE-PLIO-PLEISTOCENE**

*Bedrock*

Additional geologic features mapped included: Glacial limits, glacial erratics, cirques, moraine ridges, eskers, meltwater channels, dunes, tors, aligned landforms, and pingos.

### Stratigraphy and Sedimentology

The stratigraphic and sedimentologic data was gathered by logging river and road sections. River sections are located on Stewart River and McQuesten River and road cuts were concentrated along the Klondike highway. Stratigraphic interpretations at each section were completed by logging one or more vertical transects, depending on the complexity of the stratigraphy. At each section the total height was measured and flagging tape was placed every 2 - 5 m along the transect. Sedimentologic descriptions for each unit included:

Thickness
Prominence
Cohesiveness
Colour and moisture state
Style of contacts (e.g.. Abrupt; gradational; interfingered)
Texture
Primary sedimentary structures (e.g.. Cross bedding)
Secondary sedimentary structures (e.g.. Faults; weathering; soil development)
Organic content
Fabric analyses (only on diamictons)
Macrofossil analyses of organics (completed at the GSC)

Previous stratigraphic studies in the McQuesten map area were completed on the paleosols by Tarnocai and Smith (1989), Smith (1986), and Rutter *et al.* (1978). These studies characterized the Wounded Moose, Diversion Creek, and Stewart Neosol soils, providing important climate data about past interglaciations and the present interglaciation. Pollen analyses on last interglacial deposits and pre-Reid organics was completed by Tarnocai and Schweger (1991) and Schweger and Matthews (1991).

**Paleomagnetism**

Paleomagnetism was the main dating technique employed on pre-Reid deposits. The application of paleomagnetics to Late Cenozoic sedimentary deposits is a useful tool to correlate and date glacial and nonglacial sequences. Few dating methods are available in the range of 1 to 3 Ma making paleomagnetics an important alternative (Barendregt *et al.* 1996). The purpose of applying paleomagnetism is for stratigraphic differentiation and for correlating with the geomagnetic timescale. Differentiation of pre-Reid age sediments could provide insights into the number of glaciations represented in the stratigraphic record and would also be useful for regional correlations with the Mackenzie Mountain and Fort Selkirk magneto-stratigraphies (Jackson *et al.* 1990, Barendregt *et al.* 1996).

Eight sites from Stirling Bend section and two sites from Flat Creek section were chosen for sampling. The fine grained sediments were sampled by Dr. R.W.

Barendregt using plastic cylinders that were pressed horizontally into the face of the cleaned exposure. A compass bearing of the cylinders orientation was then recorded. In total 92 samples were collected, 72 from Stirling Bend, and 20 from Flat Creek section. Samples were processed and analyzed at the Pacific Geoscience Centre's Rock Magnetics laboratory. Magnetism was measured using an automated Schonstedt spinner magnetometer and stepwise alternating-field (AF) demagnetization was carried out using a Schonstedt GSD-5. Samples were demagnetized in 5 to 10 steps in peak fields reaching 100 mT. Thermal demagnetization was attempted on samples with incoherent magnetic directions. Lab processing and analysis was completed by Dr. R. Enkin and J. Baker of the Pacific Geoscience Center, by Dr. R.W. Barendregt of the University of Lethbridge, and by the author.

## CHAPTER 5

## LATE CENOZOIC GEOLOGY OF MCQUESTEN MAP AREA

### Pre-Glacial Drainage

The Yukon Plateaus were originally an upland traversed by broad valleys. This peneplain was incised following uplift in the late Tertiary (Templeman-Kluit 1980). Remnants of the peneplain now occur as isolated highlands surrounded by valleys that have been eroded during successive Pleistocene glacial and interglacial periods (Templeman-Kluit 1980; Fuller 1994). The earlier Miocene to Pliocene drainage system flowed south into the Gulf of Alaska prior to glaciation (Templeman-Kluit 1980). On Yukon Plateau, Templeman-Kluit (1980) identified misfit streams and underfit valleys recording a dendritic preglacial drainage to the south (Figure 12). In McQuesten map area Templeman-Kluit (1980) proposed a paleo-Stewart River draining through Ethel Lake valley (Nogold Creek) and south through Willow Creek (Figure 13). This reconstruction is supported by the present configuration of the lower Stewart River. The Stewart River, where it flows out of Tintina Trench, appears underfit suggesting that the valley has recently been occupied by the Stewart River (Templeman-Kluit 1980). Recent drainage reconstructions for the Yukon River support a south flowing Stewart River. The main channel of the paleo-Yukon River may have drained through McQuesten map area and south through Willow Creek (Figure 13; Duk-Rodkin 1997). If the Yukon River flows within its ancestral channel then it is difficult to explain why the present channel flows anomalously across the

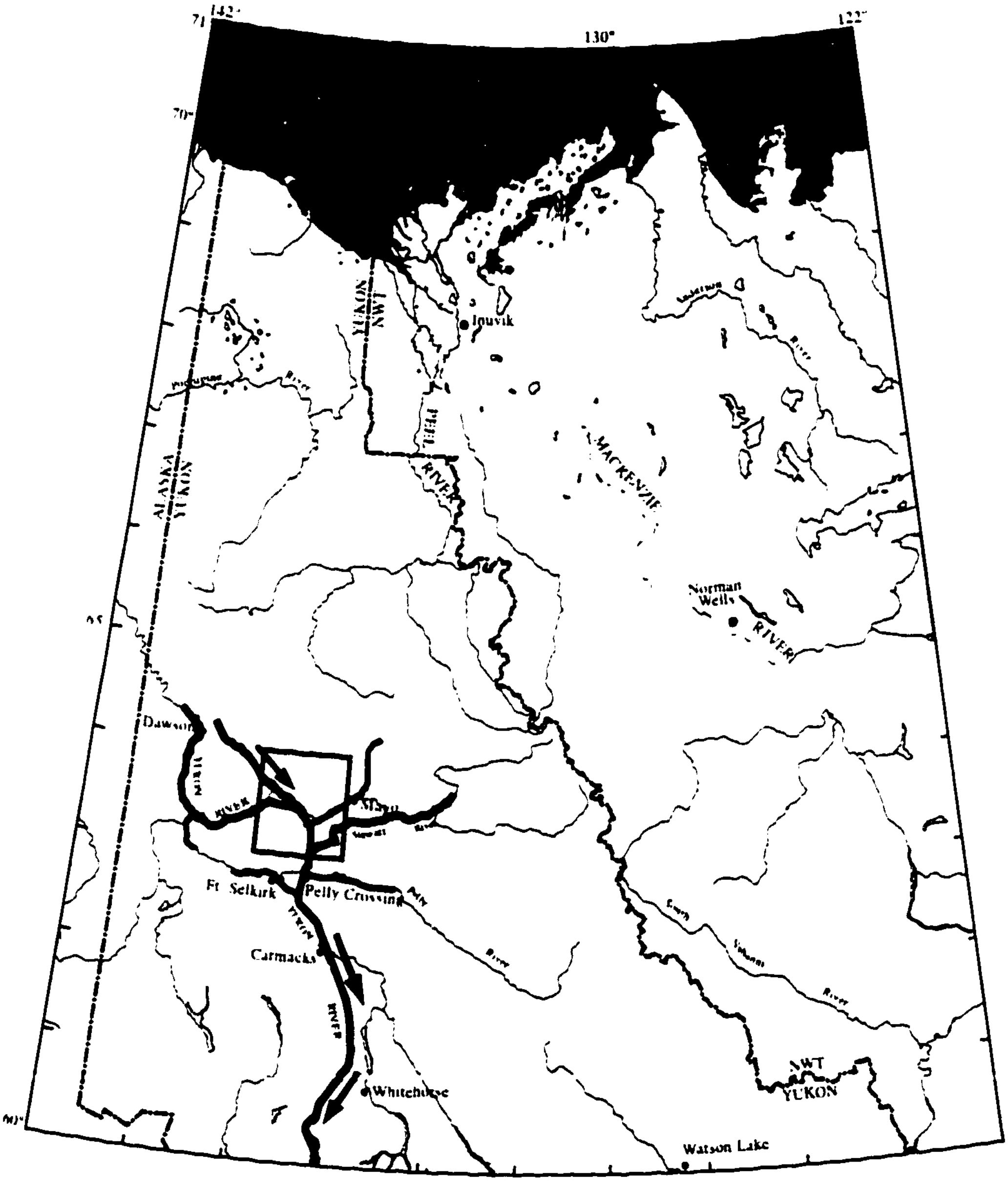


Figure 12: Generalized pre-glacial drainage for southern Yukon (overthickened line). Note the south flowing drainage and its course through McQuesten map area (after Templeman-Kluit 1980; Duk-Rodkin 1997).

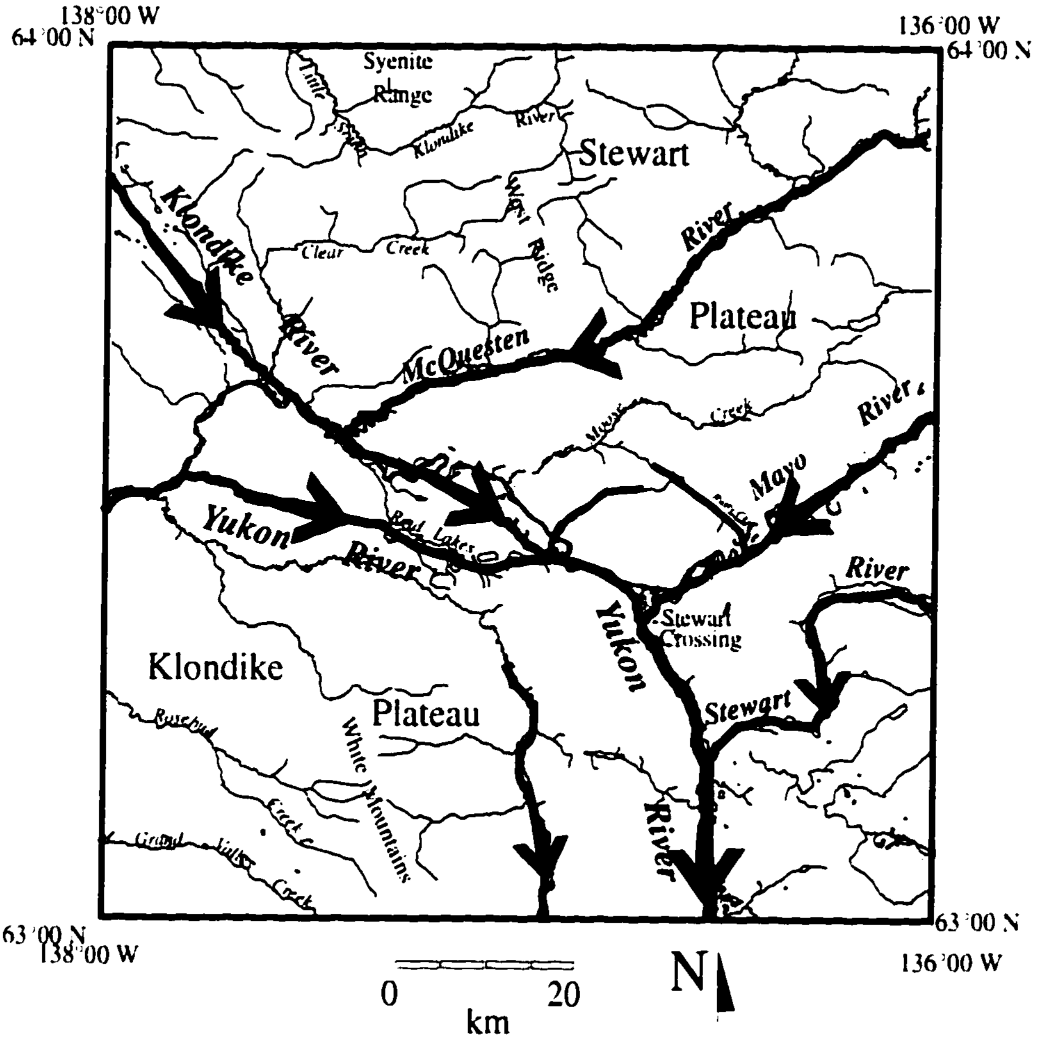


Figure 13: Pre-glacial drainage of McQuesten map area. Note the Stewart River flowing further to the south and Mayo River contained within the modern Stewart River valley. Klondike River flows within the Tintina Trench before meeting the Yukon River above Stewart Crossing. The south flowing Yukon exits the map sheet via Willow Creek valley and flows towards Pelly Crossing.

north slope of the Dawson Range, paralleling the contours of the range. Preglacial fluvial deposits were not identified in the McQuesten map area, however, White Channel-like gravel lying on bedrock in the vicinity of Clear Creek are considered to be of preglacial origin (Bostock 1966).

Uplift of the Coast Mountains in the late Miocene or early Pliocene, recorded from dates on the basinal Wrangell lavas now suspended on high peaks in the St. Elias Mountains, would have initiated local ice build up in the coast mountains (Souther and Stanciou 1976, Templman-Kluit 1980). The preglacial drainage likely remained intact during initial stages of uplift, incising through the mountain range, until the onset of the first glaciations (late Pliocene), which triggered the Yukon River drainage reversal to the northwest across the Yukon Plateau (Templeman-Kluit 1980). The Yukon River was also affected by the Cordilleran ice in the Yukon interior that diverted the river further to the west across Dawson Range and away from the Tintina Trench physiographic low.

## Glacial and Interglacial Record

The paleoenvironmental record in Yukon represents one of the most complete late Cenozoic records in North America. The unglaciated terrain bordering numerous former icefields has preserved many sites that record late Cenozoic glacial and interglacial history. The distribution and character of last glacial sediments in Yukon indicate ice advancing from St. Elias, Pelly, Cassiar, and Selwyn mountains to the central plateaus. Limits of the last glaciation are easily identified and have been mapped throughout most of the territory. Beyond the McConnell limit, glacial landforms change from being well preserved to being more subdued and intermittent. Armentrout (1983) suggested that progressive decrease in ice limits was related to uplift of the St. Elias and Alaska ranges, which progressively impeded the entry of winter precipitation into the interior. In central Yukon three glacial periods are generally identified and include the McConnell or last glaciation, the Reid or penultimate glaciation, and the pre-Reid (constituting multiple glaciations prior to the Reid). Older glaciated surfaces also provide sites recording nonglacial and glacial events that followed. Evidence of nonglacial conditions is derived from paleosols and organic deposits, whereas ice and sand wedge casts and ventifacts are remnant of glacial climates. The preservation of this record has also been aided by discontinuous and continuous permafrost. Preserved deposits include: loess, organic deposits, volcanic ash, and Pleistocene vertebrate and invertebrate faunal remains.

### *Pre-Reid Glaciations*

Pre-Reid accumulation zones were probably similar to younger Cordilleran ice sheets and was directed by the topography of the Stewart plateau, Klondike plateau, and Tintina Trench. Ice flowing from the east and south inundated Stewart River, McQuesten River, Tintina Trench, and Willow Creek. The advancing ice sheet breached the Willow Hills and the flanks of the White Mountains upon flowing west into the lowlands of Grandvalley creek and Rosebud Creek in the southwestern corner of the map sheet (Figure 14). The main ice stream continued northwest following Tintina Trench until its terminus in Dawson map area. Summits remained unglaciated in the White Mountains and on uplands bordering Tintina Trench in the northwest part of the study area (Figure 7 and 14). Characteristic landforms of unglaciated terrain or terrain near the upper limit of pre-Reid glaciation include cryoplanation terraces and tors (Figure 15 and 16). The most extensive pre-Reid ice sheet extended into Stewart map area, west of McQuesten map area. Surficial mapping indicates possible evidence for younger, less extensive pre-Reid glaciations, that terminated in the study area on Klondike Plateau. Moraines flank the west slope of the White Mountains and occur sporadically on Ice Chest Mountain and toward the west edge of the map sheet (Figure 7 and 17). Despite multiple pre-Reid moraines on the Klondike plateau, they are too discontinuous to trace and hence cannot be ascribed to separate glaciations. McQuesten area stratigraphy, rather than geomorphology, is used to describe the number of pre-Reid glaciations.

Pre-Reid ice sheets attained thicknesses well above later ice sheets: a minimum thickness of 850 m at Scheelite Dome, on the eastern boundary of the map sheet, 610 m on the White Mountains, west of Lake Creek, and 610 m in the northwest corner of the map sheet adjacent to Tintina Trench. Local cirque glaciers developed on Syenite Range, and on East and West Ridge (Figure 7). Minimum pre-Reid glacial elevations in upland regions are marked by subdued meltwater channels and resistant

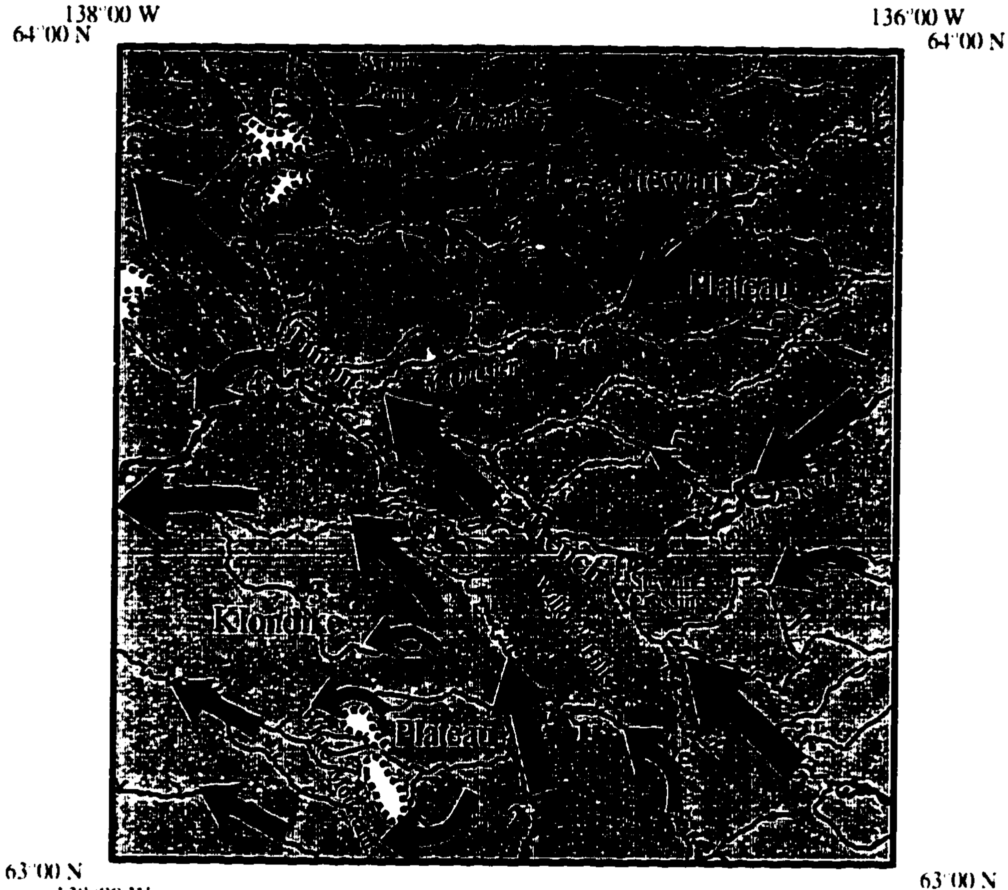
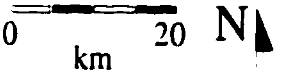


Figure 14
Pre-Reid Glacial Limit and Ice Flow Patterns in McQuesten map area



▨ Pre-Reid Glacial Limit

▢ Unglaciated

↙ Ice Flow Direction

1 Willow Lake Channel

2 Lake Creek

3 Pirate Creek

4 Stewart River Diversion

5 Interfluve Channels

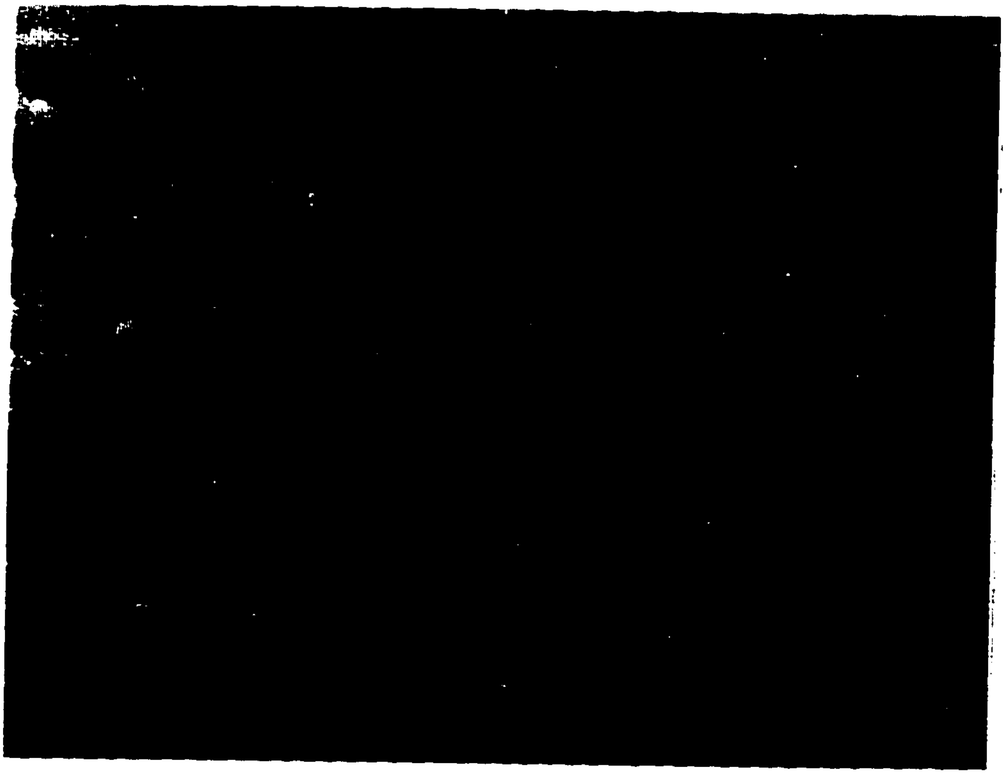


Figure 15: Cryoplanation terraces and blockfields on the White Mountains in unglaciated terrain. The terrace landforms develop by nivation processes.

Figure 16: Tors on the Willow Hills near the upper limit of pre-Reid glaciation. The tors are approximately 15 m in height.

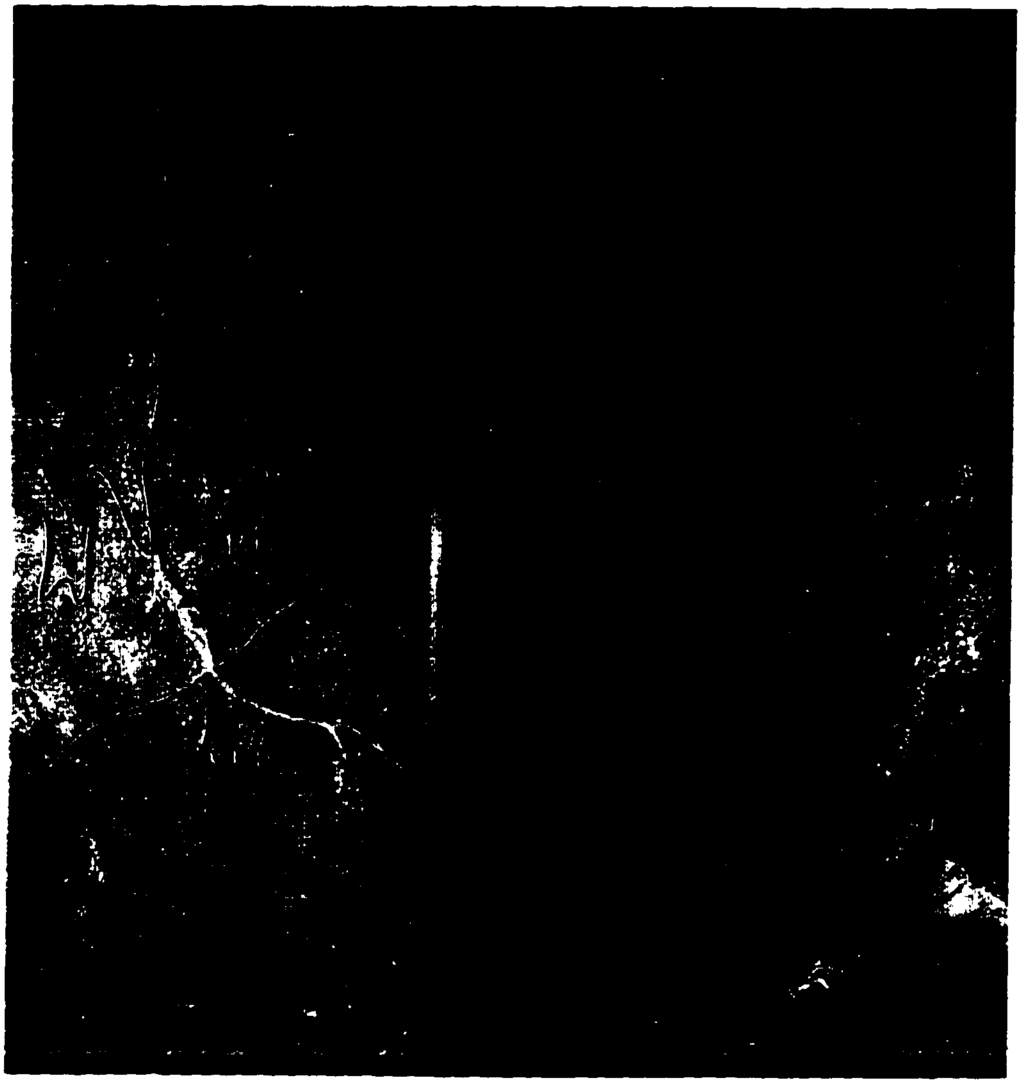


Figure 17: Pre-Reid lateral moraine ridges in Tintina Trench (see arrow). Note the subtle discontinuous surface texture of landforms of this age.

diorite erratics.

Regional ice flow east of the trench was directed by the Stewart, McQuesten, and Little South Klondike valleys (Figure 7). Pre-Reid moraines are uncommon on the Stewart Plateau where slopes are steeper and susceptible to mass wasting. Glacial flow patterns are, therefore, dependant on more stable erosional features such as meltwater channels. The physiography of the plateau is characterized by the above valleys, which decrease in size to the north. A series of north trending channels suggest meltwater breached interfluves of the major drainages (Figure 14 and 18). This suggests a northward flow of ice possibly from Tintina Trench ice blocking the flow of Stewart Plateau valley glaciers. Prominent terrace complexes of pre-Reid and possibly Reid age on Clear Creek and Little South Klondike River may consist of glaciofluvial sediment deposited from these adjoining systems (Figure 7).

Regional ice flow west of Tintina Trench was directed by the north trending White Mountains and Willow Hills. Ice flowing in Tintina Trench and Lake Creek valley surrounded Willow Hills, breaching the upland at Willow Lake valley (Figure 14, 19, and 20). This may have been enhanced by confined ice flow near the confluence of Stewart River valley and Tintina Trench causing ice to build up in Willow Creek valley and flow across the Willow Hills. This is supported by the elevation of channels on the White Mountains that indicates ice was above the Willow Hills. Tors on the summit of Willow hills suggest that either the ice sheet was thin and did not actively scour the summits or the time since glaciation has been long enough to

Figure 18: A pre-Reid meltwater channel between the headwaters of Forty Mile Creek and Little South Klondike River. The channel marks the breaching of an interfluve by the northward flow of meltwater across Stewart Plateau.

