Exploration and Geological Services Division, Yukon Region

BULLETIN 13

Placer gold deposits of the Mayo area, central Yukon

by
W.P. LeBarge[1], J.D. Bond[1] and F.J. Hein[2]

with contributions from
L. Weston[1], T. Allen[1] and L. Walton[3]

[1]Yukon Geology Program, Whitehorse, Yukon
[2]University of Calgary, Calgary, Alberta
[3]Walton Geological Services, Whitehorse, Yukon

2002

Published under the authority of the Minister of Indian Affairs and Northern Development, Ottawa, 2002.
Printed in Whitehorse, Yukon

QS-Y192-000-EE-A1 Catalogue No. R2-211/2002E ISBN 0-662-32136-7

This, and other Yukon Geology Program publications, may be obtained from:
Geoscience and Information Sales
c/o Whitehorse Mining Recorder
102-302 Main Street
Whitehorse, Yukon Y1A 2B5 Canada
phone (867) 667-3266, fax (867) 667-3267, geosales@inac.gc.ca

In referring to this publication, please use the following citation:
LeBarge, W.P., Bond, J.D. and Hein, F.J., 2002. Placer gold deposits of the Mayo area, central Yukon. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 13, 209 p.

Production by K-L Services, Whitehorse, Yukon.

Cover photo: Placer gold in the Mayo area occurs in several settings including alluvial fan-deltas, such as in this photo of Anderson Creek on Mayo Lake. Most placer mining has been concentrated at the apex of the fans, however recent exploration has found placer gold deposits in distal parts of the fan.

Preface

A study of the geological setting of placer deposits in the Mayo area was initiated in 1995 by William LeBarge, DIAND Placer Geologist. In 1996 and 1997, Bill was joined by a multidisciplinary team of researchers including surficial geologist Jeff Bond (Yukon Geology Program), and sedimentologists Frances Hein (University of Calgary), Leyla Weston (University of Calgary/Yukon Geology Program) and Tammy Allen (Yukon Geology Program). In 1998, Bill continued to gather stratigraphic and sedimentologic data from drainages in the Mayo area. This bulletin is a compilation of the work conducted during those several seasons of fieldwork in the Mayo area.

The aim of this study was to characterize placer deposits in a glaciated setting, particularly in this area at the margins of two glaciations, where the potential for placer gold deposits is highest. This study was successful in combining surficial geological mapping, geomorphology and detailed sedimentology, and lead to four placer deposit models being proposed in this glaciated setting. These new placer deposit models for glaciated areas represent an important step forward in the study of placer gold settings.

These studies could not have been completed without the cooperation and support of local placer miners, prospectors and mining companies and their assistance was greatly appreciated. We hope the publication will assist in the discovery and development of new placer resources, and that it will serve as a valuable information source for other scientists and the interested public.

Préface

Une étude du cadre géologique des placers dans la région de Mayo a été entreprise en 1995 par William LeBarge, géologue spécialiste des placers au MAINC. En 1996 et en1997, une équipe multidisciplinaire de chercheurs s'est jointe à Bill, incluant le géologue spécialiste des dépôts meubles Jeff Bond (service de géologie du Yukon) et les sédimentologues Frances Hein (Université de Calgary), Leyla Weston (Université de Calgary/service de géologie du Yukon) et Tammy Allen (service de géologie du Yukon). En 1998, Bill a poursuivi la cueillette de données stratigraphiques et sédimentologiques sur les bassins versants dans la région de Mayo. Ce bulletin présente une compilation des travaux menés au cours de plusieurs saisons sur le terrain, dans la région de Mayo. Cette étude avait pour but de caractériser les placers dans un cadre géologique glaciaire, particulièrement dans cette région aux limites de deux glaciations où le potentiel pour les placers aurifères est optimal. L'étude a permis de combiner la cartographie géologique des dépôts meubles, la géomorphologie et la sédimentologie détaillée, et a mené à la proposition de quatre modèles de placers dans un cadre géologique glaciaire. Ces nouveaux modèles de placers pour des régions glaciaires constituent une étape importante dans l'étude des cadres géologiques pour des placers aurifères.

Ces études n'auraient pas pu être menées à terme sans la collaboration et l'appui des exploitants locaux de placers, des prospecteurs et des sociétés d'exploitation minière, dont l'aide a été grandement appréciée. Nous espérons que cette publication contribuera à la découverte et à la mise en valeur de nouvelles ressources placériennes, et qu'elle constituera une source d'information précieuse pour d'autres scientifiques et pour les personnes intéressées.

Grant Abbott

Chief Geologist
Exploration and Geological Services Division
Yukon Region, Indian and Northern Affairs Canada

Géologue en chef
Division des services d'exploration et de géologie
Affaires indiennes et du Nord Canada, région du Yukon

Acknowledgements

Studies of this type do not get off the ground without considerable cooperation and assistance from several individuals and organizations. Thanks of course are due to the other contributing researchers for their excellent work: Jeff Bond, Fran Hein, Leyla Weston, Tammy Allen and Lori Walton. Excellent field assistance and interesting geological discussions were provided by Claire Wilson, Lisa MacKinnon, Dylan MacGregor and Mark Skidmore. Much appreciation goes to the many placer miners and families that gave assistance and cooperation to the project team, often well beyond what we could have imagined. In conducting this study we unexpectedly gained a new circle of friends – including the Taylor family (Frank, Bonnie, Troy, Todd, Tami), the Klippert family (Dan and Dee, Kim and Cheryl) and the Holway family (Ron, Fred and Caroline).

Others that contributed in the field and office include Paulina Mindermann, Erika Kotler, Jason Adams, Mark Nowosad, Melanie Reinecke, Panya Lipovsky, Alison Hartley, Cheryl Peters, and Julianne Madsen. Kennecott Canada kindly provided some of the digital topography of Highet Creek. Aerial support was skillfully provided by Harmen Keyser, Pat Dayman and Will Thomson of Trans North Helicopters.