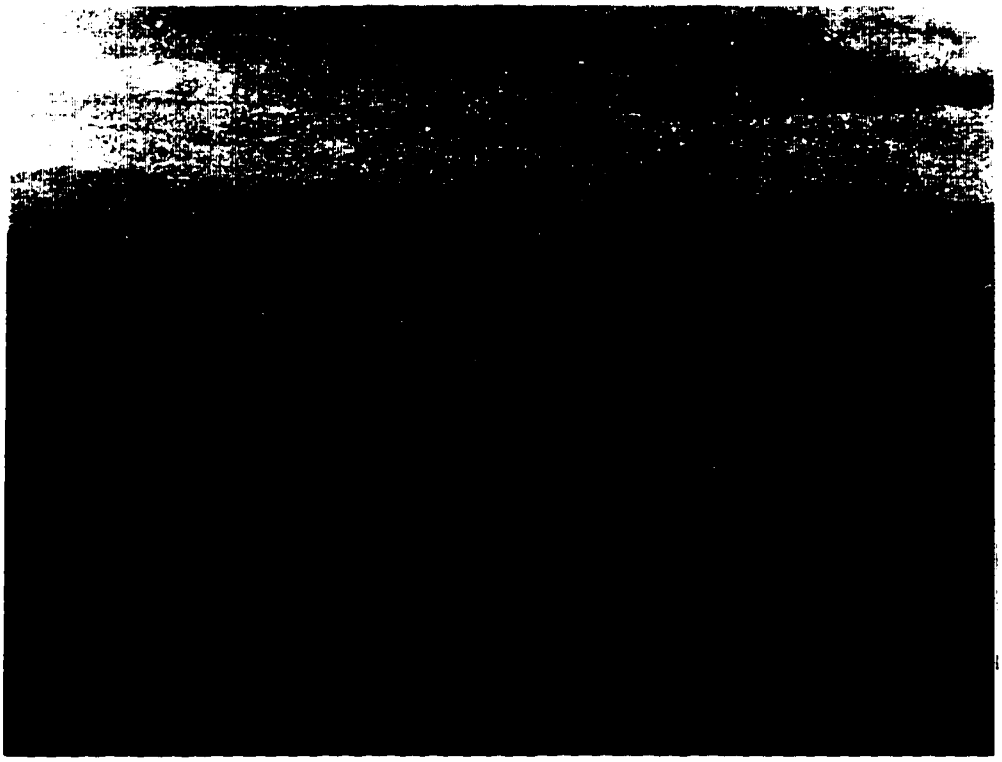


Figure 19: View to the east of the pre-Reid meltwater channel dissecting the Willow Hills on Klondike Plateau.

Figure 20: Willow Lake valley, a pre-Reid meltwater channel dissecting the Willow Hills. The channel was later reoccuppied by glacial meltwater from the Reid ice sheet that terminated along the eastern slopes of the hills.

permit the development of these landforms (Figure 16). Ice in Lake Creek valley glaciated the eastern slopes of the White Mountains, reaching elevations of 1417 m (Figure 14). Till blankets are common on the east and west flanks of the White Mountains. Where till is undifferentiated from glaciofluvial deposits the term "drift deposit" is applied. Two passes on the south flank of White Mountains permitted meltwater to drain into Rosebud Creek, and ice on the north flank breached the interfluve into Pirate Creek (Figure 14). Pirate Creek represents an ice marginal channel in Lake Creek valley that captured and redirected drainage off the north slope of the White Mountains to the west. Lake Creek ice continued west into Stewart River valley where it converged with a lobe of Tintina Trench ice flowing south (Figure 14). The modern Stewart River valley may have developed when Tintina Trench ice converged with Lake Creek ice and eroded a channel to the west. When ice in Stewart River valley and Tintina Trench receded the Stewart River valley, had been downcut below the level of Tintina Trench, resulting in the diversion of Stewart River into the Klondike Plateau. This reconstruction is largely based on the underfit Stewart River valley near the point of diversion from Tintina Trench. Ice in Stewart River valley near the terminus of the pre-Reid glaciations contributed to further downcutting of the valley and likely, the diversion of Stewart River. Pre-Reid deglaciations deposited glaciofluvial plains in the valleys of Stewart River and Tintina Trench. Tintina Trench contains more than 100 m of pre-Reid gravel, the thickest accumulation in the map area, and forms the highest terrace along the Stewart River

(Figure 21). Rosebud Creek also contains significant glaciofluvial terraces (Figure 7).

Local montane pre-Reid glaciers developed in the northern part of McQuesten map area. Cirque glaciers developed in Syenite Range and radiated into Little South Klondike river, impinging on intervening highlands north of Barlow Dome. Glaciers from the Ogilvie and Wernecke Mountains in Klondike valley may have restricted ice flow from Little South Klondike River, forcing ice into these highlands. Bostock (1966) recognized "rotten boulders, mainly of the distinctive rocks of the Syenite Range" in Glacier Creek drainage, west of Syenite Range. Also, moraines containing similar material on the northeast side of Glacier Creek (Bostock 1966). Bostock recognized this as possibly two pre-Reid advances originating from the Syenite Range. Cirque glaciers also developed on East and West Ridge, contributing sediment into the Clear Creek drainage and upper Little South Klondike drainage (Figure 19). The extent of ice from these sources is uncertain during pre-Reid glaciations.

### *Pre-Reid Interglaciations*

Sediments assigned to the early to middle Pleistocene pre-Reid interglaciations are regionally preserved on moraine and outwash surfaces beyond the Reid glacial limit. These sediments are named the Wounded Moose Paleosol. Pre-Reid interglacial organics are also preserved in section at Stirling Bend on the Stewart River. Numerous pedological investigations have characterized the Wounded Moose paleosol, contrasting it with contemporary soils and deducing its paleoclimatic

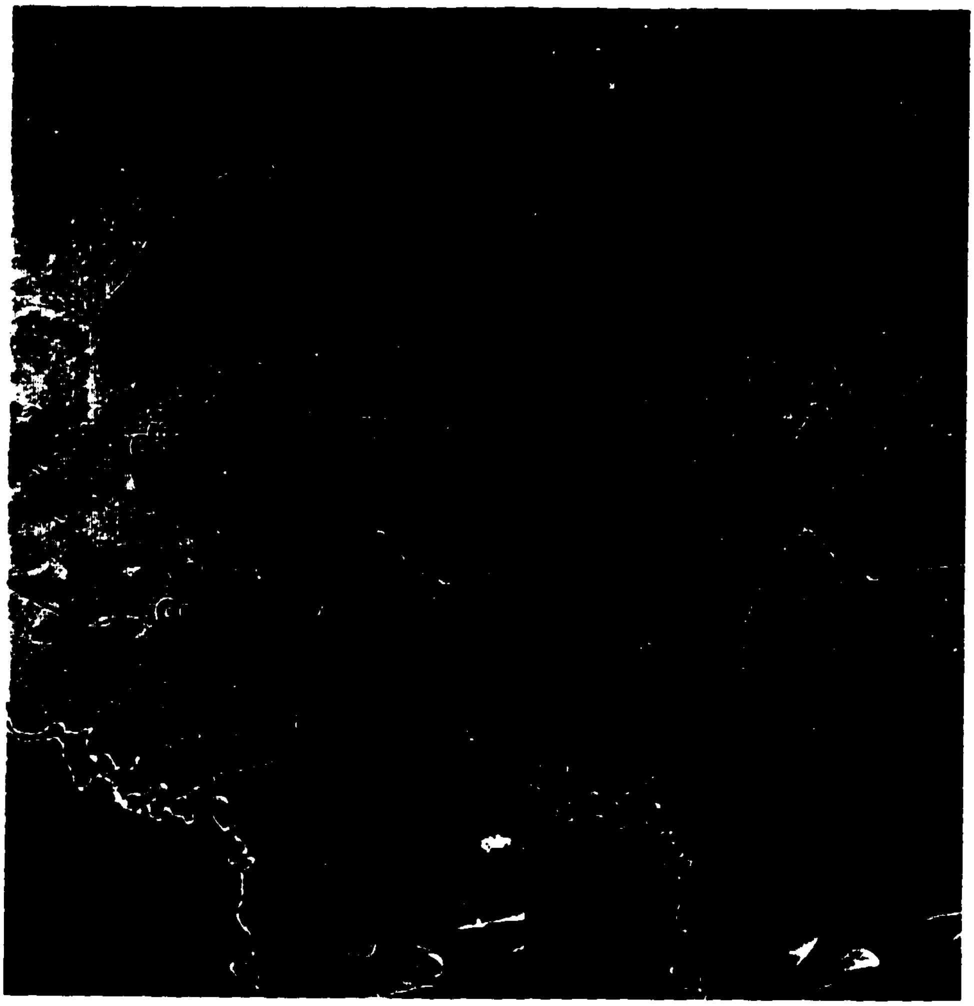


Figure 21: Four phases of floodplain development at the confluence of Clear Creek and Stewart River in Tintina Trench. Glaciofluvial plains from the pre-Reid, Reid, and McConnell glaciations, in addition to a modern alluvial plain are represented (glaciofluvial plains are differentiated by the superscript abbreviation).

Figure 22: Cirque on West Ridge that was carved during the pre-Reid and Reid glaciations.

conditions (Tarnocai and Smith 1989, Smith 1986, and Rutter *et al.* 1978). The Wounded Moose paleosol is a luvisolic soil characterized by a strongly weathered, rubific, and a thick textural paleo Bt horizon to a depth of 190+ cm (Figure 23) (Tarnocai and Smith 1989, Smith 1986, and Rutter *et al.* 1978). Moraine and glaciofluvial outwash, which constitute the parent material, contain sandy and loamy sand textures unlike the clay loam and sandy clay textures recorded from the paleosol (Smith *et al.* 1986). This suggests that the clay-sized material formed in situ through the alteration of ferromagnesian and feldspathic minerals (Smith *et al.* 1986). Rubification and strongly altered clasts in the Bt horizon, in addition to authigenic production of clay sized material, is inferred to take place under temperate climatic conditions with a mean annual temperature of 7 C or greater and a total annual precipitation of at least 500 mm (Tarnocai and Schweger 1991). In the Dawson area today the mean annual temperature is -5.1 C and a total precipitation is 306 mm (Atmospheric Environment Service, 1982b). Hence, the paleosol required a climate warmer than today (Tarnocai and Schweger 1991). Previous research had suggested a temperate and humid climate was responsible for development of the Wounded Moose soil, and even suggested an initial evolution from a warm and subhumid climate (Rutter *et al.* 1978). These climatic predictions were based on the presence of montmorillonite in the soil, which suggests a warm and subhumid climate. Degradation of montmorillonite to kaolinite suggested a temperate and humid climate (Rutter *et al.* 1978). The timing of the Wounded Moose interglaciation is uncertain,

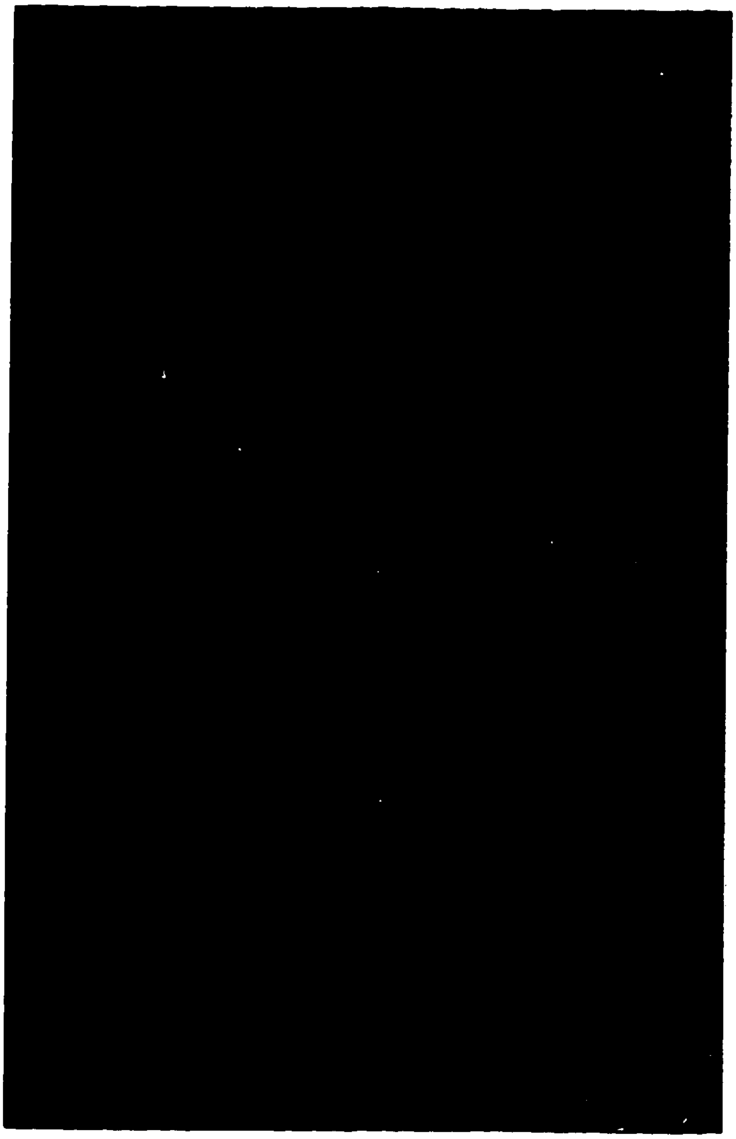


Figure 23: A sand wedge cast in the Wounded Moose paleosol near Clear Creek crossing. Formation of the sand wedge may have formed by a relatively recent pre-Reid glaciation or from Reid glaciation.

and it is also uncertain how many interglacial and glacial climates contributed to the paleosols overall development.

### *Reid Glaciation*

Development of a colder climate following a middle Pleistocene pre-Reid interglacial is preserved in the Wounded Moose paleosol by sand wedge cracks formed during Reid and younger climates (Figure 23). Deflation of the Ae horizon on the Wounded Moose soil also occurred, exposing the Bt horizon to frost shattering and further deflation. The morphology of Reid landforms is distinct and limits are easily traced in major valleys parallel to regional ice flow. Valleys transverse to regional ice flow contain indistinct markers of ice limits. Valley orientation likely inhibited ice scouring and limited sediment deposition. Ice limits are therefore extrapolated from adjoining valleys and depend on remnant ice marginal channels, kame terraces, or erratics to infer minimum ice limits.

The Reid ice sheet advanced into the study area from the east and southeast, occupying the major valleys within the Stewart Plateau, Tintina Trench and Willow Creek valley (Figure 24). Ice attained thicknesses of 518 m at Scheelite Dome and steadily declined upon intersecting Tintina Trench until reaching its terminus near Reid Lakes and the mouth of the McQuesten River valley (Figure 24 and 25). Channels cut during pre-Reid glaciations were reoccupied during the Reid glaciation, which suggests similar ice flow patterns between Reid and pre-Reid glaciations. Willow

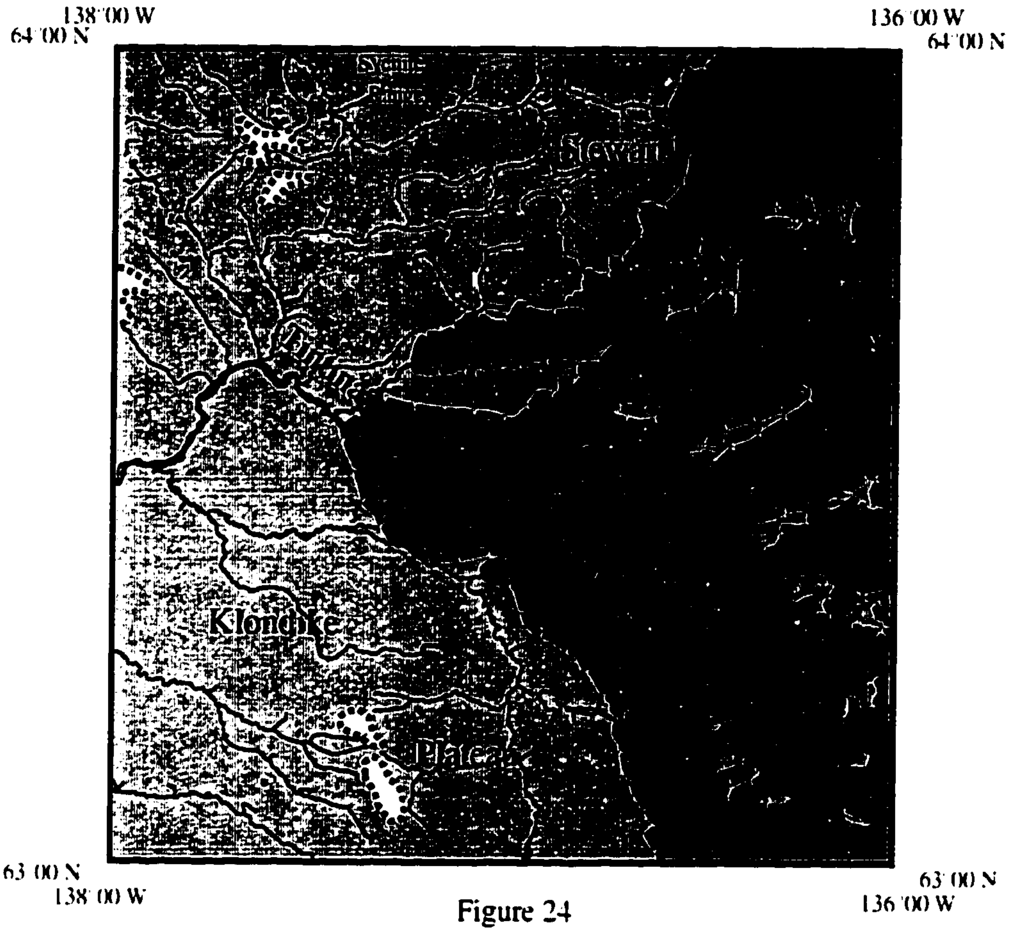


Figure 24

Reid Glacial Ice Flow Patterns, McQuesten Map Area

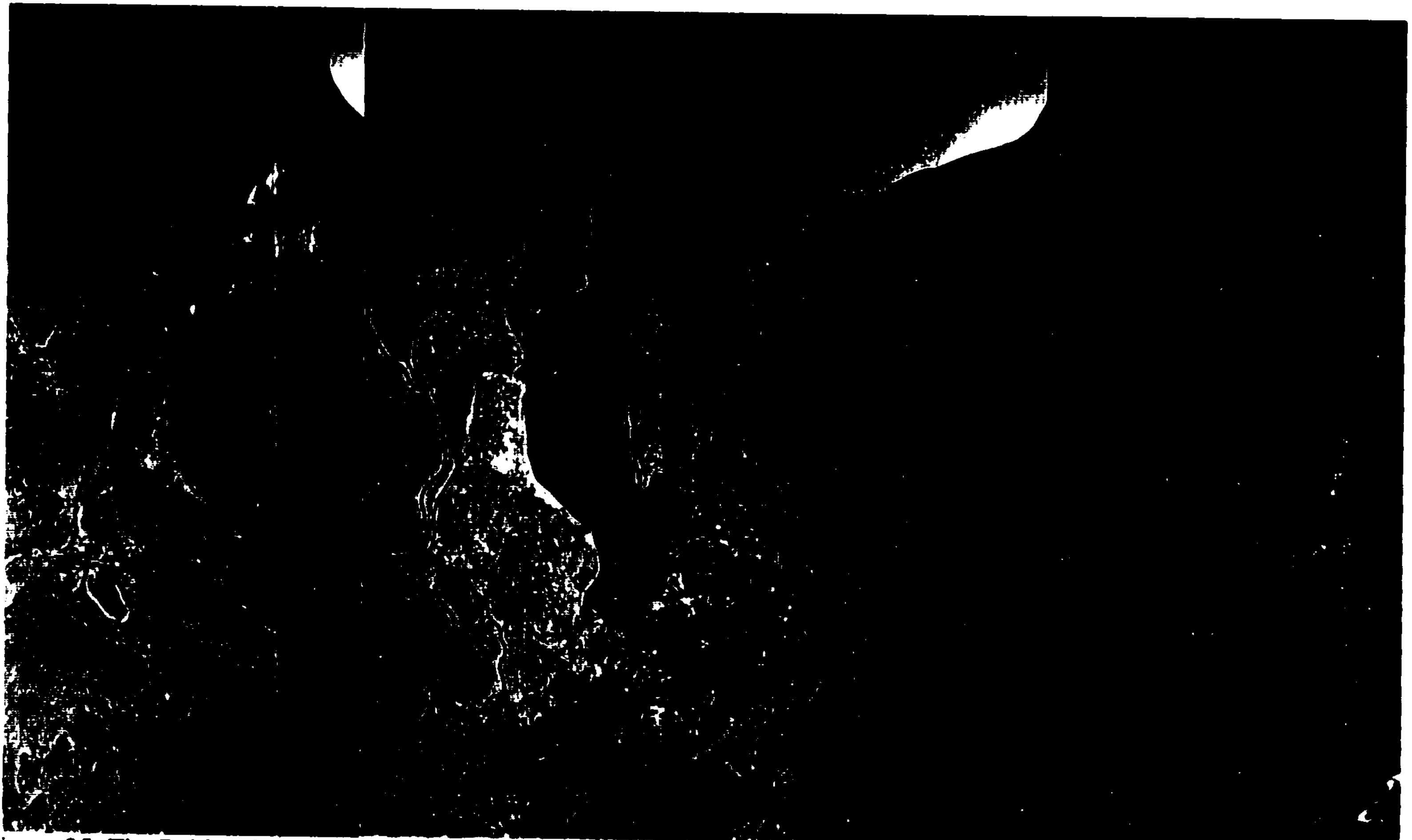


Figure 25: The Reid end moraine at Reid Lakes. This end moraine complex represents the type section for the Reid glaciation in central Yukon. The distinctive hummocky topography (Mm) signifies a stagnating ice front. Fen organics (fO) are particularly common on pre-Reid surfaces of similar origin in Tintina Trench.

Lake valley is a good example of a pre-Reid channel that was reused briefly during the Reid glaciation (Figure 20).

The distribution of Reid sediments is more easily defined than pre-Reid deposits. Moraine blankets and veneers are confined to the lower slopes on Stewart Plateau. A plain of hummocky till is present at Reid Lakes near Tintina Trench (Figure 25). Glaciofluvial outwash plains were deposited in major valleys and are preserved as glaciofluvial plains and terraces on the order of 60 m + above the present water levels on Stewart Plateau and in Tintina Trench (Figure 21 and 26). Outwash streams from the Stewart Plateau drained into the Stewart River and eventually into the Yukon River. Reid ice also dammed drainages transverse to regional flow (Rodin Creek, Red Creek, Highet Creek, and Moose Creek) developing proglacial lakes now marked by glaciolacustrine and deltaic sands. During the final stages of glaciation katabatic winds deflated outwash surfaces and mobilized silts and clays, depositing a layer of loess over valley bottom sediments. Dune fields were probably common in the valleys of Tintina Trench, Willow Creek, upper Moose Creek, and Reverse Creek where thick sand accumulations are still present (Figure 27).

### *Koy-Yukon Interglaciation*

The last interglacial, or Koy-Yukon interglaciation, has been extensively studied in northern Yukon and Alaska (Matthews *et al.*, 1990b). The term Koy-Yukon is named after warming intervals recognized around Fairbanks and western Alaska.

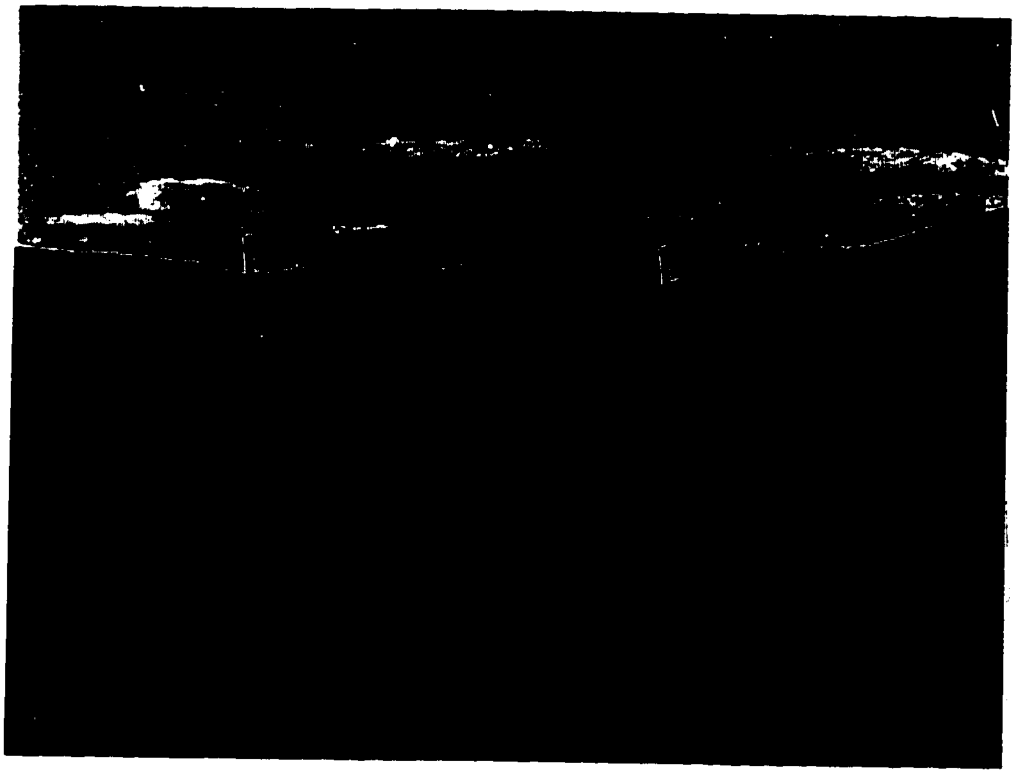


Figure 26: Prominent Reid terrace in the McQuesten River valley. Terraces are approximately 80 m above river level.

It is used in preference to Sangamonian interglaciation because periods of maximum warmth in northern latitudes may not correspond to those in the south (Matthews *et al.*, 1990b). The Koy-Yukon interglaciation is responsible for a Brunisolic soil preserved on loess, till, and glaciofluvial sediments of Reid age (Rutter *et al.* 1978). The interglacial had begun by at least 200 Ka based on the age of the Sheep Creek tephra found near Fairbanks and at Ash Bend on Stewart River (Berger 1994). The interglacial soil, referred to as the Diversion Creek soil, is best displayed at Vancouver Creek section (Figure 25). It contains weakly developed void and grain argillans in moderately well developed B horizons (Tarnocai and Smith 1989). At most localities Reid loess, including much of the Diversion Creek paleosol, was eroded by deflation during the McConnell glaciation. Remaining horizons are preserved in more resistant parent materials like glaciofluvial outwash.

Climatic comparisons suggest present day temperatures and moisture regimes are insufficient to explain the formation of clays at depths of 93 cm in the Diversion Creek paleosol (Rutter *et al.* 1978). This suggests that a cool subhumid climate prevailed in central Yukon during the Koy-Yukon (Rutter *et al.* 1978). A luvisolic profile obtained from the Reid terminal moraine (Reid Lakes) suggests climate conditions analogous to those at a mid to southern boreal forest (warmer and wetter than present; Smith *et al.* 1986).

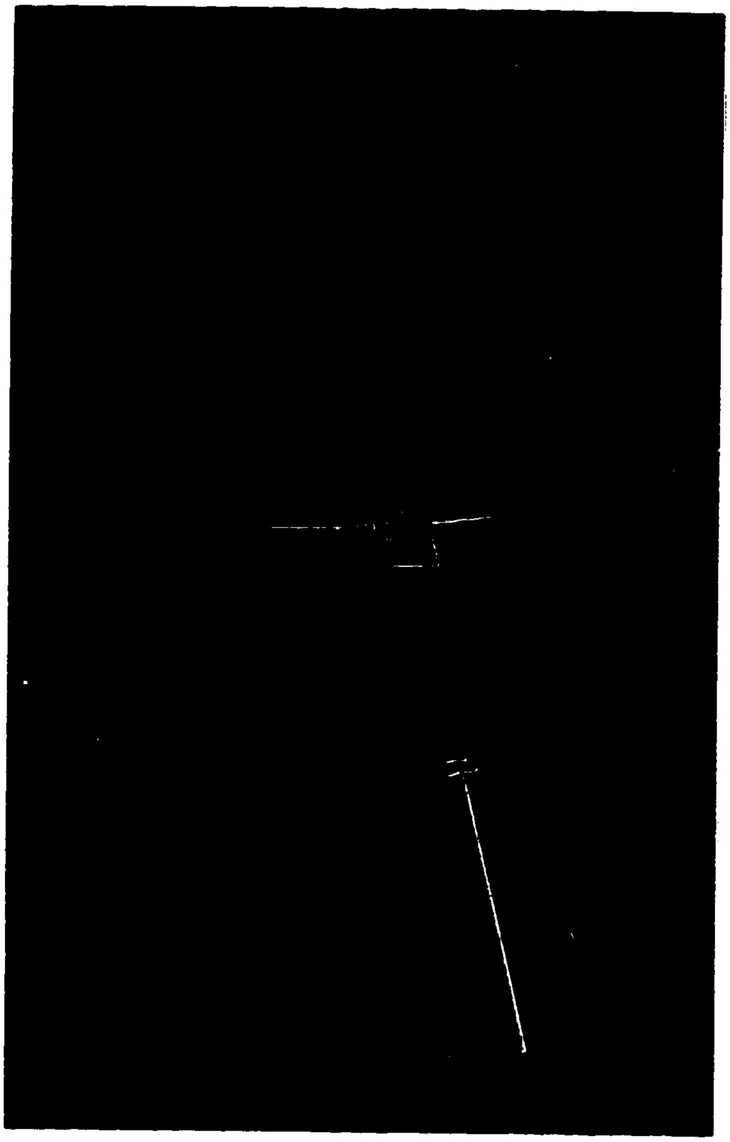


Figure 28: The paleosol at Vancouver Creek section. Identified as a complete Diversion Creek paleosol from the Koy-Yukon interglaciation. The paleosol is developed in Reid loess and outwash.

### *McConnell Glaciation*

The McConnell glaciation began prior to 29.6 Ka BP based on a $^{14}C$ date and paleoenvironmental interpretations of detrital organics below McConnell till near Mayo (Matthews *et al.* 1990). Ice-free conditions persisted near Ross River, southeast of the study area, at 26.3 Ka BP, and glacial maximum probably did not occur in McQuesten map area until sometime after 18 Ka BP (Jackson and Harington 1991; Froese personal communication 1995). These dates suggests a Late Wisconsinan age for the McConnell glaciation. The onset of a colder climate following the Koy-Yukon Thermal event is preserved in the Diversion Creek paleosol by sand wedge casts, ventifacts, and truncated horizons. McConnell katabatic winds deflated Reid loess deposits and in doing so truncated the A and parts of the B horizon of the Diversion Creek paleosol. Ventifacts formed at the interface between McConnell loess and the B horizon of the Diversion Creek soil. Loess accumulation likely began when the surface was stabilized by vegetation at the beginning of the Holocene.

The McConnell glaciation reached the eastern edge of McQuesten map area terminating approximately 20 km upstream from Stewart Crossing and extended into Tintina Trench in the southeast (Figure 29). A terminal moraine was deposited in Stewart River valley in addition to glaciofluvial outwash in Stewart River valley, McQuesten River valley and Tintina Trench (Figure 30, 31, and 32). The terminal moraine can be traced along the north edge of the valley to where it loops across the valley and intersects the Stewart River reforming along the south side of the valley.

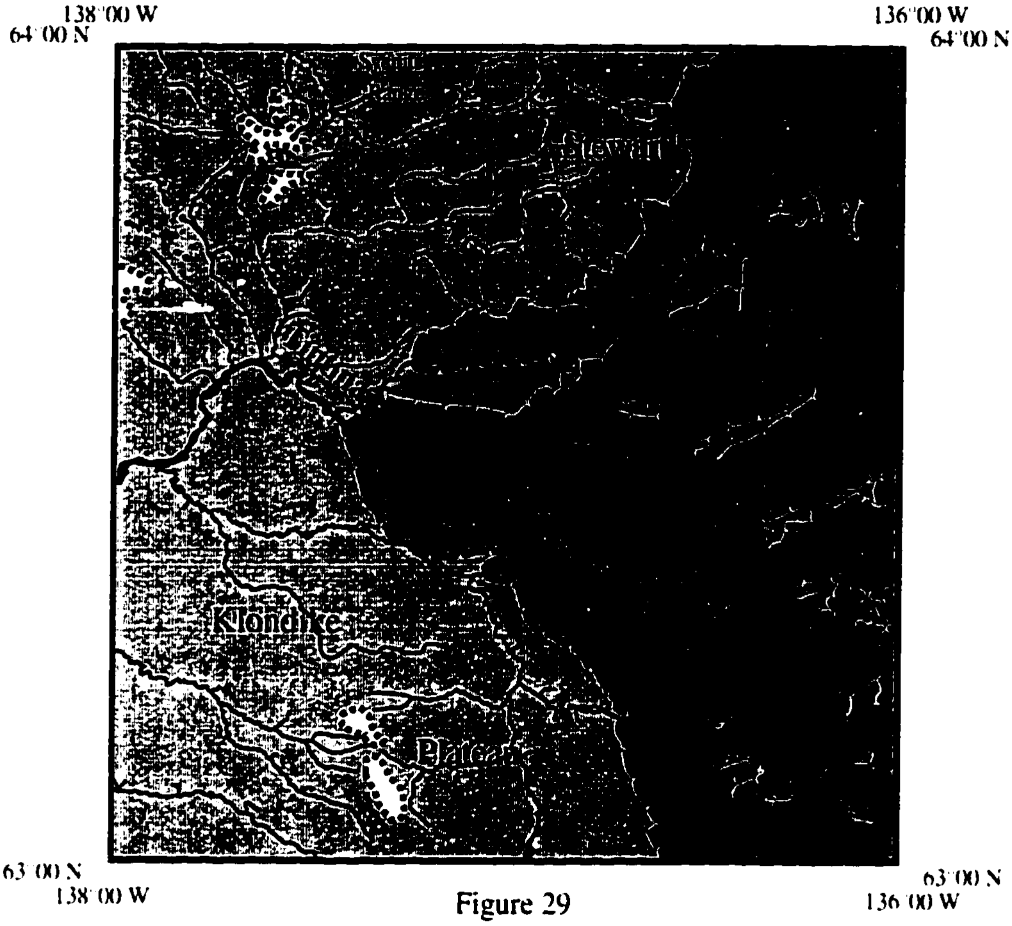


Figure 29

McConnell Ice Flow Pattern, McQuesten Map Area

0 20

km

■ McConnell Glacial limit and Ice flow

■ Reid Glacial Limit

▦ Pre-Reid Glacial Limit

▨ Unglaciated

N

Figure 30: The McConnell end moraine (Mr) in Stewart River valley. This site is the type section for the McConnell glaciation in central Yukon. The exposure used to describe McConnell glacial maximum can be seen along the Stewart River, east of the moraine. Note the well defined morphology of McConnell landforms.

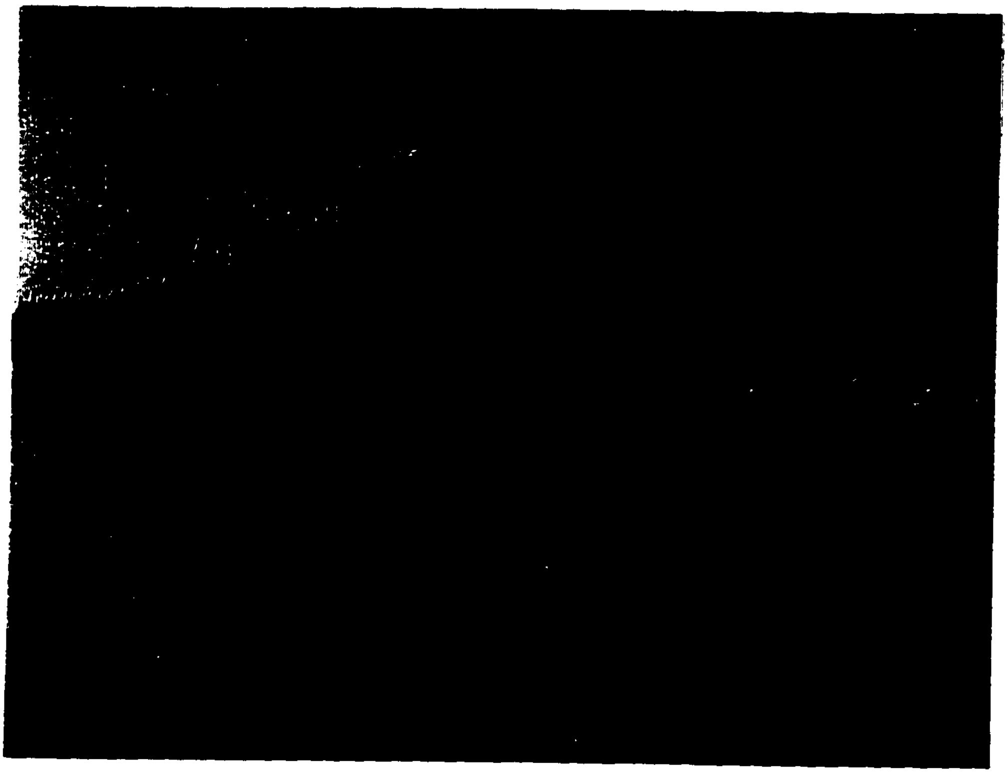


Figure 31: A McConnell glaciofluvial terrace in Stewart River valley. The terrace is approximately 15 m above river level. Photograph was taken near the McConnell end moraine.

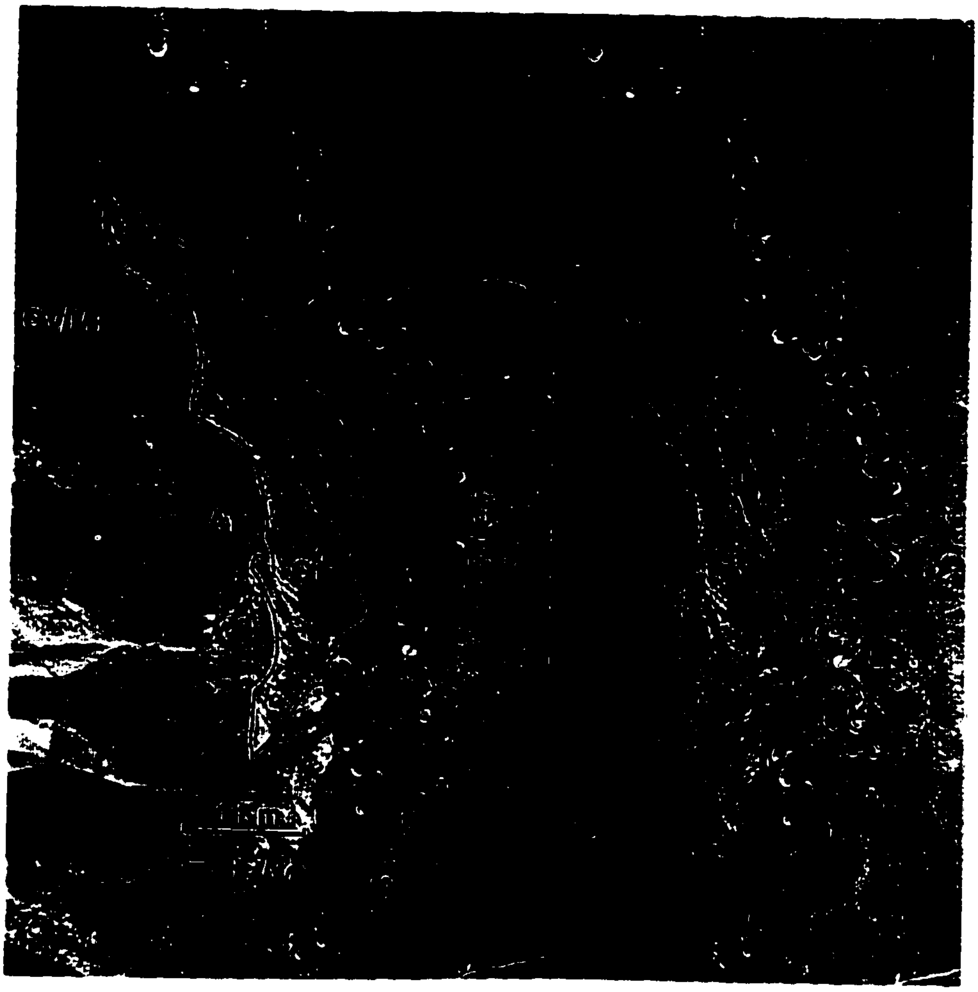


Figure 32: A McConnell glaciofluvial terrace in the South McQuesten River valley, north of Scheelite Dome. Note the remnant channel scars of a braided river on the surface of the terrace and how they contrast the modern meandering system.

The moraine represents the type locality of the McConnell glaciation in Yukon Territory (Tarnocai 1987). McConnell outwash was deposited in Stewart River valley and in the South McQuesten valley (Figure 32). Dunes developed on glaciofluvial outwash of McConnell age and in some instances Reid deposits were reactivated (Figure 27). Loess derived from McConnell outwash was redeposited as a veneer over the truncated Diversion Creek paleosol and on pre-Reid surfaces in lowlands.

### *Holocene*

The transition to an interglacial regime following the McConnell glaciation marked the development of the Stewart neosol (modern soil) on McConnell loess. Deglaciation had begun by at least 11460 ± 80 Ka BP (TO-4875) according to a date on ground squirrel bones (*Spermophilus parryii*) from Stirling Bend, which suggest an environment suitable enough for rodents and vegetation (Figure 33). Shortly after retreat of McConnell ice the climate became warmer and more humid than today, similar to a subarctic-subhumid type of climate (Zoltai and Tarnocai 1974).

The period of warmest climate during the Holocene was between 11 and 7 Ka BP (Rampton 1973; Rampton 1982; Cwynar 1982; Burn *et al.* 1986; Cwynar 1988). At Hanging Lake, northern Yukon, *Betula* pollen increased between 14.6 and 11.1 Ka BP together with an increase in the total pollen influx and organic content in lakes (Cwynar 1982). Vegetation cover not only increased but also diversified. From 11.1 to 8.9 Ka BP poplar, *Typha latifolia*, and *Myrica gale* were more abundant than at

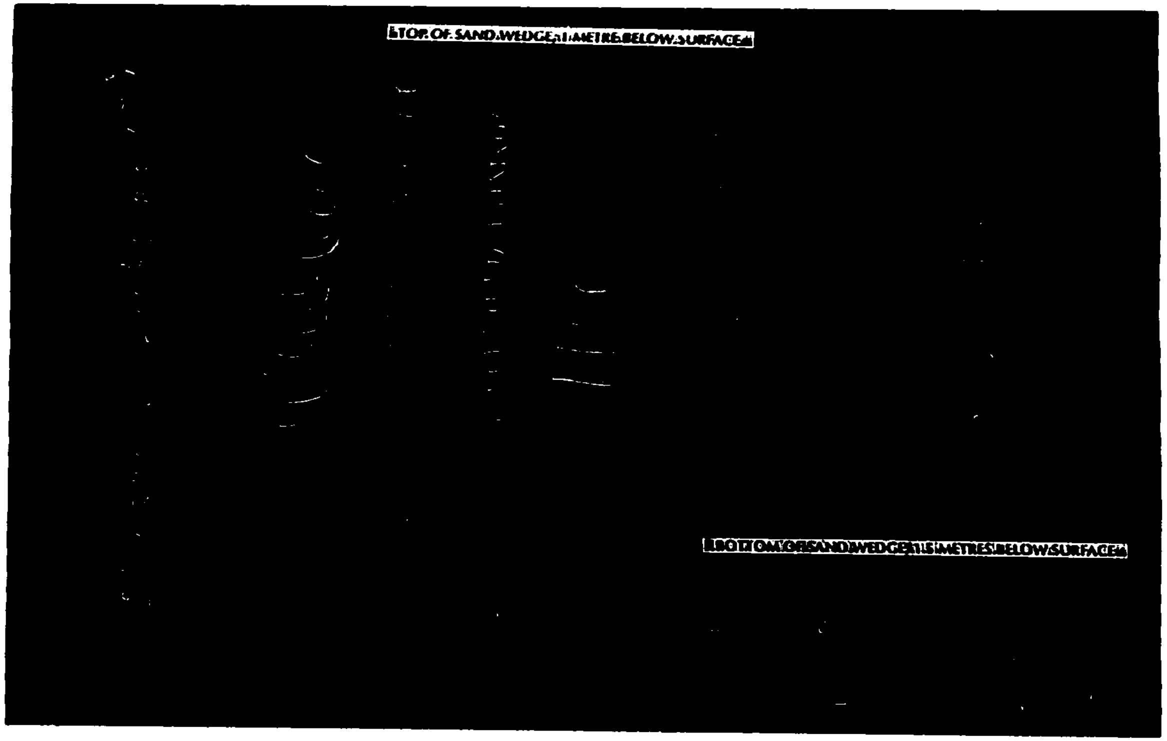


Figure 33: Ground squirrel bones (*Spermophilus parryii*) from a sand wedge at Stirling Bend. The bones were dated to 11ka BP by AMS method.

any subsequent time in the core (Cwynar 1982). These species support a warmer and wetter climate during the late Pleistocene to early Holocene (Cwynar 1982). Similar results were obtained from Kettlehole Pond in southwestern Yukon (Cwynar 1988). From 11 Ka to 9.2 Ka BP summer warmth was probably greater than that of the modern climate (Cwynar 1988). Similar evidence was suggested from ice-rich glaciolacustrine sediments near Mayo where Burn *et al.* (1986) identified a thaw unconformity corresponding with maximum active layer thickness. A date of 8.9 Ka BP from the organics surrounding the unconformity provides an age for this warm period, which coincides with dates from northern and southern Yukon (Burn *et al.* 1986). The modern subarctic-semiarid climate found today in Yukon developed after 6.0 Ka BP and may not have been established until 4.0 Ka BP (Cwynar 1988; Wang and Geurts 1991).

# CHAPTER 6

# STRATIGRAPHY

The stratigraphic record in McQuesten map area is derived from sections along Tintina Trench, Stewart River, and McQuesten River. Six sections are discussed and include deposits which span from the Pre-Reid to the Holocene. The sections will be described beginning at Flat Creek section, followed by Stirling Bend, Ash Bend, New Crossing, and Vancouver Creek section, and McConnell end moraine section.

## *Flat Creek Section*

Flat Creek section is located 24 km northwest of McQuesten map area (Figure 34). The overall sequence consists of 20.75 m of gravel overlain by 2 m of lacustrine and debris flow sediments (F.C. 1 and 3), and capped by 1.5 m of gravel (F.C. 4). The section is capped by 1 m of loess (F.C. 5). At the top of F.C. 1 there is a deep weathering horizon (F.C. 2).

### Unit F.C. 1

F.C. 1 consists of moderately stratified oxidized gravels containing large pebble and cobbles with lenses of sand (Figure 35 and 36; see Appendix II for a description of symbols used in lithostratigraphic logs). Clasts are subrounded to rounded and strongly imbricated to the southeast, indicating a paleoflow to the northwest in alignment with Tintina Trench. This unit is interpreted as a distal braided river or

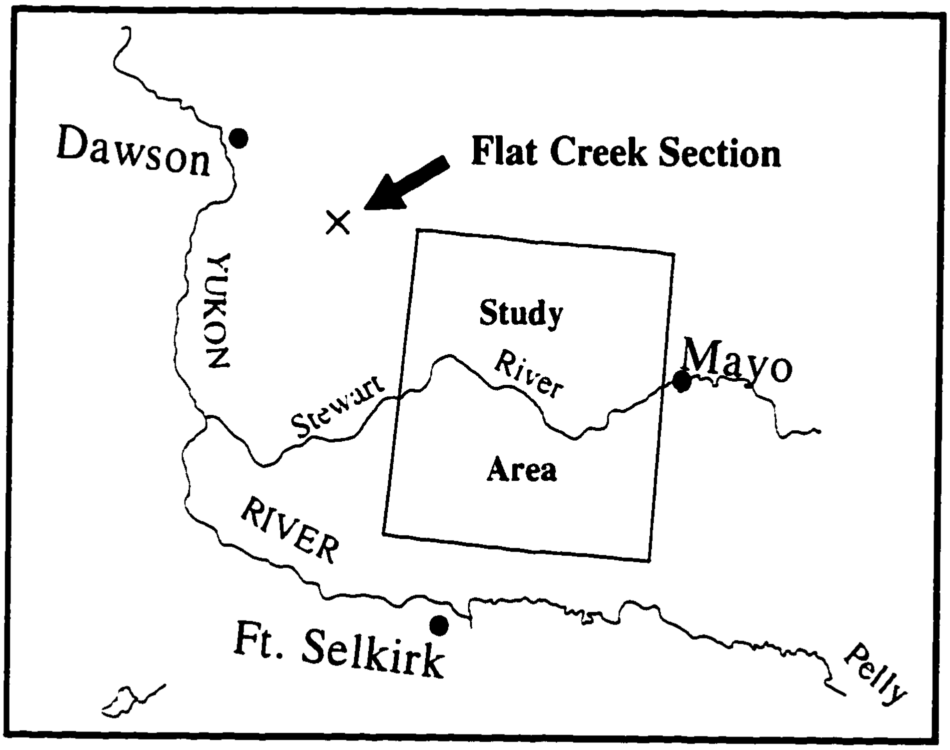
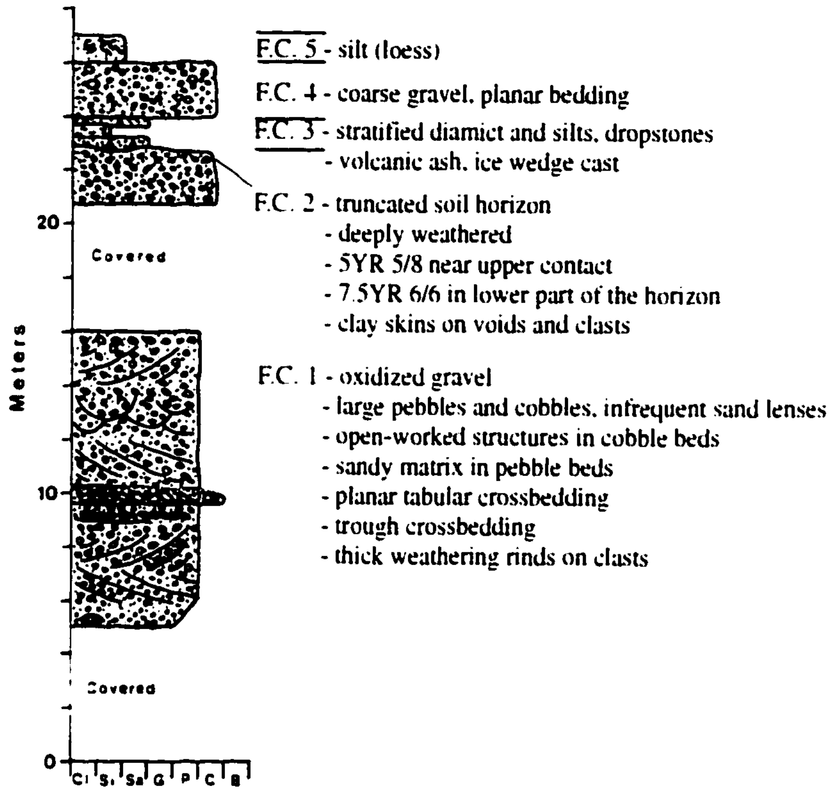


Figure 34: Location of Flat Creek Section



F.C. 5 - silt (loess)

F.C. 4 - coarse gravel, planar bedding

F.C. 3 - stratified diamict and silts, dropstones
- volcanic ash, ice wedge cast

F.C. 2 - truncated soil horizon
- deeply weathered
- 5YR 5/8 near upper contact
- 7.5YR 6/6 in lower part of the horizon
- clay skins on voids and clasts

F.C. 1 - oxidized gravel
- large pebbles and cobbles, infrequent sand lenses
- open-worked structures in cobble beds
- sandy matrix in pebble beds
- planar tabular crossbedding
- trough crossbedding
- thick weathering rinds on clasts

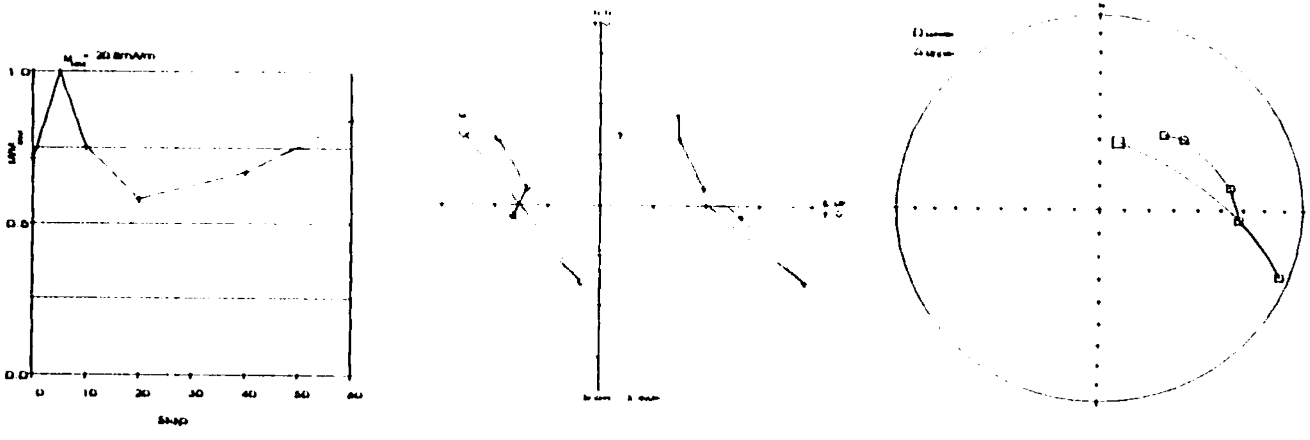
Figure 35: Flat Creek section stratigraphy and sedimentology, Tintina Trench

Figure 36: Composite photograph of units 1 - 4 at Flat Creek section. Features include the top of the pre-Reid glaciofluvial gravels (unit 1), the Wounded Moose paleosol (unit 2), a glaciolacustrine/debris flow unit with an ash and periglacial features (unit 3), and glaciofluvial-like gravels at the top of the section (unit 4).

glaciofluvial gravel.