W.P. LeBarge
Placer Geologist
Exploration and Geological Services Division
Yukon Region, Indian and Northern Affairs Canada

Abstract

Placer deposits in the Mayo area occur in a wide variety of geomorphic settings, including alluvial fans, gulch gravel, valley-bottoms (alluvial plains), and bedrock terraces (bench gravel), which have been variably buried and reworked by glaciofluvial processes. Placer gold also occurs in glacial till and glaciofluvial gravel, especially where these sediment types have intersected pre-existing placer deposits, resulting in the reconcentration of gold in a zone close to bedrock.

The Yukon has been subjected to several major episodes of glaciation, which are generally referred to as the pre-Reid (oldest), the Reid (intermediate), and the McConnell (youngest) glaciations. The pre-Reid glaciation consisted of multiple episodes, the earliest being at least 2.58 Ma. Although the Mayo area was heavily glaciated during the pre-Reid episodes, limited surficial deposits remain, and evidence mainly consists of erosional features and erratics at higher elevations. The subsequent Reid (approximately 300 000 years ago) and the McConnell (approximately 20 000 years ago) glaciations reworked and buried pre-existing glacial drift and alluvium, and left extensive surficial deposits.

While the timing of the interglacial prior to the Reid is uncertain, the Koy-Yukon interglacial prior to the McConnell glaciation lasted approximately 170 000 years. The modern (Holocene) interglacial began approximately 11 000 years ago. These three interglacials have been the main placer-forming periods in the Mayo area.

The complex stratigraphy of placer deposits in the Mayo area reflects its glacial and periglacial history. Within the glacial limit, placer deposits are best preserved near the maximum limit or terminus, where the scouring of pre-existing sediment was minimal and depositional processes were dominant. Beyond the glacial limit, periglacial climatic conditions resulted in increased slope and alluvial sedimentation that buried and reworked paleoplacers.

Based on surficial mapping, stratigraphic relationships and sedimentology, several placer deposit models may be described within the Mayo area. These can be grouped into modern, interglacial, glacial or periglacial placer settings.

Modern placers include alluvial fans, fan-deltas, alluvial plains and gulch deposits. Interglacial placer settings in the Mayo District include alluvial plains, alluvial fans and low terraces along second and third order streams and rivers, and gulches in first order tributary valleys. These are commonly buried and reworked by glacial drift and periglacial fan sediments. Glacial placer settings in the Mayo area include glacial till and glaciofluvial gravel in major valleys, the most significant of which are Reid age or older. Periglacial placers include alluvial fans in tributary valleys and fan-deltas along major water bodies including Mayo Lake.

Placer exploration targets occur in all of the above settings, however the most significant are those that remain buried in trunk valleys, which were not post-glacially re-excavated due to base-level changes. Substantial placer gold reserves may exist in these valleys but their potential remains to be evaluated. Suggested methods include a combination of seismic surveys, overburden drilling and bulk sampling.

Résumé

Les placers de la région de Mayo se présentent dans une grande variété de cadres géomorphologiques, incluant les cônes alluviaux, le gravier des ravins, les fonds de vallées (plaines alluviales) et les terrasses du substratum rocheux (gravier de terrasse), qui ont été enfouis de diverses façons et remaniés par les processus fluvio-glaciaires. On trouve aussi de l'or placérien dans du till glaciaire et du gravier fluvio-glaciaire, notamment aux endroits où ces types de sédiments recoupent des placers préexistants, donnant lieu à la reconcentration de l'or dans une zone proche du substratum rocheux.

Le Yukon a subi plusieurs épisodes importants de glaciation, que l'on désigne comme les glaciations de pré-Reid (la plus ancienne), de Reid (intermédiaire) et de McConnell (la plus récente). La glaciation de pré-Reid comprend de multiples épisodes dont le plus ancien remonte à 2,58 M.A. Bien que la région de Mayo ait été considérablement érodée par les glaciers au cours des épisodes pré-Reid, il reste peu de dépôts de surface et les seuls vestiges consistent en des formes érodées et des erratiques à des altitudes plus élevées. Les glaciations subséquentes de Reid (il y a environ 300 000 ans) et de McConnell (il y a environ 20 000 ans) ont remanié et enfoui les dépôts glaciaires et alluvionnaires préexistants et ont laissé de nombreux dépôts de surface.

Alors que la durée de l'interglaciaire antérieur à la glaciation de Reid est incertaine, l'interglaciaire de Koy-Yukon antérieur à la glaciation de McConnell a duré approximativement 170 000 ans. L'interglaciaire contemporain (Holocène) a commencé il y a approximativement 11 000 ans. Ces trois périodes interglaciaires ont été les principaux événements favorables à la formation des placers dans la région de Mayo.

La stratigraphie complexe des placers dans la région de Mayo est le reflet de son histoire glaciaire et périglaciaire. À l'intérieur des limites glaciaires, les placers sont les mieux conservés près de la limite de l'extension maximale ou front glaciaire, où le décapage de sédiments préexistants était minimal, tandis que les processus de sédimentation prédominaient. Au-delà des limites glaciaires, les conditions climatiques périglaciaires ont entraîné une sédimentation accrue sur les pentes et sous forme d'alluvions, contribuant à l'enfouissement et au remaniement des paléoplacers.

S'appuyant sur la cartographie des matériaux de surface, les liens stratigraphiques et la sédimentologie, on peut décrire plusieurs modèles de placers dans la région de Mayo. On peut grouper les placers selon le contexte : contemporain, interglaciaire, glaciaire et périglaciaire.

Les placers contemporains comprennent les cônes alluviaux, les deltas alluviaux, les plaines alluviales et les dépôts dans les ravins. Les placers de milieu interglaciaire dans le district de Mayo incluent les plaines alluviales, les cônes alluviaux et les terrasses peu élevées le long de ruisseaux et de cours d'eau de deuxième et de troisième ordre, et les ravins de vallées tributaires de premier ordre. Ceux-ci sont souvent enfouis et remaniés par les dépôts glaciaires et les sédiments alluviaux périglaciaires. Les placers de milieu glaciaire dans la région de Mayo comprennent du till glaciaire et du gravier fluvio-glaciaire dans les vallées principales, dont les plus importants sont de la période Reid ou d'une période antérieure. Les placers périglaciaires comprennent des cônes alluviaux dans des vallées tributaires et des deltas alluviaux en bordure de plans d'eau importants, y compris le lac Mayo.

On a des objectifs d'exploration des placers dans tous les contextes mentionnés ci-dessus, cependant les plus importants demeurent enfouis dans les vallées principales, qui n'ont pas été recreusées après les glaciations en raison de changements du niveau de base. Des réserves importantes en or placérien pourraient se trouver dans ces vallées mais leur potentiel reste à évaluer. Les méthodes d'évaluation proposées comprennent une combinaison de levés sismiques, de forages des morts-terrains et d'échantillonnage global.

Contents

Introduction

General Setting

Surficial sediment: Sedimentology and stratigraphy

Placer mining areas – detailed studies

Regional investigations – expanding the borders

Heavy mineral studies

Placer deposit settings and exploration targets

Appendices

Tables

Figures

In pocket

Bond, J.D., 1998a. Surficial geology of Sprague Creek map area, central Yukon (115P/15). Geoscience Map 1998-1, 1:50 000 scale.

Bond, J.D., 1998b. Surficial geology of Seattle Creek map area, central Yukon (115P/16). Geoscience Map 1998-2, 1:50 000 scale.

Bond, J.D., 1998c. Surficial geology of Mt. Haldane map area, central Yukon (105M/13). Geoscience Map 1998-3, 1:50 000 scale.

Bond, J.D., 1998d. Surficial geology of Keno Hill map area, central Yukon (105M/14). Geoscience Map 1998-4, 1:50 000 scale.

Bond, J.D., 1998e. Surficial geology of North McQuesten River map area, central Yukon (116A/1). Geoscience Map 1998-5, 1:50 000 scale.

Bond, J.D., 1998f. Surficial geology of Dublin Gulch map area, central Yukon (106D/4). Geoscience Map 1998-6, 1:50 000 scale.

Bond, J.D., 1999. Glacial limits and ice flow patterns, Mayo area, central Yukon. Geoscience Map 1999-13, 1:250 000 scale.

Lipovsky, P., Bond, J. and LeBarge, W., 2001. Mayo area placer activity map, portions of NTS sheets 105M, 106D, 115P and 116A, Yukon (1:250 000 scale). Open File 2001-35.

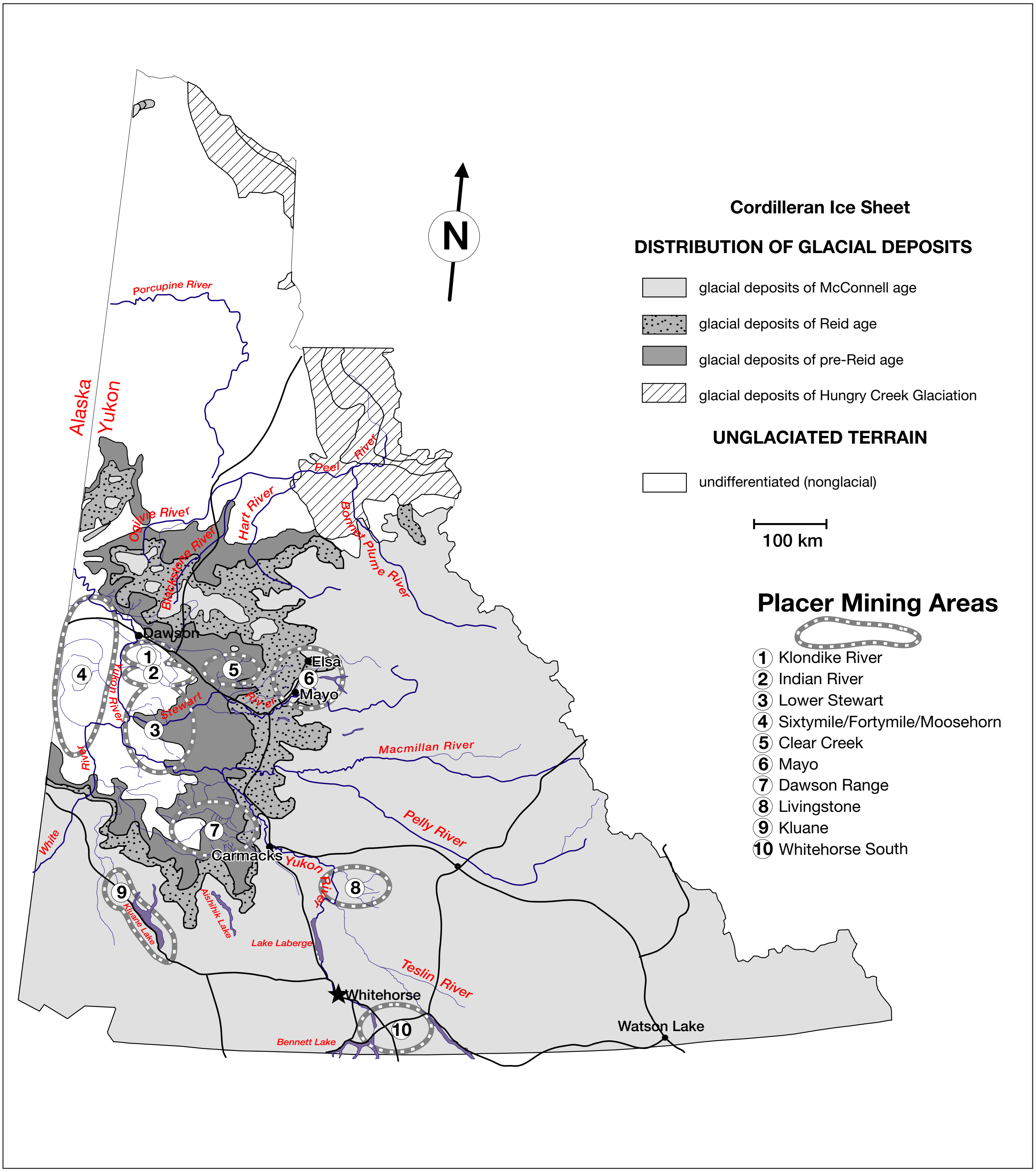


Figure 1. *Extent of Pleistocene glaciations and placer gold mining areas in Yukon (modified after Duk-Rodkin, 1998).*