Eight samples for paleomagnetic analyses were obtained from a fine sand lense 9 m above the base of the gravel pit. Results show an old normal magnetization with reverse and normal overprinting (Figure 37). The orthogonal plot in figure 37 indicates an initial Bruhnes overprint. Further demagnetization revealed a reversed overprint from the Matuyama Chron. The primary magnetic fabric (paleomagnetism at time of deposition) is not represented at the current level of demagnetization; however, the inclination (vector on the left in the orthogonal plot) must return to the origin upon full demagnetization. Fitting the vector back through the origin indicates that the primary magnetic fabric was normal. To better understand the configuration of a reversely magnetized deposit an example is shown from the Dawson City area (Figure 38). The Bruhnes normal overprint is evident in the inclination (the trend on the right side of the orthogonal plot) by a vector extending down to the right. The reverse underprint is evident by a return back to the origin. The difference between this sample and the sample from F.C. 1 is the Dawson City sample has a reversed primary paleomagnetism and F.C. 1 trends away from the origin suggesting a normal primary paleomagnetism. F.C. 1 was deposited either during a normal subchron within the Matuyama reverse chron (>0.984 Ma) or within the Gauss normal chron (>2.6 Ma; Figure 39).

## Sample 097 Flat Creek - Unit 1



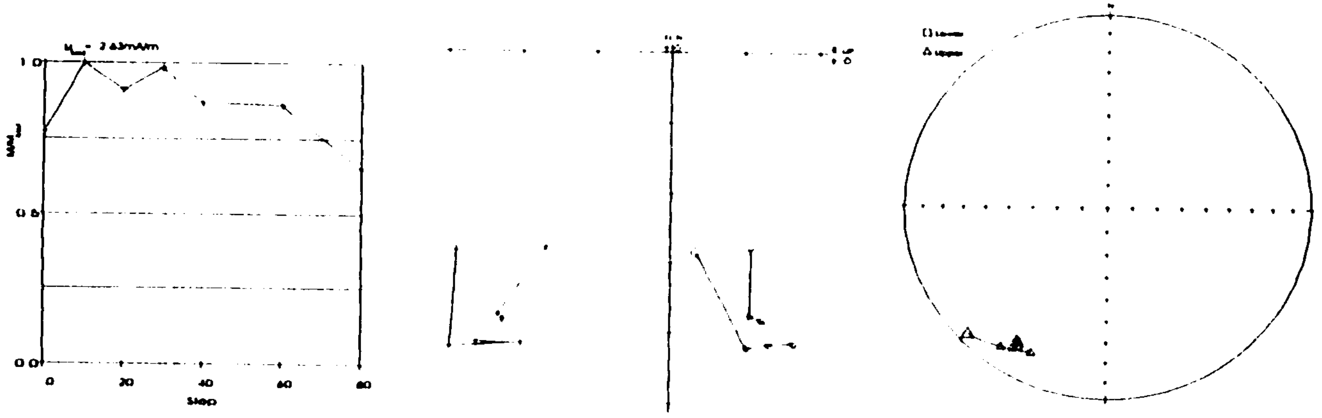
Normalized Intensities

Orthogonal Plot

Direction of Magnetization

Figure 37: Representative paleomagnetic diagrams from Flat Creek unit 1. Notice in the orthogonal plot that the vector on the left trends away from the origin. Upon complete demagnetization the vector will return to the origin. This final return to the origin represents the Bruhnes normal magnetization trend. The primary old normal magnetization is represented by the vector trending down to the right and the reverse overprint is represented by the vector up to the left.

Sample 109 Dawson City



Normalized Intensities

Orthogonal Plot

Direction of Magnetization

Figure 38: A sample from Dawson City that shows a good reversed magnetization (D.G. Froese collection)

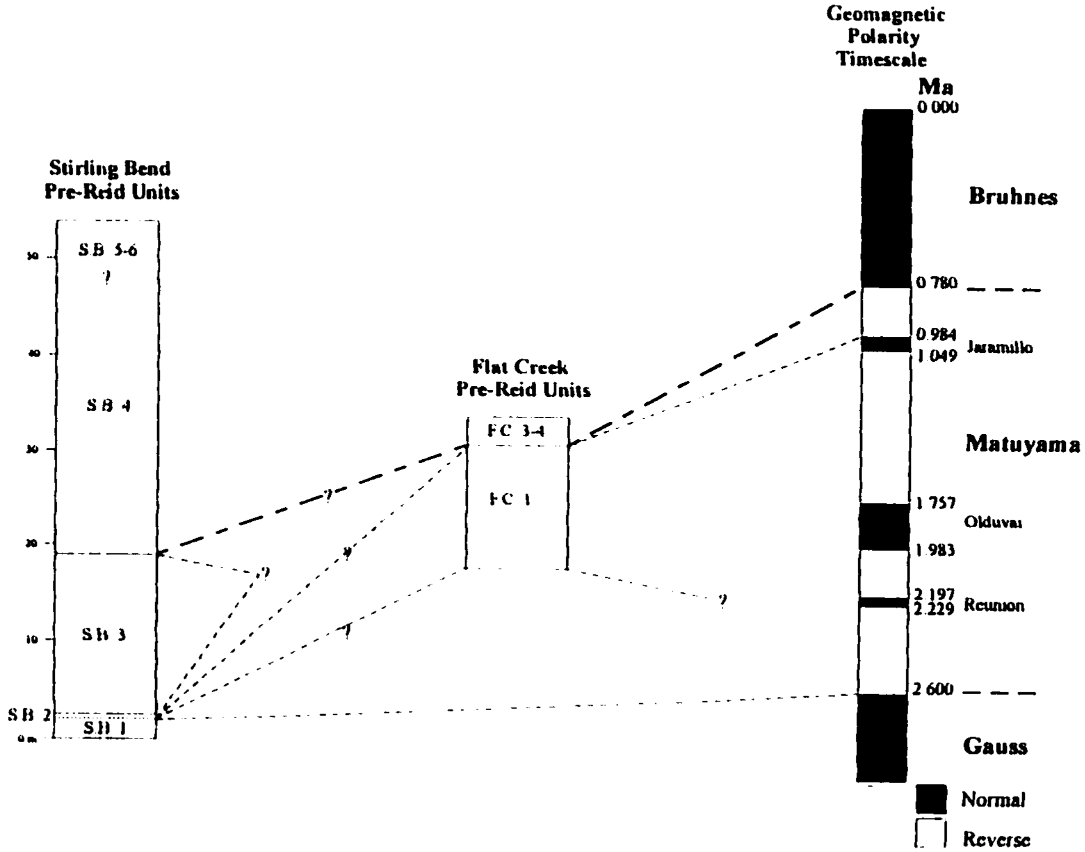


Figure 39: Stratigraphy of pre-Reid units in the study area.

### Unit F.C. 2

At the top of F.C. 1, is a weathered horizon resembling the Wounded Moose Luvisol (Figure 35 and 36). A summary of soil morphologies from the Wounded Moose paleosol in outwash and till is presented in Table 2.

**Table 2**

| **Wounded Moose Paleosol** | | | | | |
|---|---|---|---|---|---|
| Parent Material | Solum thickness (cm) | Dominant Colour Hue | | IIB horizon with clay skins % | Soils with Sand Wedges (%) |
| | | upper IIB | lower IIB | | |
| Outwash | 109 (58-205) | 5YR | 7.5YR | 100 | 34 |
| Till | 91 (50-123) | 7.5YR | 7.5YR | 100 | 75 |

(after Tarnocai and Smith 1989)

The dominant colour hue in F.C. 2 was 7.5YR 6/6 in the lower part of the soil horizon and 5YR 5/8 near the upper contact with F.C. 3. The horizon is inferred to represent the Wounded Moose paleosol based on similar rubification and the presence of clay skins in the uppermost and lower IIB horizon.

### Unit F.C. 3

Overlying F.C. 1 is a stratified diamict and lacustrine sequence (Figure 35 and 36). The diamict is matrix supported by mottled clayey silt and interspersed pebbles. It forms an erosional contact with the underlying gravel and abrupt contact with the adjacent lacustrine sequence. An unidentified volcanic ash is present within the diamict and ice wedge cast that extend into F.C. 1 and 2. This facies is interpreted as a debris flow deposit. Overlying and adjacent to the debris flow sediments are massive cohesive silty sand, with a minor clay content near the upper contact (Figure 36). Infrequent dropstones are incorporated in the silts. An erosional contact marks the upper boundary of the lacustrine sequence with a second matrix supported pebble unit, similar to the previous debris flow sediments. This facies is interpreted as being glaciolacustrine.

Twelve samples for paleomagnetism were obtained from the glaciolacustrine facies in F.C. 3. Paleomagnetic diagrams were not obtained from this unit, however, lab results suggest a good normal primary magnetic fabric. F.C. 3 was deposited during the Bruhnes normal Chron (Figure 39).

### Unit F.C. 4

A gravel sequence (F.C. 4) forms an erosional contact with F.C. 3 (Figure 35 and 36). All clasts are subrounded to rounded and bedding is planar. The position of the gravel is well above modern drainages on the Flat Creek beds suggesting a glaciofluvial origin. Furthermore, the amount of water necessary to mobilize the gravels in F.C. 4 is currently unavailable in local drainages. F.C. 4 was likely deposited by outwash from ice in Tintina Trench. A period of weathering is evident from the brownish yellow (10YR 6/6) tone to the gravel (possibly a BC horizon of a luvisol). Very little of the soil is preserved, however, it may record multiple periods of pre-Reid soil development. Fractured clasts, in the upper 20 cm of the outwash, indicate periglacial conditions after deposition.

### *Stirling Bend Section*

Stirling Bend section is the furthest downstream of three that are located on Stewart River within Tintina Trench (Figure 40). Stirling Bend is located within the Reid end moraine complex (Reid Lakes). The composite stratigraphy of Stirling Bend consists of a pre-Reid diamict and silt on bedrock (S.B. 1 and 2) overlain by pre-Reid gravel, which is overlain by sands and organics (S.B. 3, 4, 5, and 6). Reid gravel and a diamict unconformably overlie the pre-Reid sediments (S.B. 7 and 8). A truncated Koy-Yukon paleosol (Diversion Creek paleosol) and sand wedge casts occur on the Reid gravel that are subsequently overlain by McConnell loess and the Stewart neosol (S.B. 9 and 10).

Stirling Bend section is the most complex in the study area. To map the contacts, both laterally and vertically, 11 vertical transect were run that included information on the style of contacts and their sedimentology. The architecture of the section is shown in figure 41.

#### Unit S.B. 1

S.B. 1 is a diamict that overlies granite at the base of the downstream end of the section (Figure 41, 42, and 43). The diamict is 2.5 m thick and composed of highly oxidized cohesive stratified sand (70%) and pebbles (20%) with some small cobbles

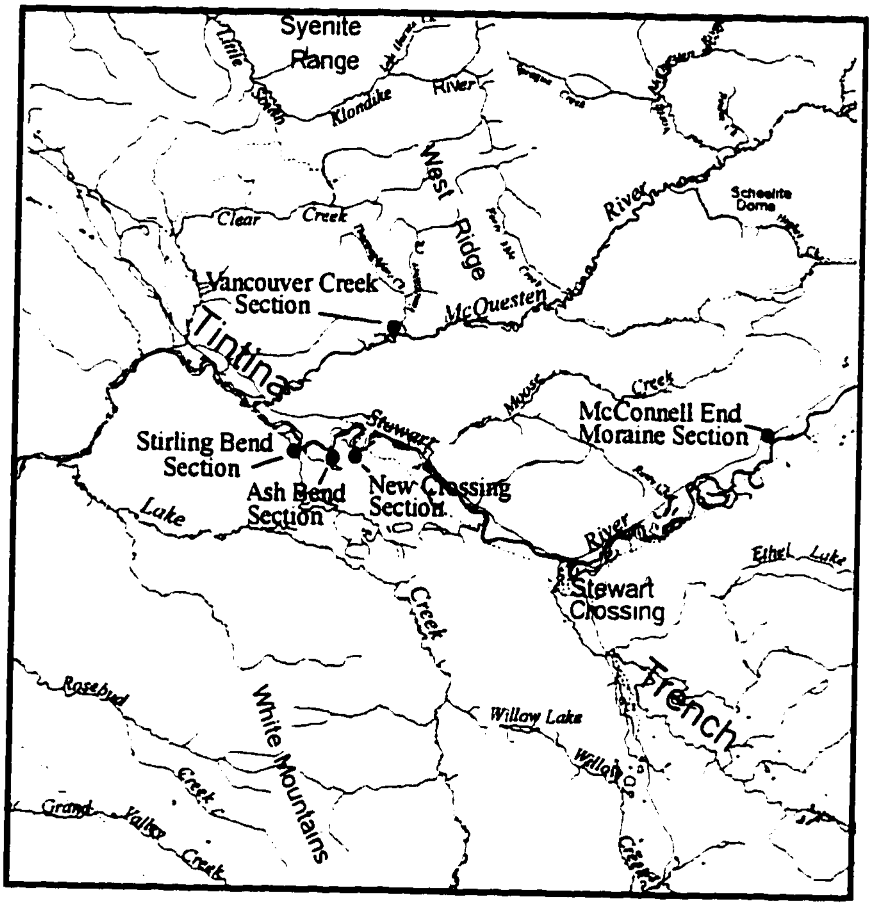


Figure 40: Location of sections studied in McQuesten map area.

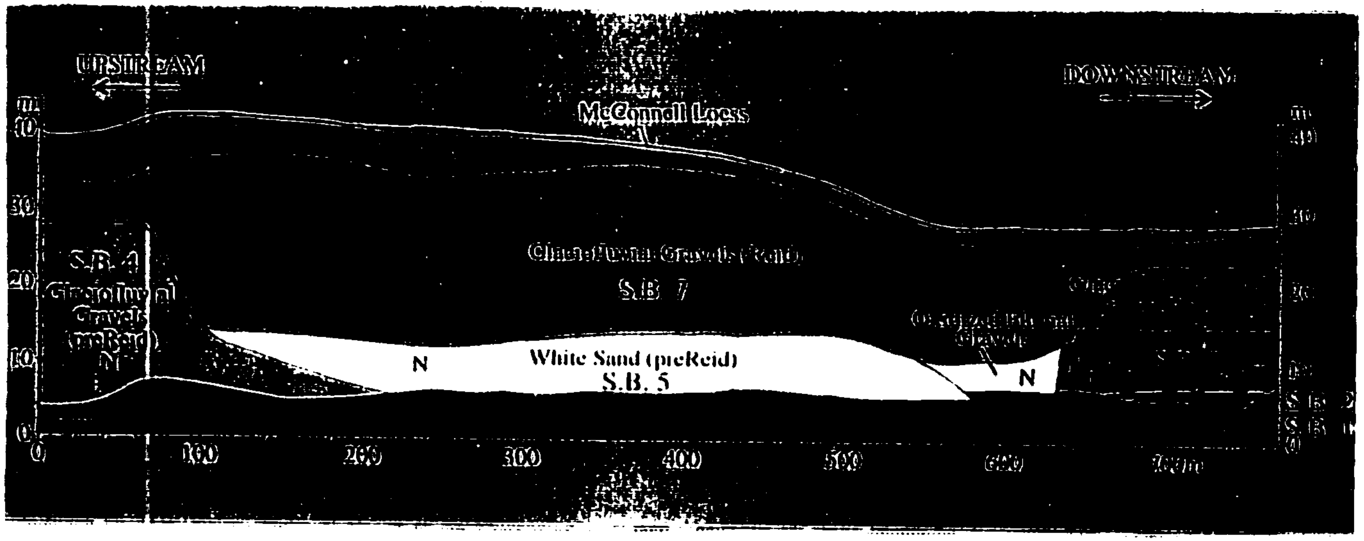


Figure 41: Stirling Bend Section

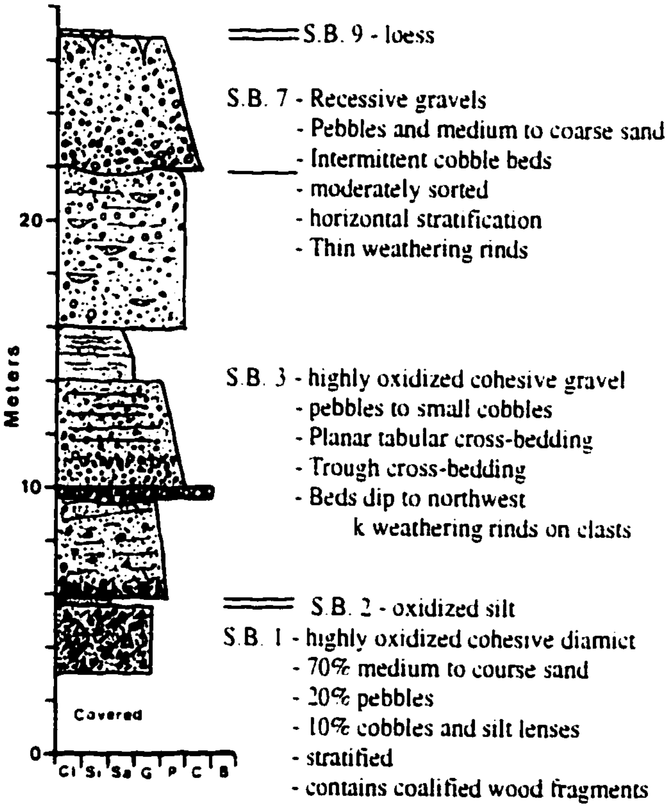


Figure 42: Stirling Bend stratigraphy and sedimentology at 740 m (740 m from the upstream end of the section).

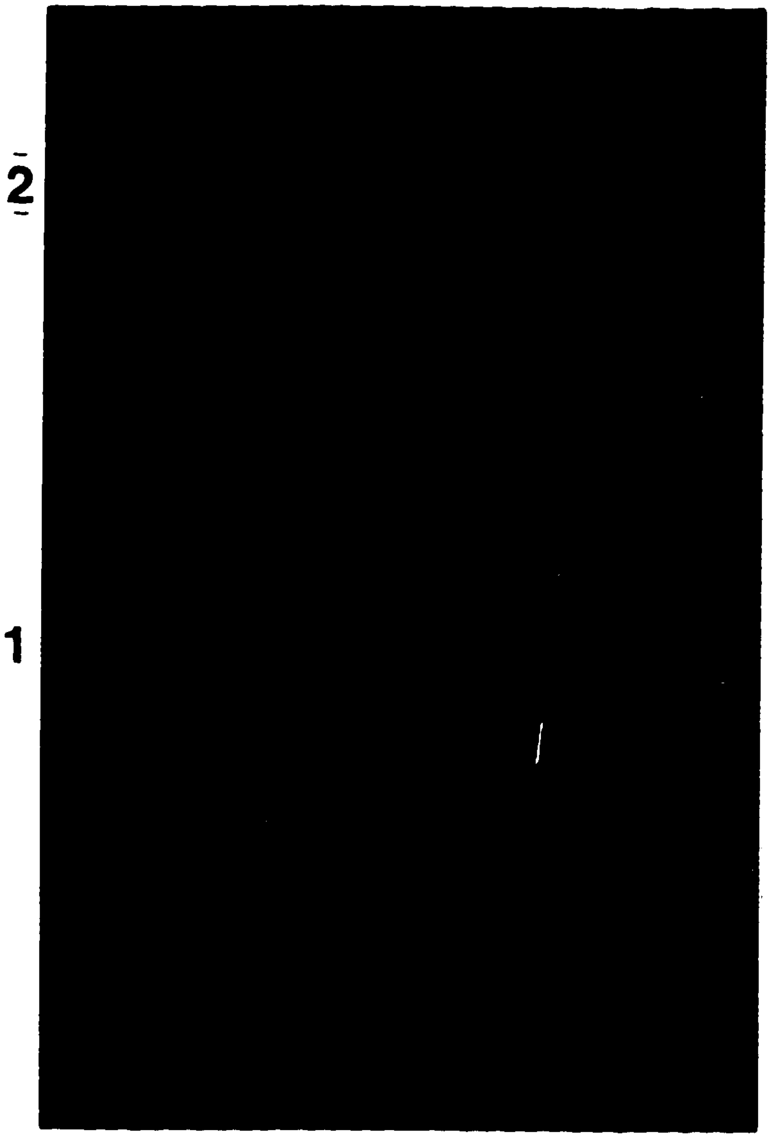


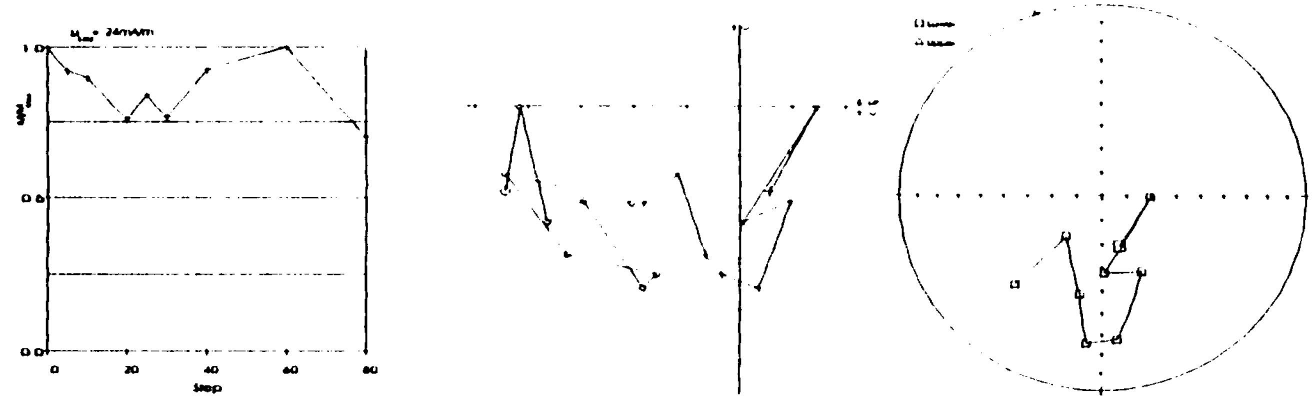
Figure 43: Unit 1, a mudflow deposit overlain by a consolidated loess sequence (unit 2), Stirling Bend.

and lenses of silty sand (Figure 43). An angular boulder (100 cm by 25 cm) of local lithology also occurs in the deposit (Figure 43). Partially coalified non-coniferous wood is incorporated into the finer sediments. Preliminary petrographic analysis of the wood indicated 0.14% lignite, suggesting it is late Tertiary (Goodarzi 1994). The intact nature of the samples suggests coalification occurred *in situ*. If the wood fragments represent reworked material then the depositional process, also involved in transporting boulders, would have shattered the coalified portion. S.B. 1 is interpreted to be a debris flow deposit. Whether the diamict was deposited in conjunction with glacial or nonglacial conditions is currently unknown.

### Unit S.B. 2

S.B. 2 consists of highly oxidized consolidated silt and forms an erosional contact with S.B. 1 (Figure 41, 42, and 43). S.B. 2 is interpreted as a loess deposit. It is currently uncertain whether S.B. 1 and 2 are contemporaneous. Samples for paleomagnetic analyses were obtained from the loess by chiseling two blocks from the face of the exposure. Orientations were drawn on the blocks upon removal and 8 samples were drilled from the blocks in the lab. Figure 44 shows an example of the quality of data from S.B. 2. In both the orthogonal plot and the stereographic projection (Direction of Magnetization diagram) it is apparent there are no trends or clustering to suggest a clear primary magnetic fabric. No paleomagnetic directions can be derived from the current samples and further sampling will be required before

## Sample 194 Stirling Bend - Unit 2



Normalized Intensities

Orthogonal Plot

Direction of Magnetization

Figure 44: Representative paleomagnetic diagrams from unit 2 at Stirling Bend. Notice the incoherent vector trends in the orthogonal plot and poor clustering in the Direction of Magnetization diagram. The paleomagnetism for this unit is indeterminable.

correlations are made with the geomagnetic timescale.

### Unit S.B. 3

S.B. 3 overlies S.B. 2 at the downstream end of the section and consists of 16.4 m of cohesive oxidized gravel (Figure 41, 42, and 45). Clasts have a subrounded to rounded appearance and the angle of crossbedding is between 8 and 22° (Figure 45). The bedding is normal and reversely graded. All clasts are highly oxidized and many have weathering rinds that penetrate the clast core. S.B. 3 is interpreted as a glaciofluvial deposit characteristic of a distal braided river regime (Donjek type, Miall 1978). Nine paleomagnetic samples were taken from S.B. 3 in sandy silt about 3 m above bedrock. Results, similar to S.B. 2, were incoherent, suggesting oxidization has scattered the paleomagnetic signal.

### Unit S.B. 4

S.B. 4 consists of 26 m of semicohesive to cohesive gravel (Figure 41, 46, and 47). Clasts are subround to rounded throughout and contacts are abrupt or erosional. An unsorted cobble bed near the base of the unit is also present (Figure 47). S.B. 4 is interpreted as a pre-Reid glaciofluvial outwash. Ten samples were collected for paleomagnetism from a lense of clayey silt 22.5 m above the river level, immediately below the contact with younger recessive gravels. Results indicate a normal magnetization, however, upon complete demagnetization it is unclear if the

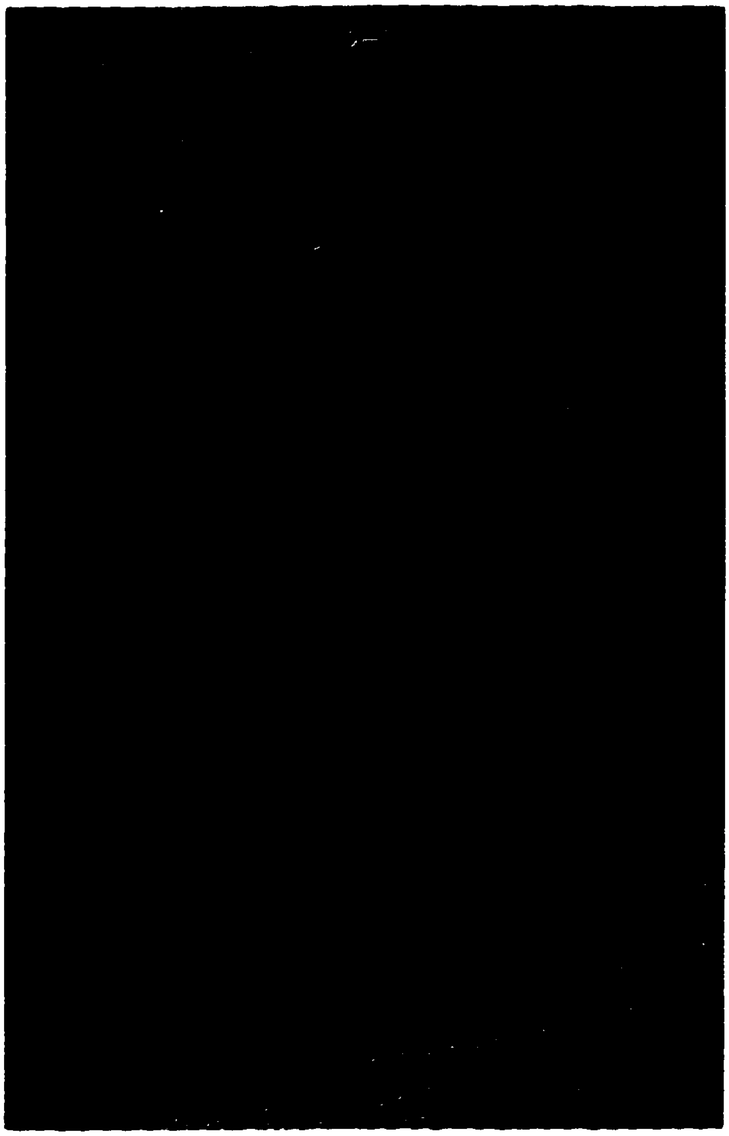
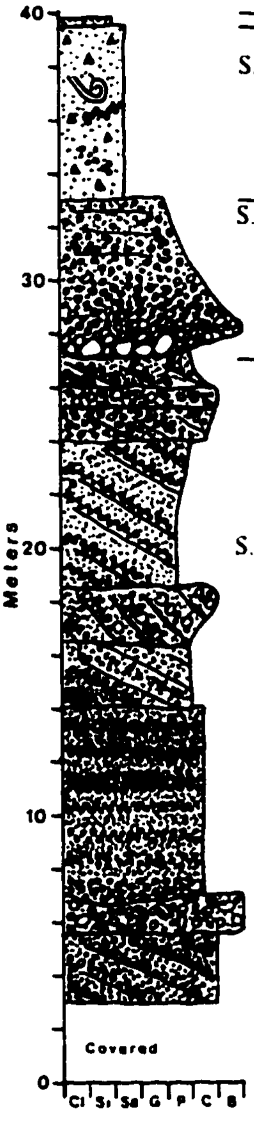


Figure 45: Unit 3, highly oxidized glaciofluvial gravels, Stirling Bend.