INTRODUCTION

The Yukon Geology Program initiated a study of the geological setting of placer deposits in the Mayo area in 1995. In May, 1996, this work continued in the form of a two-year research project designed to identify new placer potential in the Mayo Mining District. This program was largely completed as a research contribution agreement between the University of Calgary (Department of Geology and Geophysics), the Yukon Geology Program (Economic Development Branch, Yukon Government) and Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, which funded logistical and staff support. Emphasis of this study focused on the sedimentology and stratigraphic setting of the western part of the Mayo Mining District, and included detailed stratigraphic and sedimentological work in the Duncan Creek, Mayo Lake, Haggart Creek and Highet Creek areas (Fig. 2). In conjunction with the sedimentology and stratigraphy studies, surficial mapping and geochemical studies were completed along the northern extent of the Mayo Mining District.

The Mayo area is a unique district in which to examine the sedimentology of placer deposits due to the combination of well-known lode sources with a mineral zoning pattern (Franzen, 1986; Lynch, 1986, 1989; Watson, 1986), and documented placers with interesting suites of associated heavy minerals. Furthermore, the area is at the limit of several glacial ice advances, therefore allowing the opportunity to examine the distribution of gold placers within glacial sediments and glacially influenced landforms.

This bulletin complements another study of glacial placers, the Mount Nansen area of central Yukon, in which significant amounts of placer gold are associated with a glacial diamicton at the diamicton/bedrock contact (LeBarge, 1995).

LOCATION OF STUDY AREA

The study area is located within the Mayo Mining District, central Yukon, approximately 400 km by road north of Whitehorse (Figs. 1, 2). The area is part of the Stewart Plateau, northeast of the Tintina Trench, and is proximal to the southern foothills of the Ogilvie Mountains. Most of the study area lies north of the village of Mayo and can be accessed by road, with the exception of Empire Creek, which lies south of Mayo and is accessible only by winter road or helicopter. Sedimentological studies were conducted on the major drainages within these areas, including: Haggart Creek and its tributaries, Duncan Creek and its tributaries, Mayo Lake, Seattle Creek and Highet Creek. This encompasses NTS map areas 116A/1, 106D/4, 115P/15, 115P/16, 105M/13 and 105M/14.

PREVIOUS WORK

Enclosed with this bulletin are eight previously released and updated maps, including six 1:50 000 surficial geology maps (Bond, 1998a; Bond, 1998b; Bond, 1998c; Bond, 1998d; Bond, 1998e; Bond, 1998f); and two 1:250 000 scale maps, one showing glacial limits and flow patterns (Bond, 1999), and the other showing placer mining activity in the Mayo area (Lipovsky et al., 2001).

A review of previous work on placers and surficial deposits of the Mayo Mining District is presented in LeBarge (1996a, 1996b), with some highlights summarized here. Surficial geology and/or placer-related studies in central Yukon include Bostock's (1948, 1966, 1969) compilations of glacial limits; Hughes' detailed mapping of the McConnell glacial limits (Hughes, 1982, 1987; Hughes et al., 1969, 1972); Duk Rodkin's (1999) compilation of glacial limits; Quaternary geology studies by Giles (1993) of sections near the Mayo town site and Mayo Indian Village; Pleistocene mammal studies of Dublin Gulch and the Mayo placer mining areas by R. Harrington (pers. comm.); soil surveys and revegetation studies of selected mining areas near Mayo (Mougeot, 1993; Wilson et al., 1996) and permafrost studies in the Mayo and Duncan Creek areas (Burn, 1990, 1994; Burn and Friele, 1989). Mougeot and others have produced a series of geological processes and terrain hazard inventory maps for Mayo and the surrounding area (Yukon GEOPROCESS File, 2002; Mougeot and Walton, 1996a, 1996b, 1996c; Doherty et al., 1994). Earlier geochemical work on gold by Boyle and others focused on the Keno Hill area (Kindle, 1955; Boyle and Gleeson, 1972; Boyle, 1979). Bedrock gold-silver occurrences were compiled for the Yukon by Morin (1989), with a more detailed compilation of placer gold/silver occurrences in the Mayo area by Kreft (1993) and Carlyle (1995a, 1995b). This work has been incorporated into the Placer MINFILE by Hein et al. (1996). Regional geochemical stream sediment and water geochemical data for the Mayo map area (105 M) were

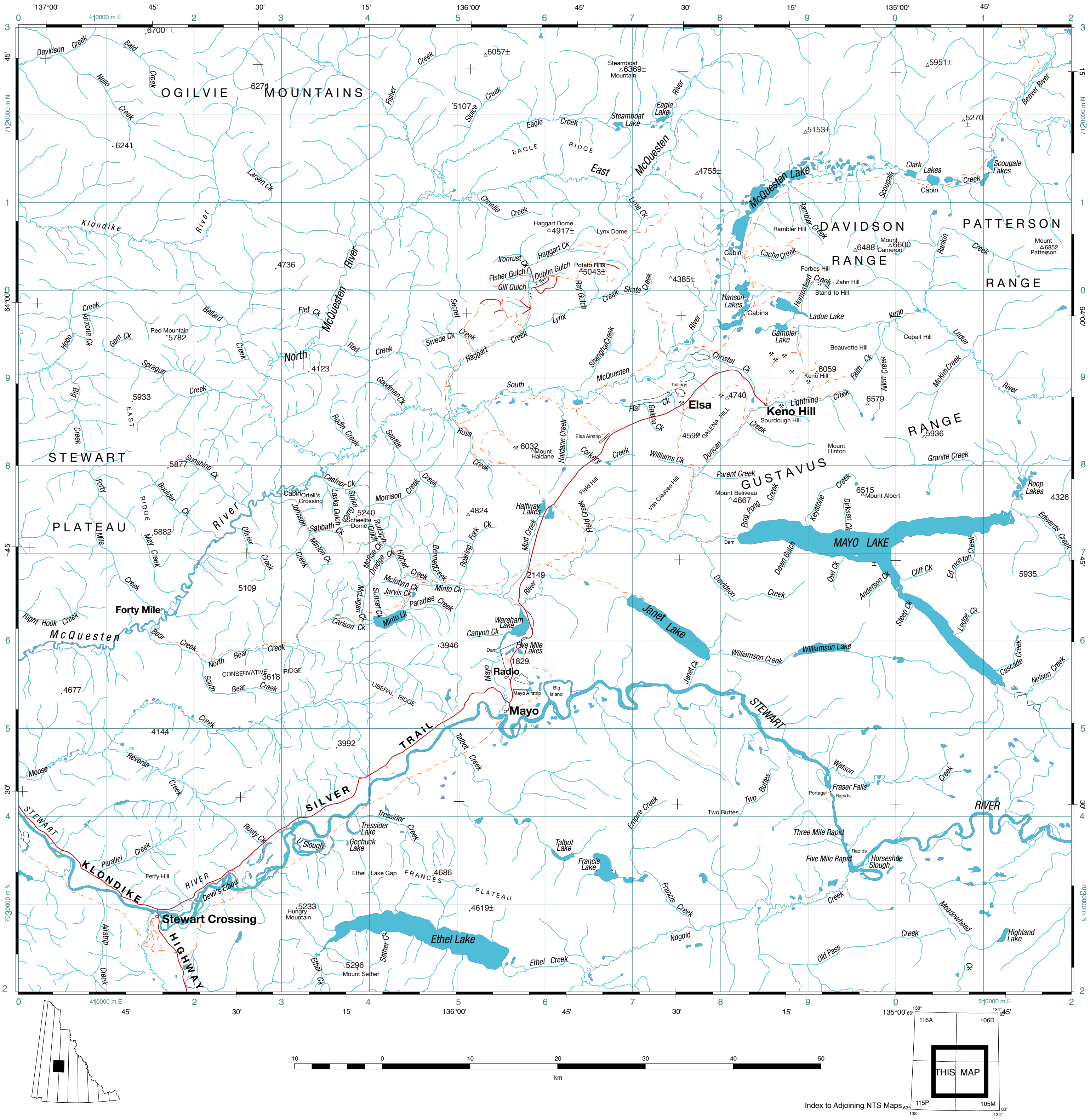


Figure 2. Mayo placer area, central Yukon.

collected and collated by the Geological Survey of Canada (Friske and Hornbrook, 1989). Regional overviews of placer geology in the Yukon are given by Morison (1989) and McLeod and Morison (1996), with summaries of central Yukon by LeBarge (1996a). Bedrock mapping in the Mayo area includes Poole (1965), Green (1971, 1972), Hunt et al. (1996), Murphy and Roots (1996), Roots (1991, 1997), and Roots and Murphy (1992a, 1992b). Lynch (1986, 1989) studied mineral zoning within bedrock in the Keno Hill area. An investigation into reprocessing of tailings at Elsa was completed by Hawthorne (1996).

Other studies of interest include the origin and permafrost characteristics of the "muck" in the Klondike region (Fraser, 1995; Fraser and Burn, 1997; Kotler, 1998); Harris' (1994) chronostratigraphic studies of glaciations and permafrost in the Cordillera; mapping of glacial limits and surficial deposits in the Dawson area and Mackenzie Mountains (Duk-Rodkin, 1996; Duk-Rodkin and Hughes, 1991; Duk-Rodkin et al., 1996); paleosol development in central Yukon (Rutter et al., 1978; Smith et al., 1986; Tarnocai et al., 1985; Tarnocai and Schweger, 1991); sedimentological studies on the Klondike Terrace placer gravels near Dawson (Froese, 1997; Froese and Hein, 1996); sedimentology and stratigraphy of placer deposits within the Haggart Creek drainage near Mayo (Weston, 1999); Quaternary and surficial geology of the McQuesten map area (Bond, 1996, 1997a, 1997b); and plant and insect fossil studies from the Mayo Indian Village section (Matthews et al., 1990).

FIELD AND LABORATORY METHODOLOGY

Surficial geological mapping, and detailed stratigraphic section descriptions of mine-cut, road, or stream-cut sections, are the main field data included in this study. In 1995, reconnaissance studies centred on the Duncan Creek and Mayo Lake areas, with some preliminary work in the Gill Gulch, Highet, Haggart, Goodman and Seattle Creek drainages. During the 1996 and 1997 field seasons, Reid and McConnell limits were mapped mainly in the eastern and central parts of the study area, and this work was published as six surficial maps and a glacial limits map (Bond, 1998a-f; Bond, 1999, in pocket, Fig. 3). Within the study area, 165 sites were visited for sedimentological and stratigraphic description, of which 138 were of sufficient exposure for detailed stratigraphic analysis (Appendices 1 and 4). Sites in areas of active placer mining were revisited during the field season to document sequential changes in sediment types and facies. These mining operations gave excellent exposure of vertical and lateral facies trends, and allowed the opportunity to ascertain the stratigraphic relationships between different units. Additional natural exposures and gravel pits along stream and road courses were measured for stratigraphic and sedimentological control. Sections were described with emphasis on physical sedimentary features, including: grain size, bed thickness, gravel fabric, primary sedimentary structures, and lithology and rounding of clasts. Other descriptive criteria included: cryogenic features such as ice-wedge casts, ice-loading contacts, and disruption of primary features; colluviation and down-slope wasting; and pedogenesis. Samples were collected for grain-size, heavy mineral, geochemical, radiocarbon, palynological and mineralogical analyses.