S.B. 10 - loess

S.B. 8 - massive sandy silt diamicton
- cohesive
- contorted lenses of pebbles and sand
- sand wedge casts

S.B. 7 - recessive gravels
- pebbles and medium to coarse sand
- intermittent cobble beds
- moderately sorted
- horizontal stratification
- thin weathering rinds
- normal grading

S.B. 4 - semicohesive-cohesive gravels
- pebbles with interspersed cobbles
- poorly to moderately sorted
- oxidized
- ersoional contacts (common)
- horizontal bedding
- planar tabular crossbeds
- trough crossbeds

Figure 46: Stirling Bend stratigraphy and sedimentology at 40 m

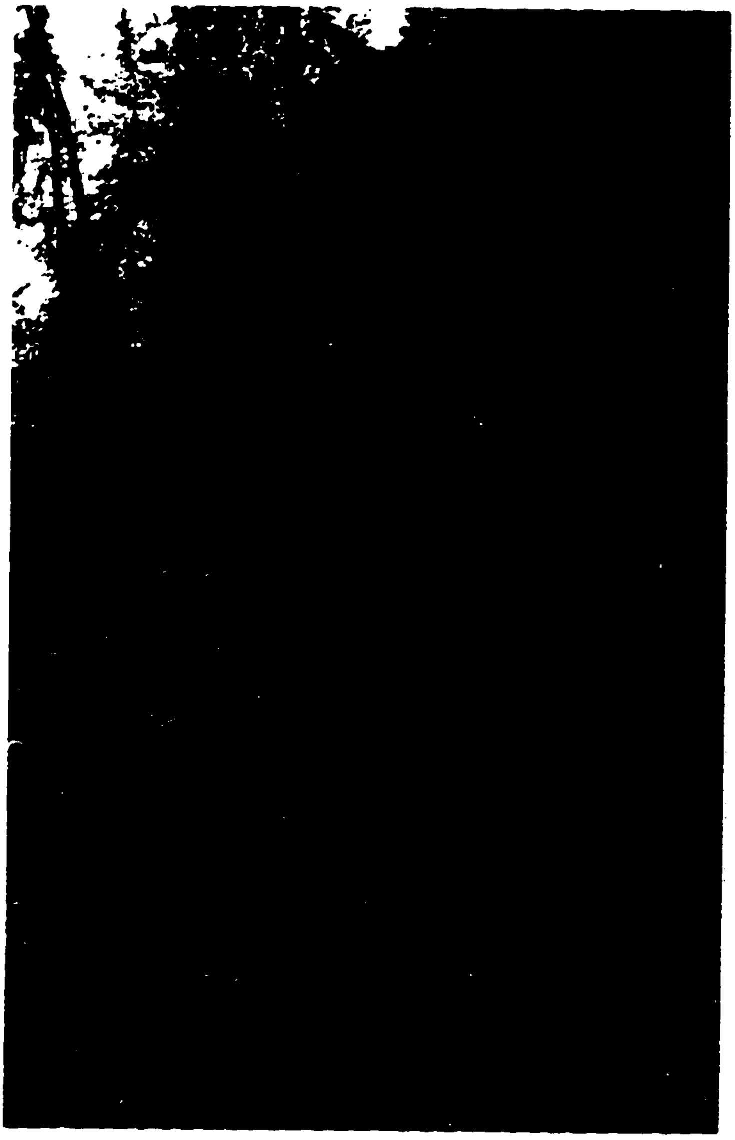


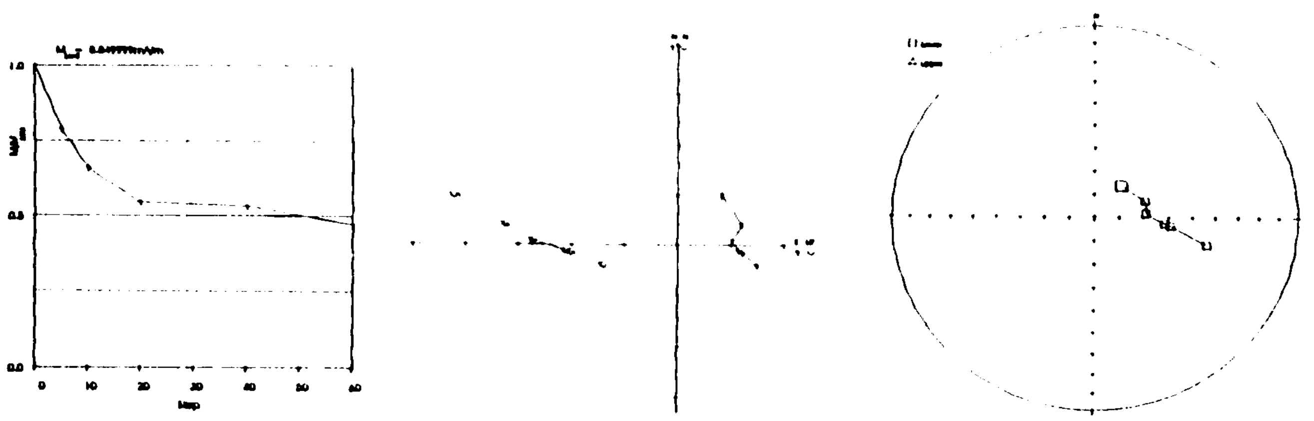
Figure 47: Unit 4, unsorted boulder and cobble facies near water level. The overall normal grading within the unit suggests a retreatal glaciofluvial outwash environment.

magnetization moves to a normal underprint or a reversed underprint. In the orthogonal plot (Figure 48) demagnetization resembles a normal trend but is not heading towards the origin. This suggests their may be an underprint yet exposed in the demagnetization process, which would take the trend back to the origin. Other samples resembled good normals but the majority had to be forced through origin. S.B. 4 is interpreted as having crude normal primary magnetism (Figure 39).

### Unit S.B. 5

S.B. 5 extends 500 m along the base of Stirling Bend section and is up to 8 m thick (Figure 41 and 49). S.B. 5 is separated from S.B. 3 by an ice wedge cast and stratigraphically overlies S.B. 4. The deposit consists of semi-cohesive stratified silty sand. Lenses of stratified medium to course sand and clay are present in finer fractions. Contorted diamict lenses interspersed with lenses of fine sand are present near the base of the unit. The sand is light gray (5Y7/1), and light olive brown (2.5Y5/4) where oxidation has occurred. Secondary tilting and faulting has occurred. At the downstream end bedding exceeds 45°, which may indicate glaciotectonism from surface loading or sediment dewatering. No organic material is visible in the unit. S.B. 5 is interpreted as a deltaic sequence in a glacial lake. The origin of the lake was likely proglacial or the result of a sediment dam in Tintina Trench. An ice marginal environment would explain the high angle bedding from the collapse of sand over melting glacier ice at depth. Twenty samples were collected for

## Sample 119 Stirling Bend - Units 4 and 5

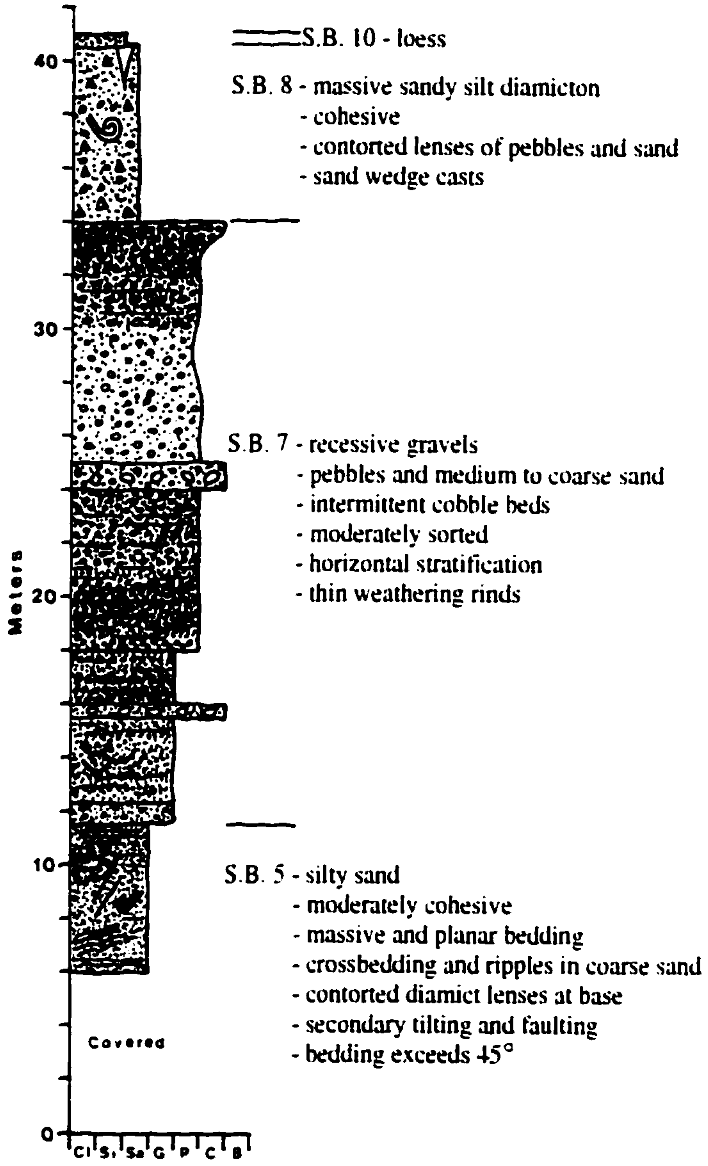


Normalized Intensities

Orthogonal Plot

Direction of Magnetization

Figure 48: Representative paleomagnetic diagrams from units 4 and 5 at Stirling Bend. While some samples from unit 5 represented good normals, others similar to this sample from unit 5 had to be forced through the origin in the orthogonal plot. This may suggest a normal or reverse under print that has yet to be exposed. Samples from unit 4 resemble this trend.



S.B. 10 - loess

S.B. 8 - massive sandy silt diamicton
- cohesive
- contorted lenses of pebbles and sand
- sand wedge casts

S.B. 7 - recessive gravels
- pebbles and medium to coarse sand
- intermittent cobble beds
- moderately sorted
- horizontal stratification
- thin weathering rinds

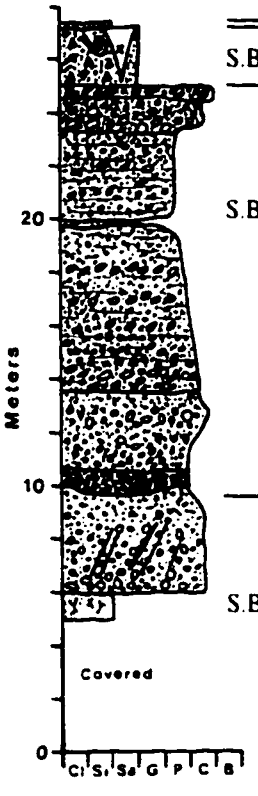
S.B. 5 - silty sand
- moderately cohesive
- massive and planar bedding
- crossbedding and ripples in coarse sand
- contorted diamict lenses at base
- secondary tilting and faulting
- bedding exceeds 45°

Figure 49: Stirling Bend stratigraphy and sedimentology at 240 m

paleomagnetic analyses from three locations in S.B. 5. Two sites were chosen near the base of the section and a third was chosen near the top. In the two lower sites the deposit was convoluted with interbedded oxidized cross-bedded sand. The upper locality consists of bedded sand with silty-clay sand. Iron oxidation is present in the coarser components. The principal magnetization from two of the groups was normal and, like S.B. 4, appear to have an underprint that may move to a normal or reversed polarity. The third sample site returned a normal paleomagnetism (Barendregt, written communication 1995). S.B. 5 is interpreted to be of Bruhnes age (Figure 39).

**Unit S.B. 6**

S.B. 6 occurs 5-7 m above the river and consists of organic-silt in a swale incised into S.B. 5 (Figure 41, 50 and 51). The deposit contains a compressed unit of peat, wood, and mixed organics in silt. Hughes *et al.* (1987) and Tarnocai and Schweger (1991) described a paleosol below the deposit and named it the Stirling Bend paleosol. The paleosol was covered by colluvium during field investigations in 1994. The Stirling Bend paleosol displayed Cryosolic soil development of pre-Reid age similar to soil characteristics in the Canadian Arctic and Subarctic today (Tarnocai and Schweger 1991). Pollen analysis from the soil indicate *Cyperaceae* pollen and other herbaceous taxa, which is overlain by horizons dominated by *Betula* pollen and minor quantities of *Cyperaceae* (Tarnocai and Schweger 1991). Pollen analysis of the overlying organic-silt with logs indicate an assemblage dominated by *Picea*, *Betula*,



S.B. 10 - loess

S.B. 8 - massive sandy silt diamicton
- cohesive
- contorted lenses of pebbles and sand
- sand wedge casts

S.B. 7 - recessive gravels
- pebbles and medium to coarse sand
- intermittent cobble beds
- moderately sorted
- horizontal stratification
- thin weathering rinds

S.B. 6 - organic silt
- peat and compressed wood
- organics are capped by oxidized gravels

Figure 50: Stirling Bend stratigraphy and sedimentology at 640 m.

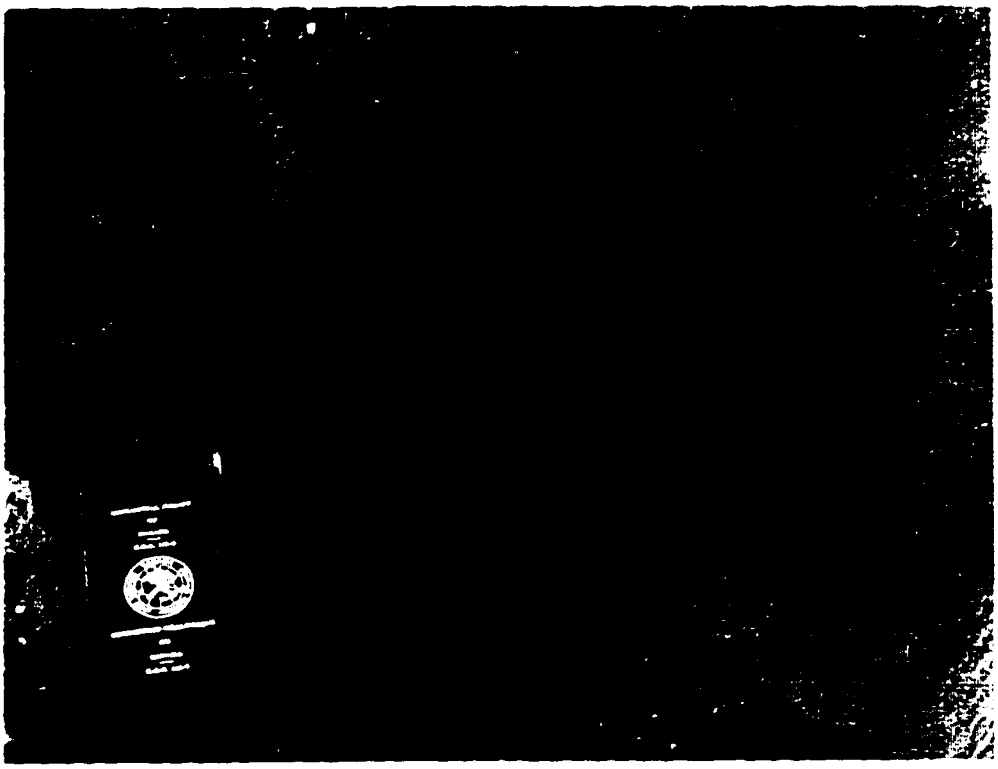


Figure 51: Stirling Bend organics (unit 6). The deposit consists of interbedded organics with silt and fine sand. The organics indicate a pre-Reid interglacial climate that was milder than today, based on macrofossil analyses. Paleomagnetic sample cylinders are evident in the photo.

*Cyperaceae*, and small amounts of *Alnus* pollen (Tarnocai and Schweger 1991). The environment reconstructed from the pollen analyses suggests a transition from sedge tundra to birch shrub tundra and into a spruce forest vegetation in a wetland environment (Hughes *et al.* 1987). Macrofossil analysis from the organic-silt is outlined in Table 3.

**Table 3**

| **Macrofossils from Stirling Bend Unit 6** | |
|---|---|
| **Plant Macrofossils** | **Insect Macrofossils** |
| *Rubus idaeus* | Pronotum: *Pterostichus (Cryobius) brevicornis kirby, coleoptera* |
| *Oxyria digym* | Head: *Lepidophorus lineacollis kirby,* |
| *Hippuris vulgaris* | Pronotum: *Lepidophorus lineacollis kirby* |
| *Carex* | Pronotum: *Morychus sp.* |
| spruce needles | *Statoblast Cristatella* |
| *Ranunculus* | *Statoblast Cristatella mucedo* |
| *Lycopus* | 3 heads: *Pterostichus (Cryobius)* |
| *Alisma* | Elytra: *Lepidophorus lineacollis kirby* |
| *Potentilla* | egg cases: Ephippia of *cladocera (crustacea)* |
| | *Dytiscida* (water beetle) |

(identification by J. Matthews, written communication 1994)

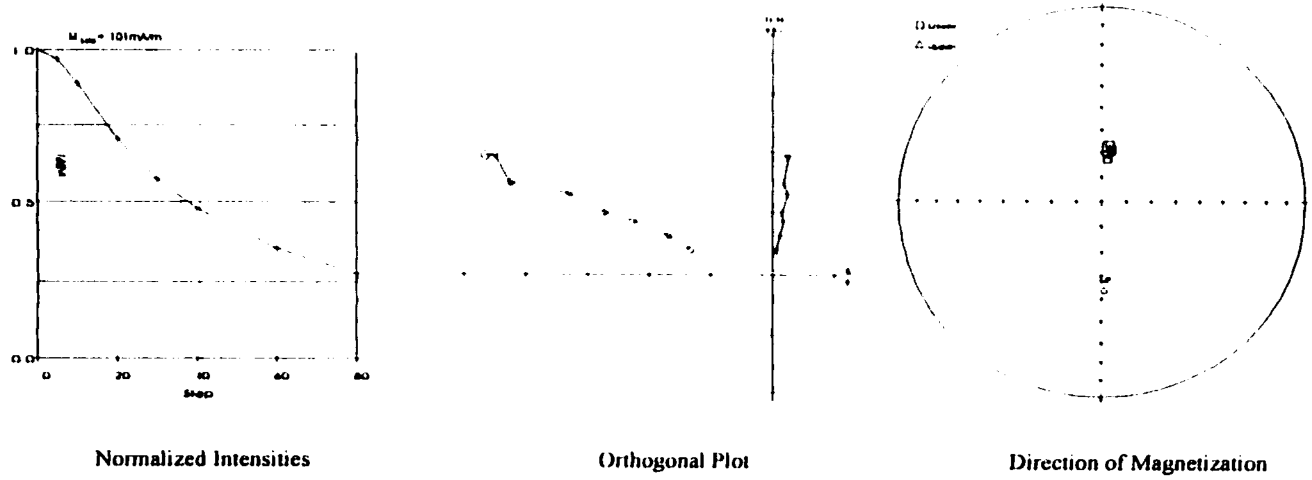
Plant and insect macrofossils suggest S.B. 6 was likely a wetland, streambank, or lakeshore in a spruce boreal forest. This is supported by the presence of bedded silty sand with peat and spruce logs. Preliminary macrofossil analysis complies with a spruce forest vegetation, and the presence of *Lycopus* and *Alisma*, species not found in the Yukon today, may suggest a climate warmer than present. This supports the pedologic data that warmer conditions have persisted in central Yukon during the early to mid Pleistocene (Rutter *et. al.* 1978).

S.B. 6 was sampled for paleomagnetics at two locations. Seventeen cylinders of sediment were collected approximately 5 - 6 m above river level. At each locality the sediment consisted of sandy-silt with organics. Organics varied and sampling was confined to areas with a high mineral content. The primary magnetic fabric is interpreted as a normal polarity. A representative stereoplot from S.B. 6 (Figure 52) shows clustering in the northern hemisphere of the stereographic projection. The vector component diagram indicates a consistent normal magnetization trending toward the origin. S.B. 6 was deposited during the Bruhnes normal Chron.

## Unit S.B. 7

S.B. 7 is the most extensive unit at Stirling Bend and overlies all pre-Reid sediments in the section (Figure 41 and 50). Differentiation of Reid and pre-Reid deposits within the section is based on the degree of weathering of clasts. Oxidation of Reid clasts is restricted to surface alteration, such as manganese staining, whereas

## Sample 153 Stirling Bend - Unit 6



Normalized Intensities

Orthogonal Plot

Direction of Magnetization

Figure 52: Representative paleomagnetic diagrams from unit 6 at Stirling Bend section. Both vectors in the othogonal plot trend to the origin, indicative of normal magnetization of Bruhnes age. The direction of magnetization diagram shows clustering in the northern hemisphere, consistent for a deposit of Bruhnes age.

pre-Reid clasts are often oxidized to the core. Pre-Reid gravel are also more cohesive in comparison to the recessive Reid gravel (Figure 53). S.B. 7 consists of moderately sorted pebbles and sand with minor cobbles (Figure 46 and 53). The upper 3 m consists of stratified sand and pebbles. A gravel sequence consisting of large cobbles and boulders of up to 1 m by 1 m overlies S.B. 4 at the upstream end of the section (Figure 53).

Secondary accumulation of manganese and iron oxides has occurred in the lower half of the Reid gravel. Initially an oxidized layer at the base of S.B. 7 was interpreted as a pre-Reid gravel. Closer examination indicated that oxidation was confined to the surface of the clasts. The build up of manganese and iron oxide in subsurface gravel is related to the leaching of soluble oxides from ferromagnesian minerals, typically of volcanic origin (Hausenbuiller 1985). The red and bluish black residue that remains in the gravel is the actual iron and manganese-oxide precipitate. Iron oxide will often oxidize to hematite upon aeration of the sediments when the water table drops (Hausenbuiller, 1985). As the Stewart River downcut into the Reid end moraine complex the precipitate was left on the surface of the clasts.

Stirling Bend is an exposed outwash plain near the limit of the Reid glaciation. Unit S.B. 7 structurally controls the morphology of the sections and plain and is therefore interpreted as a Reid glaciofluvial gravel. The sedimentological data also supports this conclusion.

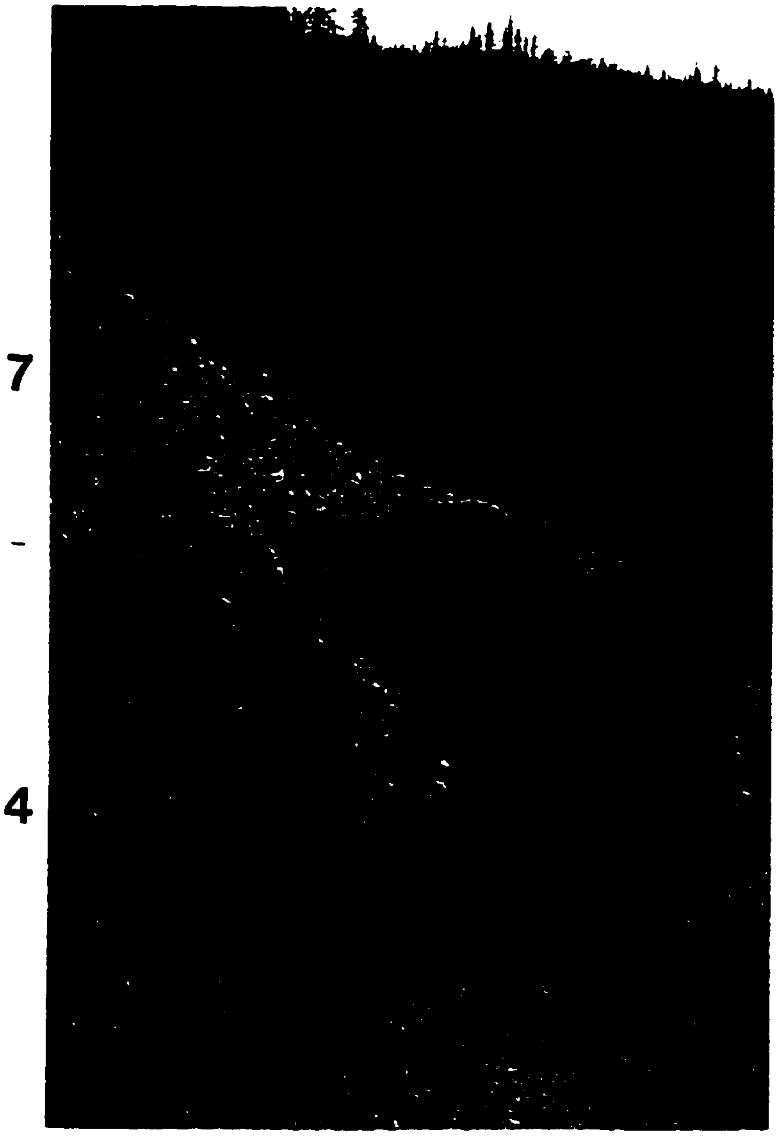


Figure 53: Unit 4, oxidized pre-Reid glaciofluvial gravels at Stirling Bend. Recessive Reid glaciofluvial gravels overlie the pre-Reid sediments.

### Unit S.B. 8

S.B. 8 is a massive sandy silt diamicton overlying all of S.B. 7 (Figure 41 and 50). The unit intermittently cuts out along the top of the section and crosscuts itself. McConnell sand wedge casts dissect the diamict. S.B. 8 is interpreted as a mudflow. The upper 2 m of S.B. 7 coarsen upward from a stratified pebbly sand to an openworked gravel below the diamict (Figures 49 and 50). The increase in grain size at the top of S.B. 7 and the deposition of S.B. 8 may have formed when a lake, within the hummocky moraine, was suddenly drained.

### Unit S.B. 9

S.B. 9 is a truncated horizon similar to the Diversion Creek paleosol described on the Reid terminal moraine near Reid Lakes (Smith *et al.*, 1986). Reid and pre-Reid surfaces in McQuesten map area commonly have an incomplete Diversion Creek soil profile - only the Bm, BC, and Ck horizons of the Eutric Brunisol were preserved following McConnell glaciation (Rutter, 1978). Erosion of the paleo A and B horizon occurred when McConnell katabatic wind deflated the upper horizons that had formed in Reid loess. S.B. 9 is interpreted as a truncated Diversion Creek paleosol.

### Unit S.B. 10

S.B. 10 consists of 20-30 cm of silt that is interpreted as McConnell loess. Associated with the loess are sand wedge casts that formed under McConnell periglacial conditions. Ground Squirrel (*Spermophilus parryii*) bones, collected from a sand wedge at Stirling Bend, were dated to 11460 ± 80 BP (Figure 33). This age suggests that periglacial conditions, imposed by the McConnell glaciation, had ameliorated in the McQuesten area by 11.5 Ka BP enabling ground squirrels to subsist.