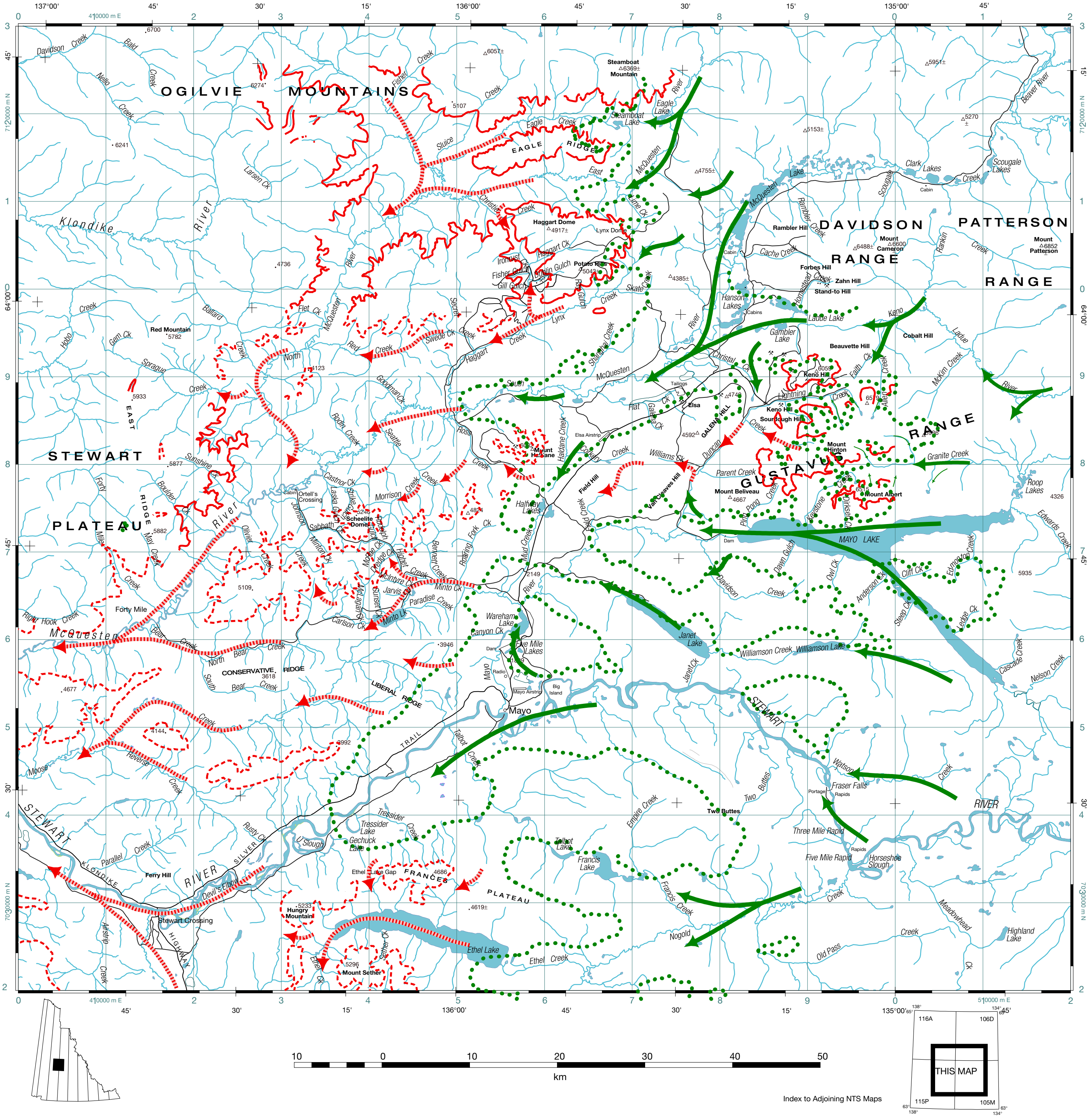
Approximately 180 bulk gravel samples were collected between 1995 and 1998. Sampled areas were scraped using a shovel to remove any surface debris and to avoid contamination. The shovel was cleaned and then used to obtain approximately 2-5 kg of bulk gravel sample. Selected samples were panned on site to document any presence of gold, while most samples were collected for grain size and heavy mineral analysis. Grain size samples were dried, split to 1.5 kg samples and sieved through #4, #10, #18, #35, #60, #120 and #230 Tyler mesh screens (Folk, 1974).

Heavy minerals from 146 samples were initially processed by recombining the #18 to #120 mesh fractions and hand panning down to a small concentrate. After heavy liquid separation, the minerals were examined with a binocular microscope and selected grains were sent for microprobe analysis. Appendix 2 details results of this study.

A total of 40 organic samples were collected for ^{14}C dating. Wood was sampled wherever possible to avoid any root contamination, which commonly occurs when bulk-sampling organic-rich soil samples.

Thirteen samples were obtained for palynological studies. Sample sites were chosen based on sediment colour, size and texture. Typical high pollen sediment is dark, fudge-brown colour and has a fine-grained texture (silt-sized particles). Samples were obtained by first digging into the section approximately 10 cm to avoid sampling any contaminated material. Approximately 500 g of sample was collected using a small, clean trowel.