### *Ash Bend Section*

Ash Bend section is located on the Stewart River upstream from Stirling Bend section (Figure 40). Ash Bend, like Stirling Bend, is an exposure of a Reid glaciofluvial plain. The section consists of 26 m of partially covered gravel (A.B. 1), 8 m of diamict (A.B. 2), 23 m gravel, which is capped by 2.2 m of diamict (A.B. 3 and 4). A truncated paleosol is weathered into A.B. 3 (A.B. 5). Also cut into the gravels, at the top of the section, is a swale containing organic-silt and the tephra (A.B. 6).

### Unit A.B. 1

A.B. 1 consists of planar stratified and clast supported strata (Figure 54 and 55). Clast size range between 2-4 cm and 12-20 cm; the dominant clast shape is subangular to subrounded. Open worked structures are more common towards the contact with the diamicton, including more disorganized bedding (Figure 54). A.B. 1 is interpreted as an Reid glaciofluvial gravel based on its position within a Reid glaciofluvial complex.

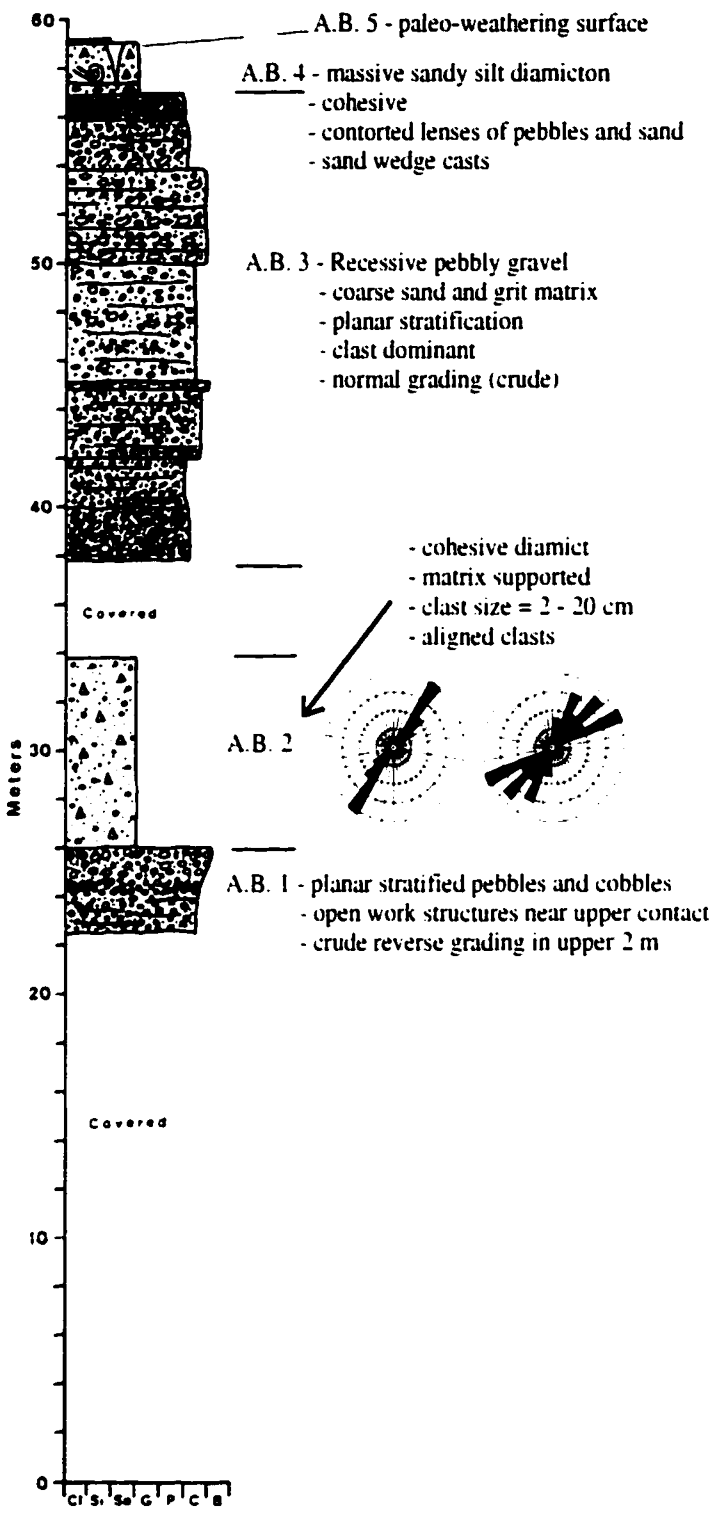


Figure 54: Ash Bend stratigraphy and sedimentology with till fabric diagrams

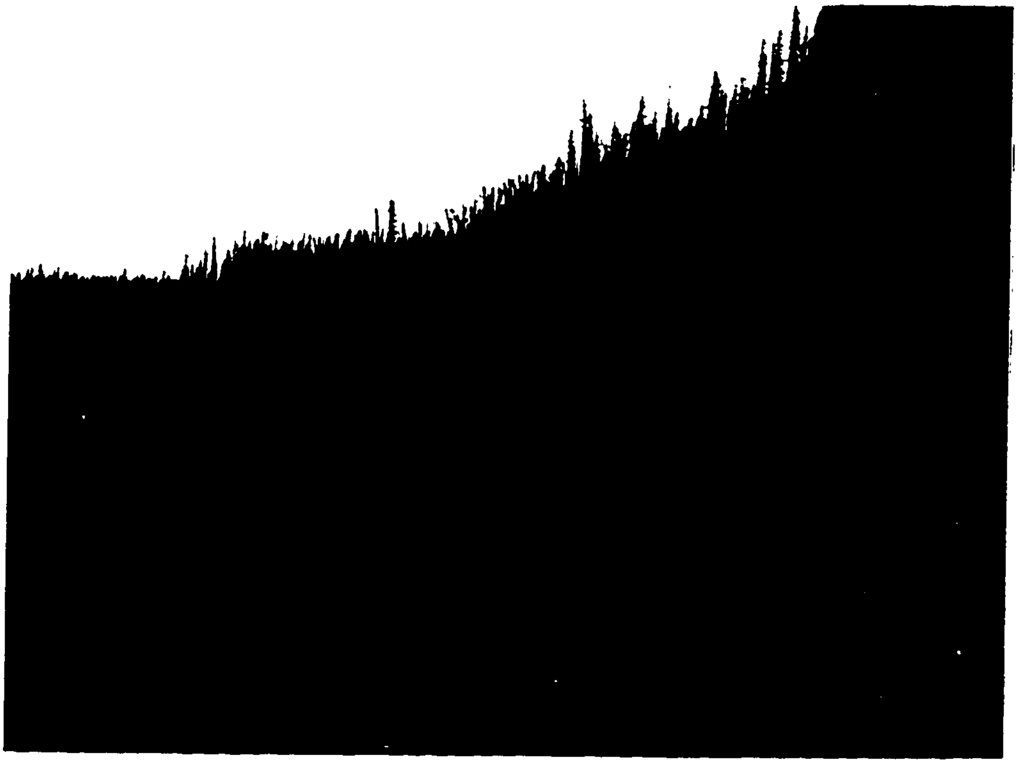


Figure 55: Ash Bend section on Stewart River near the terminus of the Reid glaciation. The cohesive till, unit 2, separates advance and retreatal outwash, units 1 and 3.

### Unit A.B. 2

A.B. 2 is a cohesive diamict deposit, that forms a prominent layer across the middle of the section (Figure 54 and 55). The diamict consists of clast ranging from 2-20 cm in a matrix of silty sand and clay. Fabric analysis indicates alignment from southwest to northeast, and dip to the northeast (Figure 54). The upper and lower contacts are erosional. From the fabric analyses, structure, and position of the diamict within the Reid end moraine complex, A.B. 2 is interpreted to be a Reid till.

### Unit A.B. 3

A.B. 3 consists of clast supported gravel with minor sand and cobbles (Figure 54 and 55). Planar stratification and imbrication are the primary sedimentary structures. The gravels are moderately to well sorted. A.B. 3 is interpreted to be a Reid retreatal glaciofluvial gravel. This is supported by the geomorphology and its stratigraphic position over the Reid till. A Mammoth tusk (*Mammuthus primigenius*) was discovered at the toe of a colluvial apron at the contact between A.B. 2 and A.B. 3 (Figure 56). The tusk has eroded from A.B. 3 approximately 45 - 50 m above river level and became wedged at the base of the fan on the resistant till layer. A conventional $^{14}$C date from internal ivory indicated an age of >33 000 Ka BP (SRC - 3606). This supports a pre-McConnell age for the deposit.

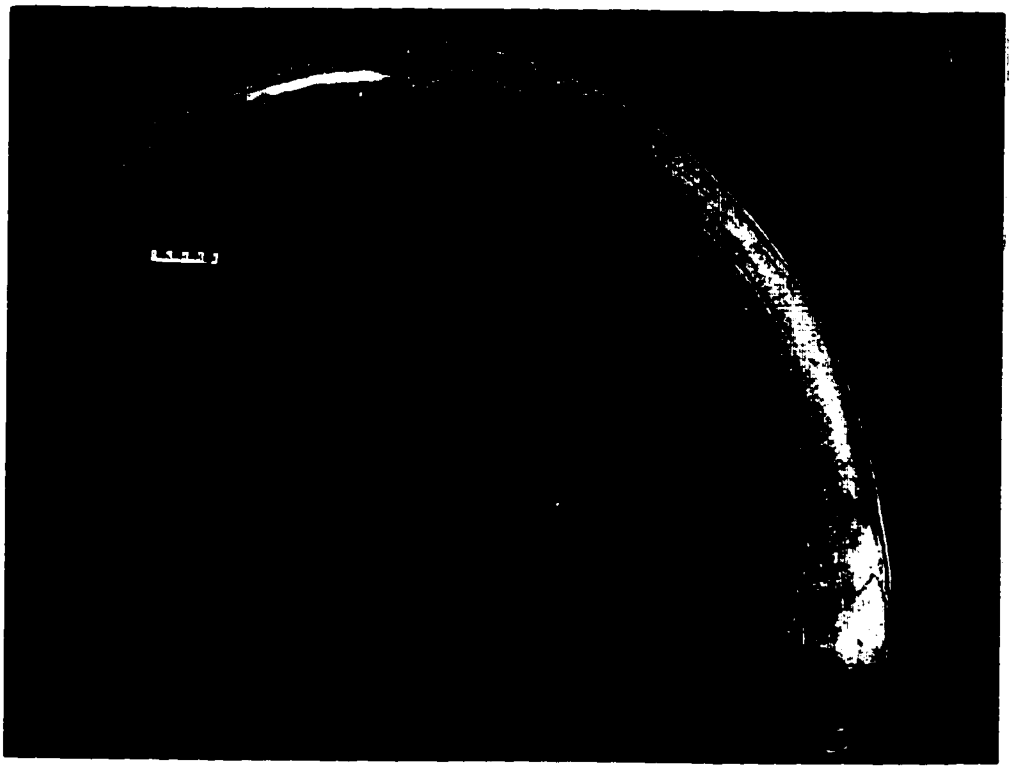


Figure 56: Mammoth (*Mammuthus primagenius*) tusk from Reid outwash at Ash Bend section (unit 3). Internal ivory was dated at >33 000ka BP.

### Unit A.B. 4

A.B. 4 is a massive diamicton, containing interspersed pebbles in a matrix of silty fine sand (Figure 55). A.B. 3 becomes openworked near the contact with the diamicton and is similar to S.B. 8 at Stirling Bend. A.B. 4 is interpreted as a mudflow that was deposited from a sudden influx of meltwater across the glaciofluvial plain, possibly from a drained lake.

### Unit A.B. 5

A.B. 5 is a truncated horizon at the top of the section. The weathering characteristics are similar to the truncated horizon documented from Stirling Bend (S.B. 9). The horizon is interpreted to be the lower horizons of the Diversion Creek paleosol that developed during the Koy-Yukon interglaciation.

### Unit A.B. 6

A.B. 6 consists of an organic swale incised 10 .5 m into the Reid outwash (Figure 57). The deposit consists mainly of interbedded organics and silt with minor clay. Sheep Creek tephra and vertebrate fossils were identified previously within the unit (Hughes *et al.* 1987; Figure 57). The post-Reid or Koy-Yukon interglaciation dates to 200 Ka, according to a date on the Sheep Creek tephra near Fairbanks (Berger 1994). Preliminary pollen and macrofossil analyses indicate a transition from a boreal forest below the tephra to arid tundra above it (Hughes *et al.* 1987). This

Figure 57: Sheep Creek tephra within the Ash Bend organic deposit. The tephra is dated at 200 Ka and provides a minimum date for the Koy-Yukon interglaciation (Berger, 1994).

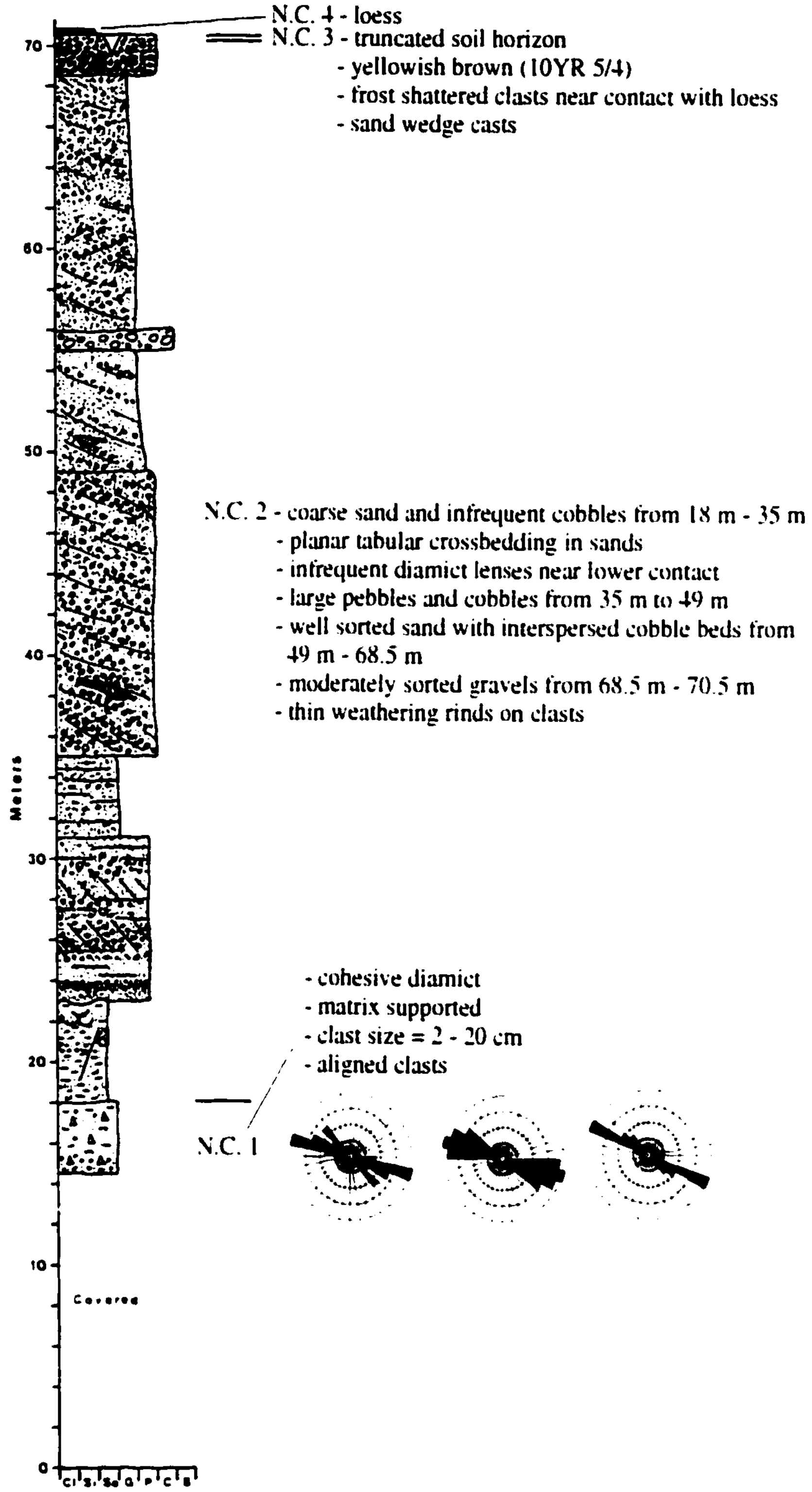
may record the onset of the McConnell glaciation. This site has also produced numerous vertebrate fossils, consisting mostly of Bison (*Bison sp.*), Mammoth (*Mammuthus*), and Moose (*Alces*). Interestingly, many Bison bones have been found 1 m below the Sheep Creek Tephra (Hughes *et al.*, 1987). This deposit may contain the most detailed record of bioclimatic conditions during the last interglacial in central Yukon. Systematic analyses of pollen and macrofossils from A.B. 6 is necessary to reconstruct the last interglacial climate in central Yukon.

### *New Crossing Section*

New Crossing section is located upstream from Ash Bend section on the Stewart River (Figure 37). New Crossing section consists of 3.5 m of glacial diamict at the base of the section overlain by 50 m of gravel (N.C. 1 and 2) and 2-3 m of gravelly diamict cap the gravel (N.C. 3). A truncated soil horizon is present at the top of N.C. 3 (N.C. 4). The section is capped by a silt unit (N.C. 5).

### Unit N.C. 1

N.C. 1 is a cohesive, matrix dominant diamicton consisting of 50% silty fine sand, 35% pebbles, and 15% cobbles (Figure 58 and 59). The diamict has a pale olive (5Y 6/3) colour. Fabric analysis indicates alignment from southeast to northwest with clasts dipping to the northwest (Figure 59). N.C. 1 is interpreted as Reid till based on its location, stratigraphic position, and sedimentologic characteristics.



N.C. 4 - loess

N.C. 3 - truncated soil horizon
- yellowish brown (10YR 5/4)
- frost shattered clasts near contact with loess
- sand wedge casts

N.C. 2 - coarse sand and infrequent cobbles from 18 m - 35 m
- planar tabular crossbedding in sands
- infrequent diamict lenses near lower contact
- large pebbles and cobbles from 35 m to 49 m
- well sorted sand with interspersed cobble beds from 49 m - 68.5 m
- moderately sorted gravels from 68.5 m - 70.5 m
- thin weathering rinds on clasts

- cohesive diamict
- matrix supported
- clast size = 2 - 20 cm
- aligned clasts

N.C. 1

Figure 58: New Crossing section stratigraphy and sedimentology. Stewart River

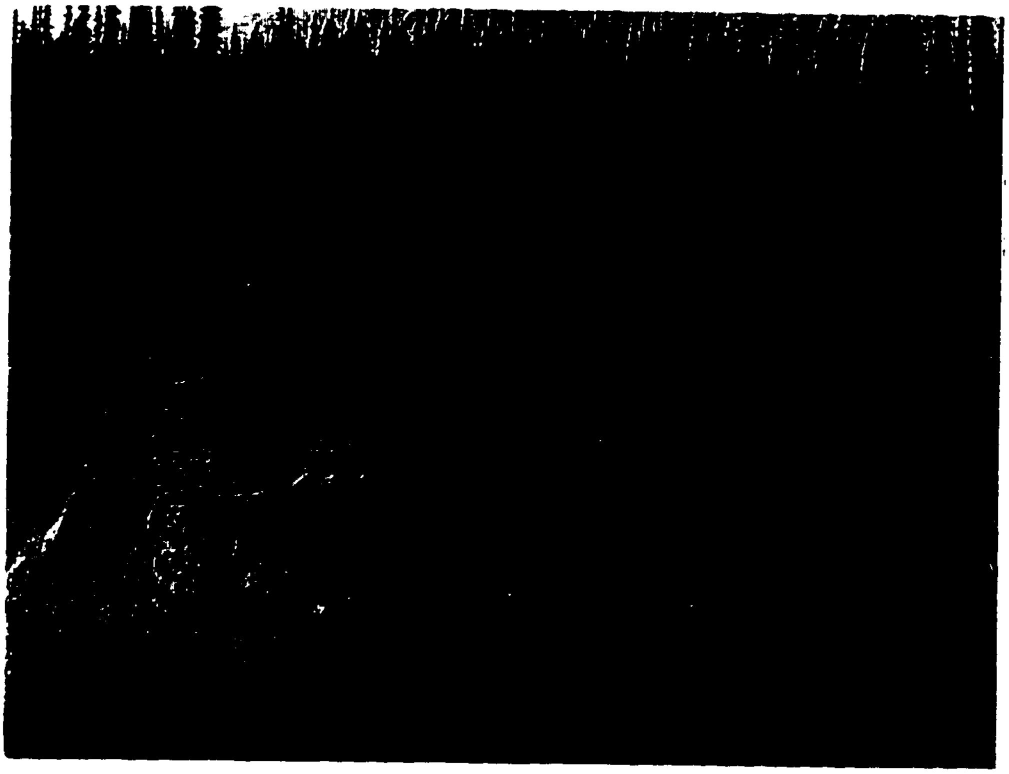


Figure 59: New Crossing section on the Stewart River, upstream from Ash Bend. The cohesive till unit (1) observed in figure 55 rests at the base of the section below a thicker unit (2) of retreat outwash.

### Unit N.C. 2

N.C. 2 can be divided into 4 facies. The lowest consists of 17 m of horizontally bedded coarse sand (Figure 58). Planar tabular crossbedded sands, dipping north at 20 degrees, and imbricated clasts, were also noted. A lense of diamict was incorporated into the sequence and likely represents rafted till from N.C. 1. The second facies change at the mid portion of N.C. 2 is characterized by cobbles between 3 and 6 cm with a larger pebble fraction. Stratification is well developed with strata dipping 5 degrees to the north. This portion of the unit is more recessive than the lower previous facies. The facie change in the upper 19 m is characterized by an increase in sand in all strata (Figure 58). Overall grain size decreases to the top, while sediments become better sorted. The final facies change consists of 2-3 m of imbricated, crudely to moderately sorted gravel (Figure 58). Unlike the underlying gravelly sand this facie is clast- dominated, indicating higher velocity. Clasts are aligned vertically where sand wedge casts penetrate this facies. N.C. 2 is interpreted as a Reid glaciofluvial gravel, correlative with A.B. 3. The increased flow at the top of the unit is a similar pattern observed at Ash Bend and Stirling Bend.

### Unit N.C. 3

A truncated soil horizon is present at the top of N.C. 2, immediately below a silt deposit. Features include a yellowish brown (10YR 5/4) horizon, calcification, and frost shattered clasts at the contact with the overlying silt. The soil horizon is interpreted to be the Diversion Creek soil (Bm horizon).

### Unit N.C. 4

N.C. 4 is silt deposit interpreted to be McConnell loess (Figure 58). Sand wedge casts (1 m across and 1.5 m deep) cut into N.C. 2 from the base of this unit.

## *Vancouver Creek Section*

Vancouver Creek section is a Reid terrace located at the confluence of Vancouver Creek and McQuesten River (Figure 40). The section consists of 75 m of gravel with lacustrine sediments (V.C. 1). The section is capped by a truncated paleosol and a silt (V.C. 3 and 4). A thicker silt sequence and a complete paleosol is also preserved in a swale on the terrace (V.C. 2 and 3).

### Unit V.C. 1

V.C. 1 consists of a sequence of gravel and lacustrine beds. From river level to 33 m the section is composed of poorly exposed pebble dominated gravel that appear to fine upward to sandier beds around 32 m. The structure was not documented because of poor exposure. 4.5 m of convoluted, cohesive silt overlie the gravel at 33 m. Lenses of pebbly sand and dropstones are also present in the silt. Bedding was noted within the silt, although grain size variation was minimal. Structurally the silt is highly indurated, possibly the result of sediment dewatering and or surface loading.

The silt is pale yellow (2.5Y 7/4) and is interpreted to be glaciolacustrine. Overlying the silt beds (37.5 m) is a second sequence of gravel consisting of pebbles and cobbles in a sand matrix. Bedding is moderately sorted and planar. From 51 m to 53 m the gravel is combined with silt blocks, similar in texture to the silt sequence previously discussed. A second silt sequence extends from 53 m to 61 m. This facies also contains dropstones and bedded silt, similar to the previous silt facies. Overlying the second silt facies is a third gravel sequence that extends to the top of the section and is poorly exposed. Large cobbles and boulders with frequent sandy beds comprise the upper gravel (Figure 60). Numerous fractured clasts (frost shattering), sand wedge casts, and ventifacts were observed at the upper contact. V.C. 1 is interpreted to be Reid glaciofluvial gravel with glaciolacustrine silt. The exposure is of a Reid glaciofluvial terrace, which also defines the genesis of the sediment. The lacustrine sequence is likely attributed to blockage of the McQuesten valley by Reid ice in Tintina Trench.

### Unit V.C. 2

V.C. 2 is a massive silt deposit preserved in a swale at the top of the terrace (Figure 28). The silt is interpreted to be Reid loess because if its structure and position on the Reid terrace. Its age and genesis is also supported by the origin of a paleosol that overprints the silt (V.C. 3).

Figure 60: Cobble sequence containing a large boulder at the top of Vancouver Creek section. A boulder this size was likely transported by glacial outwash (see arrow).

**Unit V.C. 3**

V.C. 3 is a paleosol that is preserved as a truncated horizon across much of the terrace and an intact paleosol in the swale containing V.C. 2 (Figure 28). The swale may have formed when melting glacier ice at depth caused the gravels to collapse. A minor organic horizon is also preserved in the paleosol (Figure 28). Paleo-animal burrows are also evident. Table 4 compares the colour hues of the paleosol at Vancouver Creek section to the Diversion Creek paleosol.

**Table 4**

| Horizon | Paleosol at Vancouver Creek | Diversion Creek Paleosol |
|---|---|---|
| A | Dark Brown - 10YR 3/3 | - |
| Bm 1 and 2 | Yellowish Brown - 10YR 5/8 | Yellowish Brown - 10YR 5/4 |
| BC | Olive Yellow - 2.5Y 6/6 | Light Olive Brown - 2.5YR 5/4 |
| Ck | L. Yellowish Brown 2.5Y 6/6 | Light Olive Brown - 2.5Y 5/4 |

V.C. 3 is interpreted to be a complete Diversion Creek paleosol from the Koy-Yukon interglaciation. The Vancouver Creek site represents the most complete example of the Diversion Creek soil in central Yukon.

Overlying the paleosol is sand, grit, and silt that have infilled the depression. There is four intervals of accumulation, marked by varying sediment size and thermal contraction cracks emanating from each layer. This sequence may have accumulated as gravity flow sediments at the onset of the McConnell glaciation.

### Unit V.C. 4

A silt layer unconformably overlies the Reid gravel along the top of the section. The silt has no structure and is interpreted to be McConnell Loess. The gravity flow deposit overlying the Diversion Creek paleosol is also from the McConnell glaciation, based on its position over the last interglacial paleosol. A periglacial climate during deposition of the loess is evident from sand wedge casts cutting into the glaciofluvial gravel (V.C. 1), and from frost shattered clasts and ventifacts at the interface between the loess and the gravel. Soil formation in the loess represents the Stewart Neosol. Recent accumulation of stratified aeolian sediment and organic matter over top of the buried Stewart Neosol, is the result of modern river processes exposing the fine grained sediments in V.C. 1 to the rising air currents off the exposure. The silts are subsequently eroded from the cliff face and deposited along the top edge of the terrace as cliff top dunes (Figure 60).

### *McConnell End Moraine Section*

The McConnell end moraine section is located 20 km upstream from Stewart Crossing, Stewart River (Figure 40) and was deposited at the terminus of the last glaciation. The end moraine was identified as the type section for the last glaciation in central Yukon (Figure 30; Tarnocai 1987). The section consists of 44 m of gravel, 3.5 m of diamict, and 3.0 m of gravel (M.E.M. 1, 2, and 3). The section is capped by a veneer of silt and a soil (M.E.M. 4 and 5).