In conjunction with the surficial mapping, 121 stream sediment samples were collected for geochemical



LEGEND

McConnell ice flow direction	Reid ice flow direction
McConnell glacial limit (>23 000 BP) (approximate)	Reid glacial limit (>200 000 BP) (defined, approximate)

Figure 3. *Glacial limits and ice flow patterns, Mayo area (after Bond, 1999. in pocket).*

analyses. Sample collection targeted fine-grained sediment trapped either in moss mats or in overbank deposits. The sample material was sieved on site through a 1-mm screen. Samples were air dried at Chemex Labs and then further sieved to extract the minus #80 mesh component of the sample. The samples were analysed for 32 elements by a nitric-aqua-regia leach – ICP/AES (inductively-coupled plasma/atomic emission spectroscopy). Gold analysis was completed using fire assay. The detection limits for gold and the 32 elements are outlined in Appendix 3. The gold values (ppb) are also presented on the surficial geology maps.

MINING HISTORY

Lode mining

Lode gold was discovered in Dublin Gulch in 1907 (Mayo Historical Society, 1990). The first recorded discovery of silver-lead was the Silver King vein on Galena Hill, found in 1903; high grading took place from 1913 to 1915. In 1919, rich silver-lead ore (No. 9 vein) was discovered on Keno Hill. This operation sparked a staking rush and prospectors staked much of the ground on Keno Hill and Galena Hill. Since that time, the Mayo area has seen a large number of silver-lead mines, the most important one being United Keno Hill Mines Ltd., which consolidated most of the properties in 1945.

The Keno Hill camp was once Canada’s second largest producer of silver. Table 1 summarizes the production history of lode mining in the Keno Hill area. Almost 50% of the total has come from the Elsa, Keno (No. 9), Lucky Queen, Silver King, Sadie-Ladue and Husky Mines. Over 1.8 million kg of cadmium and nearly 100 000 g of gold have also been recovered.

Placer mining

The discovery of placer gold in the Mayo district began on the Stewart River in 1883. A party of prospectors worked from the mouth of the Stewart River to the McQuesten River and mined US$10 per day on river bars (Mayo Historical Society, 1990). During the winter of 1894-1895, several bars on the Stewart River were found that produced 50 cents to the pan. By the summer of 1895, approximately 75 men had stampeded into the area to mine the bars. Ogilvie estimated that between 1885 and 1886 US$300 000 was taken from the bars, with occasionally up to $100 per day (Mayo Historical Society, 1990). This equates to 14,500 fine ounces (451 000 g) in two years from rocker-box technology, or $3.8 million at US$265 per ounce today. The Stewart River thus became the grubstake river for many prospectors in the central Yukon, and provided a means to fund exploration in tributaries further east (Mayo Historical Society, 1990).

In 1892, Ray Stewart discovered gold on the McQuesten River, and in 1895 placer gold was noted on Haggart Creek. Discovery claims were recorded on Johnson and Haggart Creeks in 1898. At this time a Swedish trio named Gustavson had located themselves at the canyon on Duncan Creek, approximately 15 km upstream from its confluence with the Mayo River. For about two years the Gustavsons mined the canyon deposit, undisturbed, and had avoided recording their claim for fear of initiating another stampede. In 1901, to the Swedes misfortune, four young Dawson stampeders discovered their camp and the Gustavson trio lost their discovery and some of the best paying ground in the Mayo district. The Swedes left the country with gold valued at US$30 000 (Mayo Historical Society, 1990). The stampede to Duncan Creek began not long after and soon the entire length of

Table 1. *History of lode mining production, Keno Hill area*

Years	Company	Tonnes milled	Silver (kg)	Lead (kg)	Zinc (kg)
1921-1941	Treadwell	588 503.4	1 533 087. 3	44 008 249.0	
1953-1956	Galkeno	102 408.8	117 818. 6	5 396 968.6	2 816 255
1953-1954	Bellekeno	10 499.9	27 961. 5	1 573 419.5	166 552
1941-1982	others	841.9	8 314. 1	480 322.0	6 322
1946-1988	United Keno	4 170 169.0	5 081 832.0	222 163 088.0	150 209 254
1921-1988	**Total**	**4 872 423.0**	**6 769 013. 5**	**273 622 047.0**	**153 198 383**

the creek was staked. Exploration in surrounding regions began shortly thereafter, and discoveries were posted on creeks flowing into Mayo Lake and in the Minto Creek region in 1903. This included the rediscovery of Highet Creek and its bench deposit. Warren Hiatt had reportedly discovered gold on Highet Creek prior to 1903 while working in Johnson Creek, but had written it off as having water problems (Mayo Historical Society, 1990). During the overflow from Duncan Creek, re-examination revealed that Highet Creek contained a significant quantity of gold. Rudolph Rosmusen and partners acquired an area of the bench opposite Rudolph Gulch and found the richest bench ground on the creek, yielding upwards of US$140 000 or 6773 fine ounces (210 664 g) of gold at US$20.67 per ounce. The amounts on these claims alone surpassed the total gold taken out of Duncan Creek in its first 14 years. In 1920 the Highet Creek Dredging Co. attempted to dredge Highet Creek, however, this lasted only a year and a half due to the inability of the dredge to handle large boulders.

Intermittent activity continued until an upsurge of mining occurred following the dramatic rise in the price of gold in the late 1970's and early 80's. Modern methods of mining, utilizing large bulldozers and excavators have become prevalent, especially in areas that were once considered to be too deeply buried by barren glacial overburden. Although most modern mining is still concentrated on the creeks, which were initially mined at the turn of the century, some new ground has been explored and mined on a few non-traditional creeks. Today, successful placer mining of the widespread glaciated terrain has required exploring deeper channels, bench settings, or isolated pockets adjacent to the traditional sites. Placer gold mining continues to be a major contributor to the economy of the Mayo area. Although records prior to 1978 are sparse and incomplete, recorded placer gold production from available sources at Mineral Resources, Indian and Northern Affairs Canada, is given in Table 2. Historic and current placer mining activity in the Mayo area are shown on a 1:250 000-scale compilation map along with glacial limits and flow patterns (Lipovsky et al, 2001, in pocket).