### Unit M.E.M. 1

M.E.M. 1 is a coarsening upward sequence of interstratified sand and gravel (Figure 61). The gravel is in conformable contact with an overlying diamicton (Figure 62). The lower part of the unit consists of cross and planar bedded medium to fine grained sand with intermittent layers of gravel (Figure 51). The upper part of the unit coarsens and consists of subrounded gravel, with interstratified lenses of sand (Figure 61). Imbrication suggests a flow from the northeast. Near the upper contact the gravel becomes openworked with cobbles with minor pebbles. Cobbles in contact with the diamict are fractured, likely from surface loading. M.E.M. 1 is interpreted to be advance McConnell outwash.

### Unit M.E.M. 2

M.E.M. 2 consists of 3.5 m of cohesive diamict that is in erosive contact with the underlying gravels (Figure 61 and 62). The diamict is pale yellow (2.5Y 7/4) and has an equal composition of clasts to matrix. 100 clasts were measured for fabric and indicate a flow to the southwest, parallel to the valley (Figure 61). M.E.M. 2 is interpreted to be McConnell till.

### Unit M.E.M. 3

M.E.M. 3 consists of 3 m of poorly sorted, matrix dominant gravel. The unit fines upward and is poorly exposed because of its recessive nature. No sedimentary

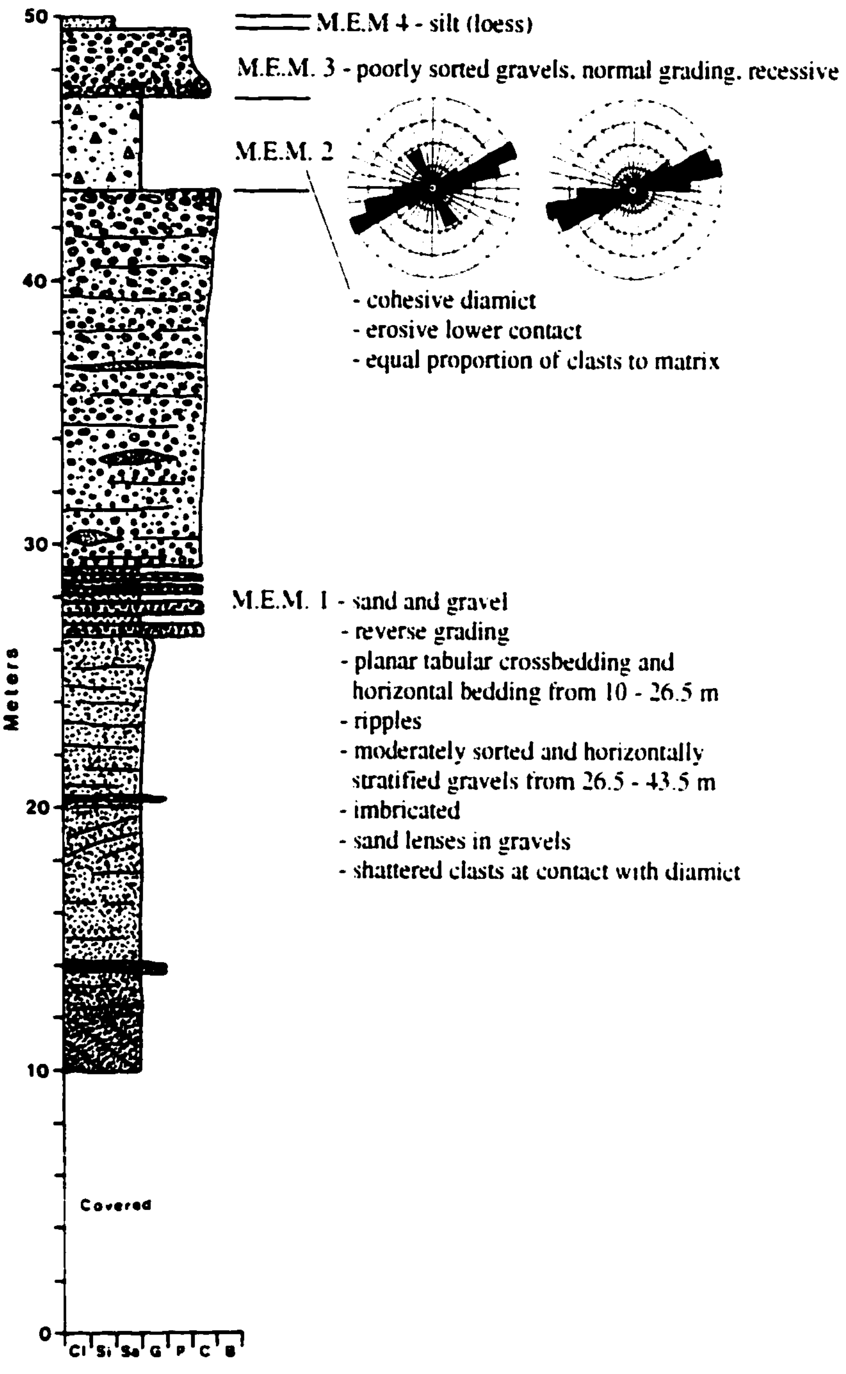


Figure 61: McConnell end moraine stratigraphy and sedimentology with till fabric diagrams

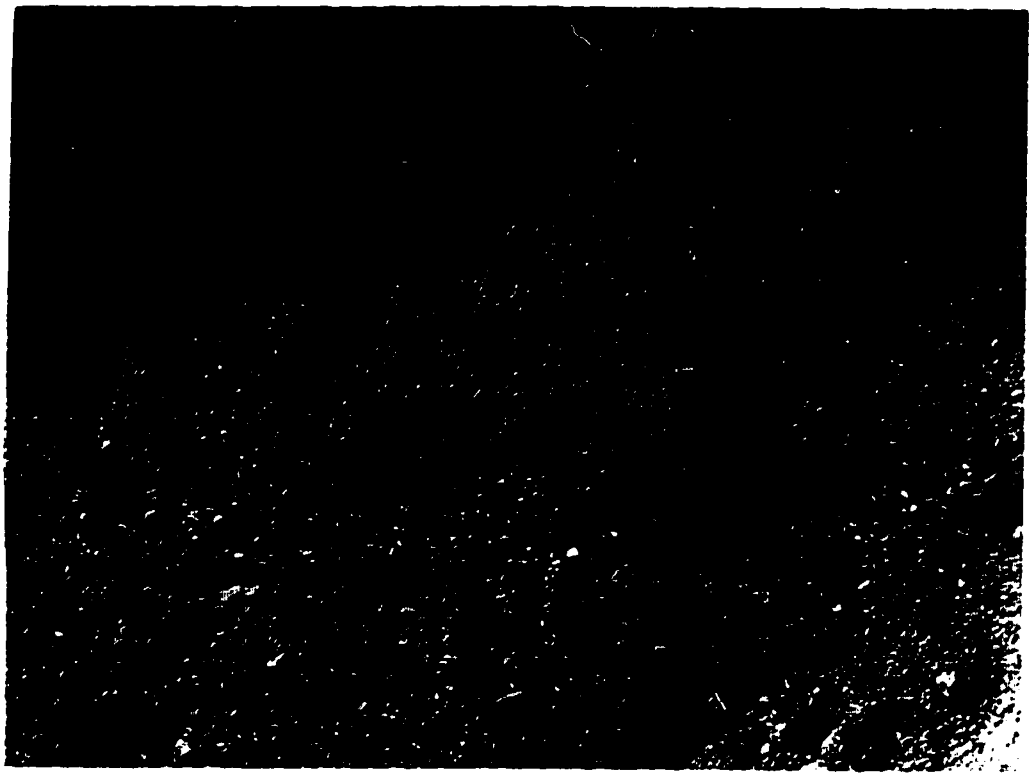


Figure 62: McConnell age advance outwash (unit 1) capped by till (unit 2) at the terminus of the McConnell glaciation in Stewart River valley.

structures were identified. The stratigraphic position of M.E.M 3 to the underlying units suggests an outwash origin for this unit. M.E.M. 3 is interpreted to be retreat McConnell outwash.

### Unit M.E.M. 4

M.E.M. 4 is a thin silt layer with no structural features. M.E.M. 4 is interpreted to be loess that was deposited by katabatic winds from the McConnell outwash plain (Figure 62). Katabatic winds are the result of pressure differences created by the ice sheet. Cold, dense air, flows off the ice sheet and mobilizes silt and sand on outwash plains; draping the valley bottom with a veneer of silt. Entrenchment by early postglacial streams into thick valley fill sequences is also important as it exposes sediments susceptible to wind erosion (Eyles and Paul 1983).

### Unit M.E.M. 5

M.E.M. 4 is a soil horizon formed in the McConnell loess. The soil is shallow and was interpreted to be the Stewart neosol. The Stewart neosol is a weakly developed Orthic Eutric Brunisol, characterized by a shallow solum and lack of clay accumulation in the IIBm horizon (Tarnocai 1987a). The type locality for this soil is on the McConnell end moraine in Stewart River valley (Tarnocai 1987a).

# CHAPTER 7

# DISCUSSION/SUMMARY

The Plio-Pleistocene record of central Yukon includes a multiple glacial and interglacial history. Preservation of this record is likely related to uplift of the St. Elias Mountains, which has progressively reduced the influence of Pacific air masses in Yukon (Armentrout 1983). The result has been progressively less extensive glaciations, and interglaciations that have become more arid and cooler. The central Yukon, at the limit of these glaciations, best records this evolution. In McQuesten map area a minimum of two pre-Reid glaciations and interglaciations are preserved. The middle Pleistocene Reid glaciation terminated in the map area providing the type section for this event. The Diversion Creek paleosol (Koy-Yukon interglaciation) is preserved on Reid surfaces and the type section for the late Pleistocene McConnell glaciation is also in the study area.

The oldest surficial deposit was identified at Stirling Bend as a late Tertiary debris flow deposit (S.B. 1; Figure 63). It is uncertain if the deposit originated from a glacial or interglacial environment and further paleomagnetic and palynologic analyses are required to better understand its age and genesis. Additional paleomagnetic sampling from the overlying silt unit (S.B. 2) may provide a minimum age for the debris flow.

The pre-Reid glaciations covered the study area, leaving nunataks in the White Mountains and ridges adjacent to Tintina Trench. Ice entered the study area from the

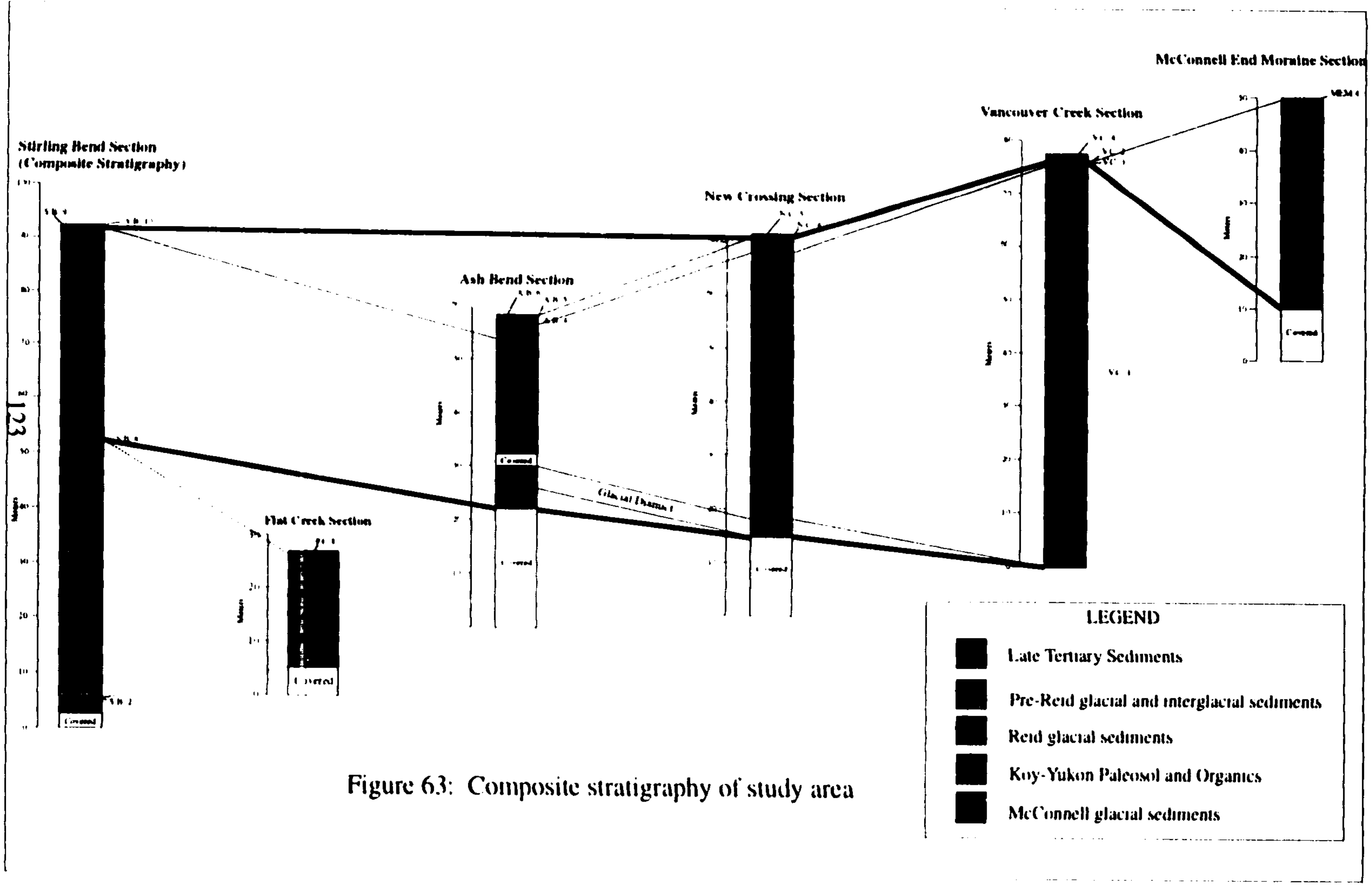
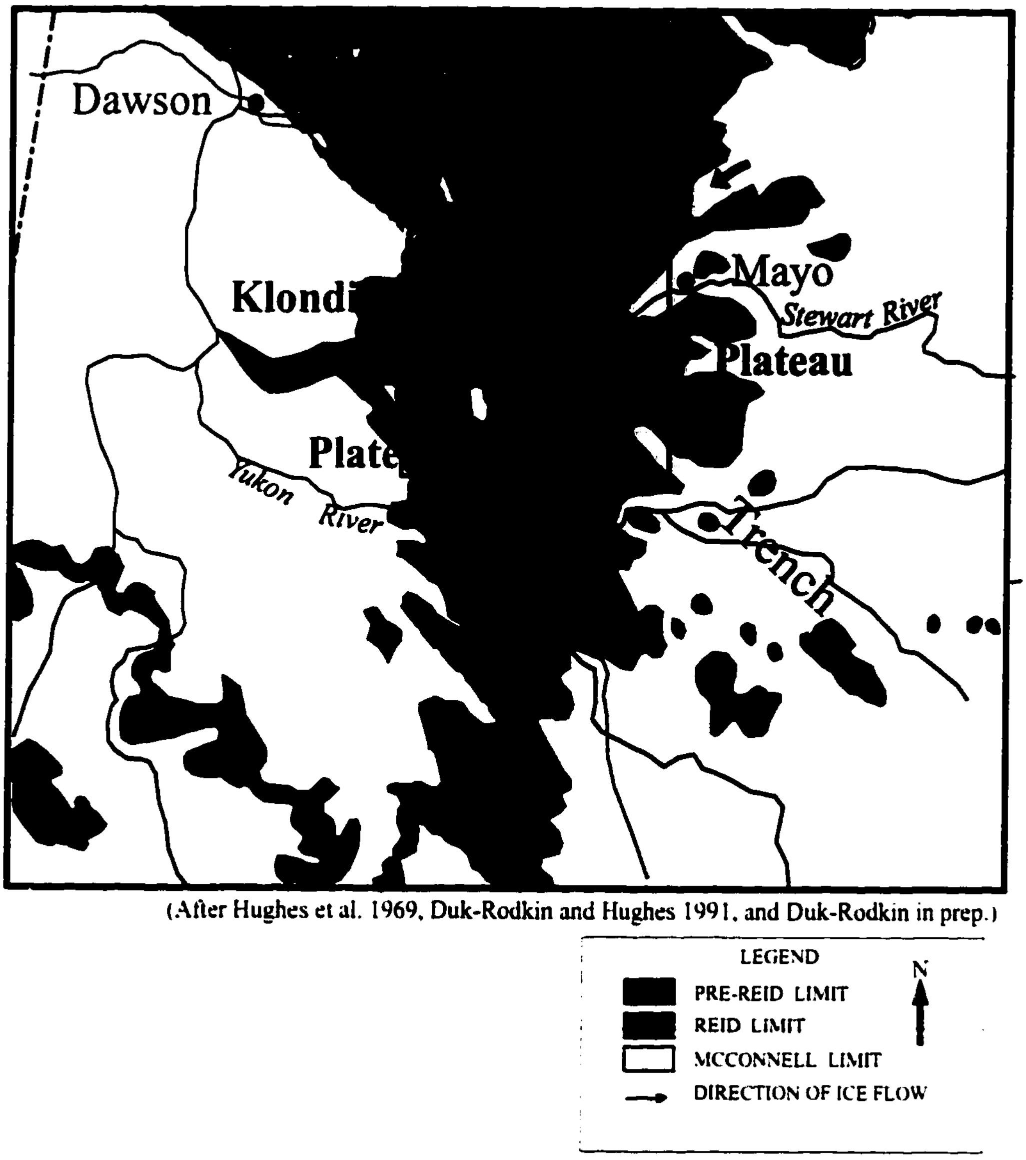


Figure 63: Composite stratigraphy of study area

south, southeast, and east, and was directed by the topography of the Klondike and Stewart plateaus (Figure 64). Ice-flow on the Klondike Plateau was directed by topography and likely forced to the west by ice flowing off the Stewart Plateau. Ice confined to the Klondike plateau terminated at the mouth of the Stewart River, approximately 70 km west of the McQuesten map area (Duk-Rodkin in prep.). Ice-flow on Stewart Plateau was to the southwest and became redirected to the northwest upon entering Tintina Trench (Figure 64). Stewart Plateau ice breached interfluves between major drainages, which established a flow of ice to the northwest. This may have been caused by confined ice-flow at the intersection of Tintina Trench and Stewart Plateau. Deposits from the pre-Reid glaciations are preserved in Tintina Trench and on Klondike plateau, beyond the Reid glacial limit. The Flat Creek beds, in Tintina Trench, may contain the most complete record of pre-Reid glaciations in central Yukon. Unfortunately no exposures substantially penetrate the deposit in the study area. Recent stratigraphic studies and surficial mapping by Duk-Rodkin (1997) in the Tintina Trench, north of Dawson, and Froese *et al.* (1997) on the Klondike River terraces has revealed a multiple pre-Reid glacial and interglacial history.

The oldest pre-Reid glacial sediments in the study area are found at Flat Creek section. The paleomagnetic signal for the Flat Creek outwash (F.C. 1) is a normal-reverse-normal succession, indicating an age >0.984 Ma. It is possible that F.C. 1 was deposited during the Olduvai subchron or Gauss chron. Preliminary results from the Klondike terraces near Dawson suggest the oldest pre-Reid outwash, overlying the



(After Hughes et al. 1969, Duk-Rodkin and Hughes 1991, and Duk-Rodkin in prep.)

Figure 64: The glacial limits for central Yukon and McQuesten map area. Approximate ice flow directions are plotted in the study area. Note the contrasting ice flow directions between the Klondike and Stewart Plateaus.

White Channel gravels of Miocene age, are time continuous in that the whole sequence registers a normal polarity, most certainly of late Tertiary or Gauss age (Froese 1997). A lateral correlation of the Flat Creek gravels with the Klondike outwash is not certain, however, a correlative braid plain between Flat Creek section and the Klondike has been suggested (Froese *et al.* 1997).

At least three pre-Reid units can be placed into the early Bruhnes Chron. This includes the upper units at Flat Creek (F.C. 3 and 4) and Stirling Bend units 4, 5, and 6 (Figure 63). The upper Flat Creek units include the lacustrine-diamict deposit and the overlying glacial gravels. The diamict unit has a good normal polarity with no overprinting, which suggests a Bruhnes age for F.C. 4 (Figure 63). Preliminary results from units 4 and 5 at Stirling Bend suggest normal polarities with no apparent overprinting. It is possible that unit 4 may have an unreadable reverse underprint, and therefore, further sampling is necessary to clarify the paleomagnetism. The origin of unit 4 is glaciofluvial and unit 5 appears to be glacio-deltaic.

Pre-Reid interglacial units are found at both Flat Creek (F.C. 2) and Stirling Bend (S.B. 6). F.C. 2 is dissected by an ice-wedge cast containing a tephra from the overlying diamict unit. The tephra is currently being dated by fission track analyses and will provide a minimum date for the Wounded Moose climatic event. Position of the tephra within the normally magnetized diamict suggest that it should date within the early Bruhnes Chron, and therefore, the paleosol would date to at least this age. The Wounded Moose luvisol suggests a warm and more humid climate than today in central Yukon (Rutter *et al.* 1977). Two paleosols with Wounded Moose characteristics were documented in the study area and include the paleosol observed at the surface of the Flat Creek beds and in the subsurface at Flat Creek section. Similar pre-Reid soils have been documented in the Mackenzie Mountains (Duk-Rodkin 1996). At Stirling Bend, the pre-Reid organic deposit (S.B. 6) also suggests a climate milder than today based on the presence of two species of plants currently not found in Yukon, *Lycopus* and *Alisma*. S.B. 6 has a normal polarity (Figure 63).

Preliminary stratigraphic and paleomagnetic analyses of pre-Reid deposits in McQuesten map area suggest a minimum of two and a maximum of five glaciations (Figure 63). The paleomagnetic record at Flat Creek section clearly changes from an older normal in unit 1 to a Bruhnes normal for units 3 and 4. Likewise for units 4 and 5 at Stirling Bend a Bruhnes normal magnetization seems most likely. This clearly separates two ages of glacial deposits. Correlating Flat Creek section with Stirling Bend is currently not possible and therefore it is uncertain if more than two glaciations are recorded in the stratigraphy. In total, 5 deposits have been identified as pre-Reid glacial deposits (F.C. 1, F.C. 4, S.B. 3, and S.B. 4 and 5) and an additional 3 deposits have unidentified origins. A minimum of two and maximum of 5 pre-Reid glaciations are recorded in the stratigraphy of McQuesten map area. Further sedimentologic and paleomagnetic sampling is necessary to determine the origin and age of Stirling Bend units 1, 2, and 3 in relation to the central Yukon stratigraphy. The results of this work have identified and mapped numerous pre-Reid deposits, which confirm our understanding of the multiple glacial theory during the early Pleistocene. Additional paleomagnetic dating may clarify the stratigraphy and provide an important link between the Plio-Pleistocene records of Fort Selkirk and Dawson.

Additional areas, in the Yukon and Mackenzie Mountains, have produced a multiple pre-Reid glacial and interglacial records (Figure 65). In the Liard Lowland Klassen (1987) identified a till older than 760 Ka and in the Mackenzie Mountains Duk-Rodkin (1996) has identified four glacial deposits that precede what possibly equates to the Reid glaciation. At Fort Selkirk, in central Yukon, Jackson (1996) identified two pre-Reid glaciations, the older being greater than 1.19 Ma. A similar stratigraphy was also noted in the St. Elias Mountains, Ogilvie Mountains, and Old Crow Basin. In each of these areas an older glaciation predates the middle Pleistocene glaciation(s) (Figure 65). Pre-Reid interglacial units most similar to the McQuesten map area are found in the Mackenzie Mountain stratigraphy. In comparison to the rest of the Yukon, the Mackenzie Mountain stratigraphy appears most similar to the McQuesten record. The two pre-Reid glaciations in the study area may correlate with two of the four pre-Loretta glaciations in the Mackenzie Mountains (Figure 62).

The Reid glaciation covered much of Stewart Plateau in McQuesten map area, south of the McQuesten River. The ice remained confined by valleys through the study area and upper parts of plateaus remained unglaciated. Ice terminated upon reaching Tintina Trench near Reid Lakes (Figure 64). Glacial landforms from the Reid glaciation are well preserved in the main valleys. Reid outwash deposits parallel the

|  | Oxygen Isotope Stage | Geomagnetic Time Scale | Liard Lowland<br>Klassen 1987 | St. Elias Mtns.<br>Denton and Stuiver 1967 | Central Yukon<br>Bond 1996 Jackson 1996 | Mackenzie Mtns.<br>Duk-Rodkin 1996 | Ogilvie Mtns.<br>Vernon and Hughes 1966 | Old Crow Basin<br>Morlan 1980 |
|---|---|---|---|---|---|---|---|---|
| Holocene | 1 | Brunhes |  | Slims Nonglacial Interval 12.5 ka | 11.5 ka |  | 13.7 ka | 12.5 ka |
| Late Wisconsinan | 2 |  | Till D<br>23.9 Ka | Kluane Glaciation<br>29.6 ka | McConnell Glaciation<br>29.6 ka | Mackenzie Lowland Formation | Last Glaciation | Glacio-lacustrine Clay<br>< 25 ka |
| Sangamonian | 5e |  | Intertill Unit C-D | Boutellier Nonglacial<br>>37.7 ka | Koy-Yukon Interglacial<br>Diversion Creek Paleosol<br>Sheep Creek Tephra 200 ka | Brunisol |  | Alluvium<br>"Disconformity A"<br>Old Crow Tephra 140 ka |
| Middle Pleistocene | 6-16 |  | ?<br>Till C<br>? | ?<br>Icefield Glaciation<br>? | ?<br>Reid Glaciation<br>Wounded Moose Paleosol<br>Younger Pre Reid Glaciation(s) | Loretta Alloformation<br>Brunisol<br>Little Keele Alloformation<br>Brunisol<br>Rouge Mountain Alloformation | ?<br>Intermediate Glaciation<br>>53.9 ka<br>? | Alluvium ? |
| Early Pleistocene | 16-100 | Matuyama | Intertill Unit B-C<br>>0.23 Ma<br>Till B?<br>Intertill Unit A-B?<br>>0.76 Ma | Silver Nonglacial<br>Shakwak Glaciation? | Younger Pre Reid Glaciation(s)<br>Fort Selkirk Tephra > 1.19 Ma<br>Older Pre Reid Glaciation(s) | Luvisol<br>Abraham Alloformation 1.77 1.95 Ma<br>Luvisol | Old Glaciation?<br>Mosquito Gulch Tephra<br>1.22 Ma | Alluvium ?<br>Little Timber Tephra<br>>1.2 Ma |
| 1.69 Ma<br>Pliocene | >100 | 2.58 Ma | Till A? | ? |  | Inlin Brook Alloformation 1.95 2.58 Ma | Old Glaciation? | Lacustrine Clay |
|  |  | Gauss |  |  |  | Colluvium |  |  |

Figure 6.5 : Yukon Stratigraphic Correlations

McQuesten River and Stewart River within the Tintina Trench. Broad outwash deposits are found in Willow Creek valley and Tintina Trench, southeast of Stewart River valley (Figure 7). The type area for the Reid glaciation, Reid Lakes, is geomorphically well preserved. The glacial stratigraphy is also well preserved along the Stewart River in Tintina Trench at Ash Bend and New Crossing sections. These sections include a full glacial stratigraphy consisting of advance outwash, till, and retreatal outwash (Figure 63).

The Reid glaciation occurred prior to 200 Ka, according to dates on the Sheep Creek tephra that overlies Reid outwash. Elsewhere in Yukon and Mackenzie Mountains glacial deposits of a similar stratigraphic age are present (Figure 65). It appears that throughout the Yukon a prominent middle Pleistocene glaciation occurred. In the Mackenzie Mountains the Loretta glaciation stratigraphically coincides with the Reid glaciation from central Yukon. Isotopically, the Reid glaciation occurred at or prior to stage 7, if the 200 Ka date on the Sheep Creek tephra is accurate. The Reid glaciation has traditionally been correlated with the penultimate advance immediately prior to the Sangamon (Koy-Yukon interglaciation). It is possible that the penultimate advance was less extensive than the McConnell glaciation in central Yukon and is, therefore, not represented in the geomorphic record. The Reid glaciation may represent a middle Pleistocene advance prior to the penultimate glaciation and may correlate with the Little Keele or Rouge Mountain formations from the Mackenzie Mountains (Figure 65). The Nome River glaciation in

Alaska, not represented in Figure 65, was dated at 0.470 Ma by Ar-Ar methods and may correlate with the Reid glaciation (Hamilton 1994). Dates bracketing the Reid, Icefield, Till C, and Intermediate glaciations are necessary to fully understand the middle Pleistocene record (Figure 65).

The Koy-Yukon interglaciation is well represented in McQuesten map area by paleosol development and organic deposits (Figure 63). The most complete Diversion Creek paleosol known in central Yukon was discovered at Vancouver Creek. At this site cryoturbated lenses of organic are preserved and is considered to be the first documented Diversion Creek A-horizon. Microanalysis of last interglacial soils developed in central Yukon and Mackenzie Mountains (Little Bear paleosol 5; Figure 65), show similarities in clay development and may suggest regional climatic similarities within the interglacial (Tarnocai and Smith 1989). At Ash Bend section an organic silt deposit is preserved in a swale on the Reid outwash surface. Previous research identified the Sheep Creek tephra within the organics, which suggests an age of 200 Ka for the deposit (Berger 1994). The organics represent the largest intact deposit of Koy-Yukon pollen and macrofossil material in central Yukon. Future environmental studies in this area should focus on compiling this record for a better understanding of the climate and vegetation history of central Yukon during the last interglaciation.

The McConnell glaciation or last glaciation in Yukon terminated in Stewart River valley approximately 20 km upstream from Stewart Crossing and Tintina

Trench. The end moraine complex, and section exposed by the Stewart River, constitutes the type section of the McConnell glaciation in central Yukon. The end moraine section consists of outwash, till, outwash, and loess (Figure 63). Deposits from the McConnell glaciation consist of sandy moraines within the glacial limits and outwash terraces beyond the glacial limit. Katabatic winds off the ice sheet deposited loess across lowland areas in Stewart River valley, Tintina Trench, and McQuesten River valley. Beyond the McConnell glacial limit, on Reid and pre-Reid surfaces, sand wedge casts developed. Comparison of sand wedge casts between the Reid and McConnell glaciation revealed no characteristics that would differentiate them. Previous research by Rutter *et al.* (1978) proposed a difference between Reid and McConnell sand wedge casts. Reid casts were said to be much larger, characteristic of the intensity or duration of glaciation. Whereas the McConnell casts were substantially smaller. This was found to be true on pre-Reid surfaces in Tintina Trench, however, McConnell casts on Reid surfaces were equally as large as Reid casts on pre-Reid surfaces. In other words, it seems problematic to infer a climate based on the size of a sand wedge cast. When comparing Reid and McConnell sand wedges on a pre-Reid surface in Tintina Trench it would be expected that the Reid casts are larger because the Reid glaciation terminated closer to the Flat Creek beds. Using sand wedge casts as a method to infer climate or designate an age seems difficult and dependant on factors related to site conditions and location to glacial limits.

Advance of the McConnell glaciation into the area occurred after 29.6 Ka BP according to an AMS date on seeds from the Mayo area (Matthews *et al.* 1990). Ice free conditions persisted near Ross River at 26.3 Ka BP, and therefore, glacial maximum occurred after this time in McQuesten map area (Jackson and Harington 1991). These dates suggest a Late Wisconsinan age for the McConnell glaciation. The McConnell glaciation correlates well throughout Yukon and in the Mackenzie Mountains (Figure 65).

The present interglacial or Holocene interglacial began following the retreat of McConnell ice from the Cordillera. The early Holocene was marked by a warm period that developed a soil indicative of a subarctic-subhumid climate and was followed by the present cooler climate that developed a soil indicative of a subarctic-semiarid climate (Zoltai and Tarnocai, 1974). A similar trend was noted in southern Yukon. In McQuesten map area ground squirrel bones were found in a sand wedge cast of McConnell age at Stirling Bend section. An AMS date of 11.5 Ka suggests that the climate had moderated enough by this time to support borrowing animals. The modern subarctic-semiarid climate found today in Yukon probably did not develop until after 6.0 Ka and may not have been present until 4.0 Ka (Cwynar 1988; Wang and Geurts 1991).

# CHAPTER 8

# APPLICATIONS

## Mining Exploration

Both placer and bedrock exploration programs can benefit from applied Quaternary research and surficial geology. In conducting geochemical surveys it is important to understand the characteristics and genesis of terrain deposits. Surficial geology maps provide a useful guide to assessing terrain deposits and soil characteristics. For instance, active slope processes such as solifluction and colluviation, particularly above tree-line, displace Quaternary sediments and must be accounted for when interpreting geochemical anomalies. Terrain hazards such as slumping and rock falls within a watershed contribute an anomalous quantity of sediment to a stream and may adversely affect the geochemical results. Excessive sedimentation may mask a sediment anomaly or may enhance an anomaly. If masking occurred then measures should be taken to continue the sampling program upstream from the anomalous sedimentation source.

Understanding terrain deposits and the history of their deposition is also beneficial when conducting stream sampling in a mountainous environment such as Stewart Plateau. Samples obtained above the confluence of two creeks may not provide representative assays from their respective drainages. When a tributary stream enters the main valley it begins to incorporate sediment derived from the main valley, diluting the minerals from the original tributary valley. To avoid this, samples from the tributary stream should be obtained from the confines of its own drainage.

Surficial geology maps also provide information regarding the composition of terrain deposits. This information is important for soil sampling programs because it provides information regarding the proximity of Quaternary sediments to their bedrock source. For example, a basal till is composed of sediment derived from a proximal source, and if the ice movement history is understood then it is possible to predict where the anomaly originated. Glaciofluvial outwash or meltout till, on the other hand, consist of supraglacial and englacial sediments (far traveled debris) and provide less concise information about sediment origins.

Quaternary history can provide valuable information regarding ice movement and the depositional history of Quaternary deposits. Plotting glacial ice flow patterns, based on certain landforms and a regional understanding of glacial history, is necessary to follow up on soil geochemical anomalies. In the McQuesten area the glacial history is complicated by its location at the terminus of multiple glaciations. Understanding the nature and distribution of these older deposits, as portrayed in the surficial geology map, can provide valuable information concerning soil and stream sediment characteristics. This information, combined with an understanding of physiographic characteristics, can provide interesting placer exploration data.

### *Placer Exploration*

The geomorphology of the study area can be characterized by the nature of the physiography and glacial history. Displacement of the Yukon plateau, by Tintina fault, has offset two physiographic plateaus that have regional topographic and fluvial order differences. These factors are important in the location of current placers in McQuesten map area. Presently, placer mining is confined to the Highet Creek, Clear Creek, and Stewart River areas. Little to no placer exploration is currently present on the Klondike plateau.

Stewart Plateau has steeper slopes and consistently higher terrain in comparison to the Klondike plateau (Figure 3). These differences have influenced the thickness and distribution of the surficial materials in the area. Stewart Plateau, because of its morphology, confined glacial deposition to valley bottoms and the lower flanks of valleys. Surficial sediments on Klondike plateau, on the other hand, are more evenly distributed, meaning glacial deposits are likely to be found at higher elevations. In addition, Klondike Plateau was closer to the terminus of pre-Reid glaciations than Stewart Plateau. Terminal areas generally have thicker accumulations of glacial sediments. The flow of pre-Reid ice into McQuesten map sheet from the south was enhanced by the northwest trending Dawson Range and redirected ice flow into the lowlands of Lake Creek, Grand Valley, and Willow Creek. This concentration of flow contributed to excessive glacial sedimentation on Klondike Plateau in McQuesten map area, potentially masking placer deposits.

Fluvial systems are also different between the Stewart and Klondike Plateaus. Major drainages on the Stewart plateau have headwaters in the Selwyn Mountains, which emit larger rivers across the plateau. Higher order river systems and more vertical relief accounts for greater erosion and redistribution of surficial sediments, especially of pre-Reid sediments. In contrast, Klondike Plateau contains only local drainages, such as Lake Creek and Grand Valley Creek, which have proximal headwaters and consequently low order discharges and low capacity for erosion and exposure of placer deposits.

Placer gold occurrences in McQuesten and surrounding map areas are generally confined to unglaciated environments, areas of sparse glacial sediments, or high relief drainages (gulch-like placer accumulations). These attributes have no doubt been governing factors in the location of past and current placer mines in central Yukon. It is probable, based on the presence of placer gold in surrounding regions, that Klondike Plateau in McQuesten map area has potentially significant placer gold occurrences. Exploration has likely been limited to glacial deposits that do not actually reflect the true quantity placer gold in the drainage. In other words, low energy streams have yet to downcut through a placer deposit, hence, a factor of topography, fluvial setting, and excessive glacial fill hindering placer exploration. Streams on the Stewart plateau, in contrast, have undergone base level adjustment following glaciation, which caused downcutting of streams through glacial sediments and exposure of auriferous interglacial gravel.

Finally, reconcentration of placer gold in a glaciofluvial deposit should not be overlooked. Large volumes of outwash have scoured and redistributed interglacial pay units and could, potentially, act as an environment for placer accumulation. The main draw back is thick overburden hampering exploration efforts. Application of in geophysics and drilling, in addition to extensive field sampling and understanding of preglacial environments and glacial processes, could overcome this problem.

## Natural Hazards

Natural hazards include slope processes such as slumping, rock falls, or debris slides, that pose a potential hazard to human occupation. Most slope activity in McQuesten map area is confined to the northern part of Stewart Plateau where the terrain is steeper. Few active slide faces were observed, however, sporadic stabilized slumps were mapped (Figure 66). Reactivation of old landslides is likely if the permafrost is reexposed to the surface in these areas. Fine grain deposits that are mapped as glaciolacustrine units potentially provide unstable surfaces for construction (Figure 7).

## Granular Deposits

Granular material for road construction is not in short supply in the McQuesten region. Extensive glaciofluvial plains and terraces, and drift plains in Stewart River valley, Willow Creek valley, and Tintina Trench provide ample construction material

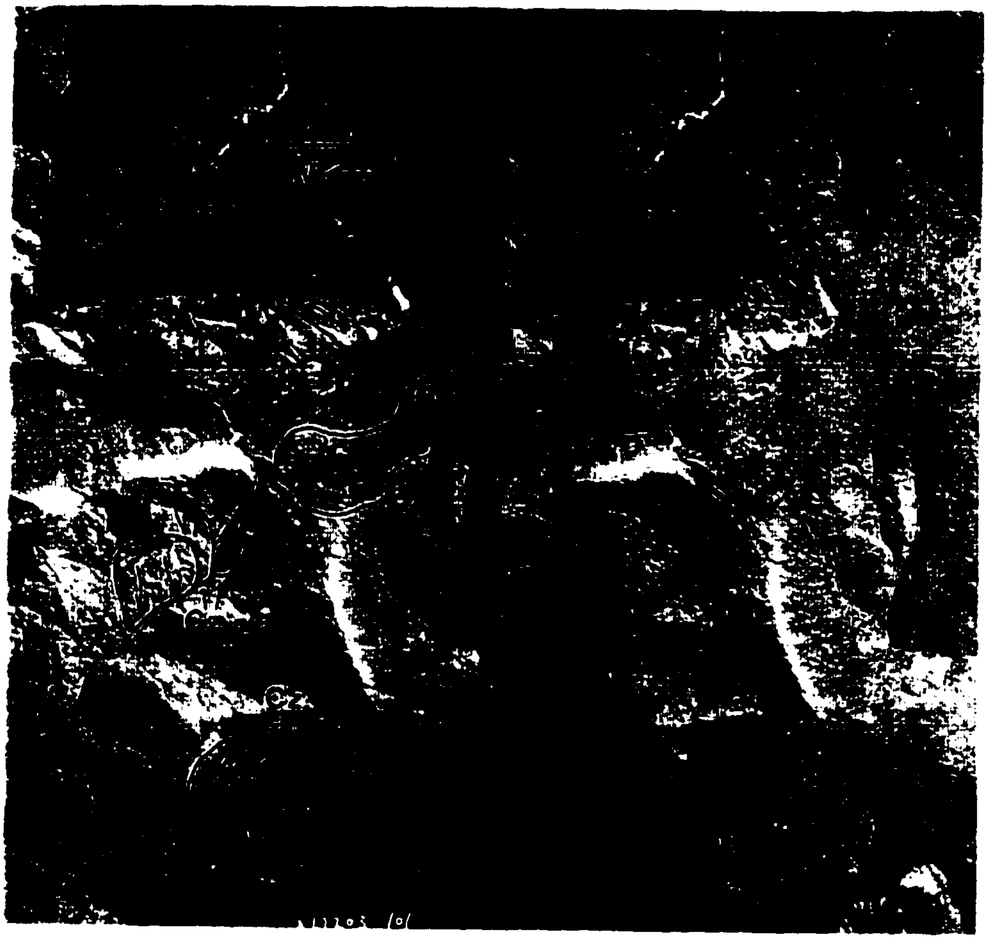


Figure 66: Stabilized slumps on Stewart Plateau near Scheelite Dome

for the Klondike Highway and Silver Trail. Future mining trails, especially in the southwest portion of the map sheet, will benefit from the location of glaciofluvial terraces and plains in the valleys of Grandvalley Creek, Rosebud Creek, and Lake Creek (Figure 7).

## Chapter 9

## Conclusions

The Quaternary record in McQuesten map area provides stratigraphic evidence of at least four glaciations and three interglaciations. Evidence for at least two pre-Reid glaciations was documented with a good possibility of three additional pre-Reid glaciations represented. A complete Diversion Creek paleosol, from the Koy-Yukon interglaciation, was documented. Type sections for the Reid and McConnell glaciations were also logged. Applications of surficial geology and glacial history to placer research indicated possible undiscovered gold deposits on the Klondike Plateau, inside the pre-Reid glacial limit.

A late Tertiary debris flow deposit marks the oldest documented surficial deposit in McQuesten map area. The oldest glaciation, dated by paleomagnetism, is older than 0.984 Ma. Two pre-Reid interglacial units were described, including the Wounded Moose paleosol and the Stirling Bend organics. The Stirling Bend organics were deposited during the Bruhnes normal Chron and contain *Lycopus* and *Alisma* seeds, plants that suggest a pre-Reid climate warmer than today in central Yukon. In addition, the Wounded Moose paleosol was observed at two stratigraphic levels, which suggests two pre-Reid interglacial climates warm enough to develop luvisolic soils. The best preserved middle Pleistocene glaciation in McQuesten map area is the Reid glaciation. The timing of the Reid glaciation remains unresolved following this study, however, previous research suggests that it occurred at or prior to isotope stage

7. A full glacial stratigraphy for the Reid glaciation was documented at Ash Bend and New Crossing sections. The Koy-Yukon interglaciation was dated to at least 200 Ka according to Berger (1994). An intact Diversion Creek paleosol from this period was documented at Vancouver Creek section and marks the first fully intact paleosol of its kind in central Yukon. The late Wisconsinan glaciation or McConnell glaciation reached McQuesten map area after 26.3 Ka and terminated in Stewart River valley and Tintina Trench (Jackson and Harington, 1991). A full last glacial stratigraphy was documented along the Stewart River near the end moraine complex. Periglacial conditions had ameliorated in McQuesten map area by 11.5 Ka and by 9.3 Ka BP the climate of Yukon warmed to temperatures above present day norms (Cwynar 1988). The modern semi-arid climate in southern Yukon began at approximately 4100 BP (Cwynar 1988).

Surficial mapping and field investigations described the character of surficial sediments and their distribution. Glacial deposits are more widespread on Klondike Plateau because of physiography, low order drainages, and proximity to the terminus of the pre-Reid glaciations. In contrast, glacial deposits on Stewart Plateau are confined to lower slopes and valley bottoms of the main drainages. Tintina Trench contains a thick Pleistocene record of glaciofluvial outwash and drift plains.

The contrasting geomorphic setting in the study area may govern the distribution of known placers. Most placer gold exploration and development has occurred on Stewart Plateau, as opposed to Klondike Plateau. The distribution of surficial sediments and physiographic differences between the two plateaus may be responsible for the concentration of work on Stewart Plateau. Future placer exploration in McQuesten map area should focus outside the Reid glacial limits in the north part of Stewart Plateau and on Klondike Plateau near the White Mountains.

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# APPENDIX I

## SURFICIAL GEOLOGY

### *Classification of surficial geology*

The geological materials portrayed in the enclosed map (Figure 7) may be divided into two categories: (1) bedrock of pre-late Cenozoic age and (2) unconsolidated materials or late Cenozoic sediments. The following descriptions will focus on the surficial geology, mapped in accordance with the Terrain Sciences Division at the Geological Survey of Canada. The terrain inventory of the Pelly River area (Jackson 1994) was used as a guide in these descriptions.

## Description of map units

### *Organic deposits (fO)*

Consist of accumulations of peat, woody material, and minor mineral deposits. Fen organics have a uniform surface appearance and mask the morphology of the underlying sediments. Appear as bogs and fenlands on poorly drained lowlands. Numerous organic deposits were left unmapped at this scale.

### *Colluvial veneer (Cv) and Colluvial blanket (Cb)*

Consist of gravel, diamicton, shattered bedrock, and lenses of sand and silt. Colluvial veneers (<1 m) form on slopes through processes of physical and chemical weathering of bedrock and in-situ glacial sediments. Transport of the dislodged debris occurs as surface creep, solifluction, or debris flows. Colluvial blankets (>1 m) form a slope-toe complex where an apron of sediment collects at the base of a slope. Colluvial veneers typically grade into a blanket deposit. The sediment composition of colluvium reflects the source material on the slope.

### *Colluvial complex (Cx)*

Consists of gravel, diamicton, shattered bedrock, and lenses of sand and silt. Comprises two or more colluvial components. Typically groups colluvial veneers, blankets, and minor mass wasting processes under one heading where differentiation is limited.

### *Alluvial plain sediments (Ap)*

Represent floodplain sediments of modern fluvial systems. Consist of stratified gravel and sand more than 1 m thick with minor silt and clay lenses. Backswamp areas, typical in meandering streams, consist of silt, clay, and organic deposits, with minor sand and gravel lenses. Alluvial plains are flat with remnant channel scars and levees. Alluvial plains host a variety of plant species on the variable topography created by meandering channel systems.

### *Alluvial terrace (At)*

Represent flat-lying benches of a former floodplain surface. Composed of stratified gravel and sand more than 1 m thick with minor silt and clay lenses. Alluvial terraces may cut across bedrock bearing a veneer of fluvial sediment over bedrock. Relatively higher terraces represent older floodplains that may have developed at the beginning of the Holocene and contain coarser sediment.

### *Alluvial fan (Af)*

A fluvial deposit consisting of cobbles, gravel, sand, and diamicton. The sediment composition varies with the source material and position on the fan. Alluvial fans form when a stream leaves its confined upland drainage and deposits its load in a valley or basin. The apex of the fan receives courser material, which grades into finer sediments at the toe of the fan. Debris fans form in mountainous areas under fluvial and colluvial processes. They typically exceed 15 degrees and grade into alluvial fans. Where debris fans coalesce they are mapped as colluvial blankets, otherwise they are part of the alluvial fan designation.

### *Alluvial complex (Ax)*

Consists of gravel, sand, diamicton, and minor silt and clay. An alluvial complex is two or more alluvial processes that combine to produce one deposit. Sediments are stratified with interfingered depositional phases. Alluvial complexes are common in narrow valleys where alluvial fans blend with the alluvial plain and alluvial terraces.

### *Eolian ridges (Er)*

Medium to fine grained sand and silt transported and deposited by wind. Eolian ridges are represented by inactive dunes in McQuesten map area. Dunes vary between 2 m and 75 m in height and contain infrequent blow-out areas. Eolian ridges represent a period of strong winds and sparse vegetation during the last glaciation and or Holocene. The sediment is possibly Reid age and was reactivated during the last glaciation.

### *Eolian blanket (Eb), Eolian veneer (Ev), and Eolian ridges (Er)*

Medium to fine grained sand and silt transported and deposited by wind. Eolian blankets are >1 m thick and veneers are <1 m thick. Blankets and veneers have little surface texture on air photographs and frequently border eolian ridges.

### *Glaciofluvial plain (Gp)*

Coarse gravel, sand, and minor silt deposited in a former glacial stream. Structures include massive and planar bedded gravel with sand. Glaciofluvial plains form beyond the ice margins typically as braided and wandering gravel bed river. Thicknesses vary from veneers to valley fills several tens of meters thick.

### *Glaciofluvial terrace (Gt)*

Coarse gravel, sand, and diamicton appear as benches of former glaciofluvial floodplain surfaces. Glaciofluvial terraces may form ice marginally as isolated terraces in upland environments or form as flights of terraces cut into valley fills. Stewart River valley in Tintina Trench and Klondike Plateau, contain numerous flights of terraces cut from glaciofluvial plains and drift surfaces, marking the separate glaciations. Flights of terraces at Clear Creek indicate multiple glacial stages or the waning stages from the same glaciation. Glaciofluvial terraces vary from being several meters thick (Gt) to a veneer cut into bedrock (Gtv).

### *Glaciofluvial complex (Gx)*

Deposits of gravel, sand, and diamicton that include variations of plains, terraces, eskers, and deltaic sediments. Textures are variable and include coarse gravel deposits to flat-lying and ripple bedded sands and planar stratified gravels separated by till. Glaciofluvial complex incorporates numerous mechanisms of glaciofluvial deposition and minor deposition associated with ice contact environments such as debris flow diamicts.

### *Glaciolacustrine plain sediments (Lp)*

Glaciolacustrine sediments consist of bedded fine sand, silt, and clay more than 5 m thick. Appears as a flat to gently rolling surface. Bedding is complicated by slumping from dewatering and melting of in-situ ice lenses. Kettle features mark the surface where ice has melted out.

### *Glaciolacustrine blanket (Lb)*

Glaciolacustrine sediments consisting of silt, fine sand, and clay 1 - 5 m thick. Deposits conform to the underlying valley form and are locally disrupted by gullying and colluviation.

### *Till blanket (Mb) and till veneer (Mv)*

Till blankets occupy valley bottoms and the lower slopes of valleys and grade into till veneers upslope. Till blankets are also common near the limits of pre-Reid, Reid, and McConnell glaciations. Erosion of till increases with slope angle and exposure. Subdued moraines are common on most slopes particularly on the older pre-Reid surfaces. Erosion by surface runoff is more common on south facing slopes, which have less permafrost and vegetation to secure surface sediments.

### *Till complex (Mx)*

A combination of moraine blankets, veneers, hummocky terrain, and minor glaciofluvial deposits. Till complexes occur at or near ice margins.

*Till plain (Mp)*

Low relief till deposited as a plain beneath the ice sheet. Commonly found in broad valleys bottoms.

*Till hummocks (Mm)*

Hummocky or rolling moraine found near terminal moraines where ice stagnation occurred. Relief is between 5 m and 20 m depending on the age of the surface.

*Drift plain (Dp)*

Consist of undivided till and glaciofluvial sediments of pre-Reid age that are > 5 m thick. Drift plains have flat to gently sloping forms, with little surface texture.

*Mass Wasting (Cz)*

Consists of a variable sediment composition depending on the source material. Includes slumping of glacial deposits and bedrock, rockfalls, and debris slides of glacial sediments and bedrock. In the northern part of the map sheet, where mass wasting is most prevalent, deposits consist of boulder accumulations with a minor diamict component.

*Cryoplanation terrace (CT)*

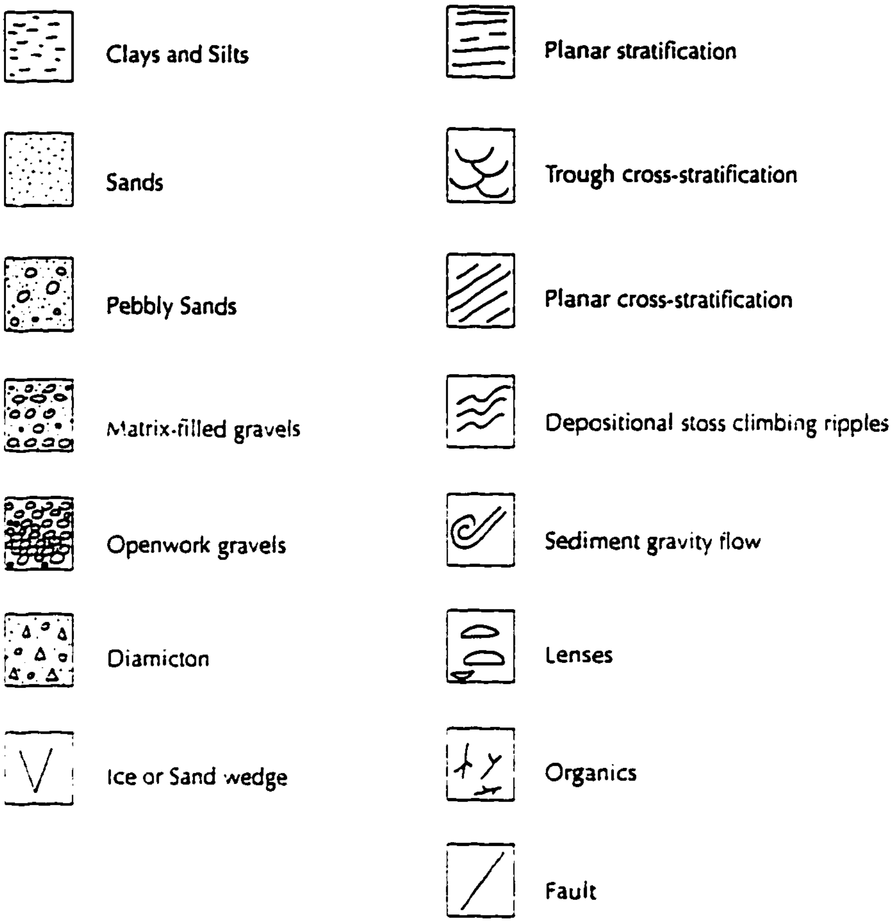
A bedrock terrace covered by felsenmeer of variable thickness developed by frost shattering, nivation, and gelifluction in unglaciated areas or areas proximal to the upper limit of pre-Reid glaciations.

### *Bedrock (R)*

Includes bedrock on summits, ridgetops, and slopes. The Syenite Range, East and West Ridge, Red Mountain, Scheelite Dome, and White Mountains have relatively significant exposures of bedrock in McQuesten map area.

## APPENDIX II

### LEGEND FOR VERTICAL LITHOSTRATIGRAPHIC LOGS



| | | | |
|---|---|---|---|
| x | Radiocarbon date | P | Pebbles |
| Cl | Clay | C | Cobbles |
| Si | Silt | B | Boulders |
| Sa | Sand | | |
| G | Granules | | |