Table 2. *Placer gold production, Mayo District*

Stream or river	Tributary to	Gold production 1874-2000 (crude ounces)	(grams)
Anderson	Mayo Lake	434	13 499
Bear	McQuesten	1331	41 399
Carlson	Minto	105	3 266
Davidson	Mayo River	1596	49 641
Dawn	Mayo Lake	15	466
Dirksen	Mayo Lake	31	964
Dublin Gulch	Haggart	27,177	845 300
Duncan	Mayo River	33,277	1 035 031
Empire	Francis Creek	997	31 010
Gem	Sprague	428	13 312
Haggart	S. McQuesten	50,574	1 573 028
Highet	Minto	46,743	1 453 871
Hope Gulch	Lightning	8	249
Johnson	McQuesten	12,935	402 324
Ledge	Mayo Lake	6137	190 882
Lightning	Duncan	4667	145 160
McQuesten	Stewart	27	840
Minto	Mayo River	1508	46 904
Morrison	Seattle	16	498
Russell	Macmillan	287	8 927
Seattle	McQuesten	208	6 470
Steep	Mayo Lake	219	6 811
Stewart	Yukon	6735	209 482
Swede	Haggart	3830	119 126
Thunder	Lightning	4434	137 913
Vancouver	McQuesten	928	28 864
Various Mayo creeks		1565	48 677
Total		**206,212**	**6 413 915**

GENERAL SETTING

BEDROCK GEOLOGY

A generalized bedrock geology map is given in Figure 4. Bedrock in the Mayo area includes Upper Proterozoic - Lower Cambrian Hyland Group metasandstone, conglomerate, siltstone, shale and phyllite; Ordovician Road River Group siltstone and chert; Devonian Earn Group coarse chert-pebble conglomerate, sandstone, siltstone, with minor dark grey to black limestone and chert, and Mississippian Keno Hill Quartzite (Murphy and Héon, 1994; Roots, 1997). The Hyland Group is divided into two formations, the Yusezyu and the Narchilla. The older Yusezyu formation comprises predominantly phyllite, metasiltstone, medium- to coarse-grained metasandstone, metaconglomerate, and sandy marble, whereas the Narchilla Formation includes quartzofeldspathic sandstone, maroon and green argillite, and grey weathered marble (Green, 1971; Murphy and Héon, 1994).

These metasedimentary rocks occur in broad, open folds and widely spaced thrust faults offset by narrow, northwesterly trending faults. In the central and northern part of the study area, Mississippian Keno Hill Quartzite is locally intensely fractured, folded and foliated with prominent quartz-veining, and intruded by local diabase and metadiorite dykes and sills. The Robert Service Thrust Fault, which traverses the area from Mt. Haldane to Tiny Island Lake, has associated fold-and-fault intersections, overturning of the stratigraphy, and local quartz veining. A northwesterly trending band of Cretaceous granitoid intrusions cross the area from the Roop Lakes to the Potato Hills near Dublin Gulch, and Scheelite Dome near Highet Creek. Other major intrusions or dyke systems occur to the south in the Talbot Plateau area, and northwest of the map area towards the Clear Creek drainage (Murphy and Héon, 1994; Murphy and Roots, 1996; Roots, 1997).

MINERAL DEPOSITS

Keno-Galena Hill area

Within the Keno Hill district, there are more than 65 mineral deposits in an area 26 km long and 1 to 7 km wide (Yukon MINFILE, 1997, 105M 001). Most of the deposits, with the exception of the Sadie-Ladue vein, are confined to the Mississippian Keno Hill Quartzite (Yukon MINFILE, 1997). This quartzite is about 700 m thick, is structurally overlain by phyllite and sericite schist of the Late Proterozoic-Early Cambrian Hyland Group, and is underlain by graphitic schist, phyllite and sericite schist of the Devono-Mississippian Earn Group. Triassic metadiorite sills intrude the sequence.

The metasedimentary rocks strike east and dip 20° to 30° south. In the Keno Hill-Galena Hill area, these rocks form the south flank of the McQuesten anticline. The mineral deposits consist of mineralized vein-faults 0.3 to 30 m wide in the Keno Hill Quartzite. Metasedimentary rocks commonly show left-lateral offsets of more than 150 m across these faults, which strike northeast and dip steeply southeast. The ore zones are cut by steep unmineralized cross faults, which strike northwest and show right-lateral offsets ranging from 1 to 610 m, and by bedding-plane thrust faults which have up to 30 m of movement (Yukon MINFILE, 1997).

Mineralization consists of argentiferous galena, freibergite (argentiferous tetrahedrite), and pyrargyrite (ruby silver), along with sphalerite, pyrite and minor polybasite, stephanite, argentite and native silver. The silver to lead ratio varies from 3:1 to 11:1 depending on the tetrahedrite content. Siderite is the main gangue mineral (Yukon MINFILE, 1997).

Placer silver nuggets have been recovered on Duncan Creek, a few kilometres downstream from silver-bearing quartz veins during historic and present placer mining. Silver- and galena-bearing quartz veins on Keno Hill are likely the local source. In Thunder Gulch, the placer gold is more angular and less travelled, perhaps originating from local bedrock veins within the headwaters on the west flank of Mount Hinton (Yukon MINFILE, 1997, 105M 052). Upper Duncan, Granite and Keystone creeks also host placer gold that may have been derived from Mount Hinton. Other local gold sources include quartz veins within phyllite, grit and phyllitic schist of the Hyland Group bedrock; local stocks, veins, intrusions or hydrothermal systems associated with plutons at Roop Lakes; and locally auriferous Tombstone age dykes and sills trending approximately east-northeast throughout the district (Roots and Murphy, 1996).

Dublin Gulch/Haggart Creek area

The most important mineral deposit in the Dublin Gulch area is hosted by the Potato Hills granite stock (Yukon MINFILE, 1997, 106D 025). The Potato Hills

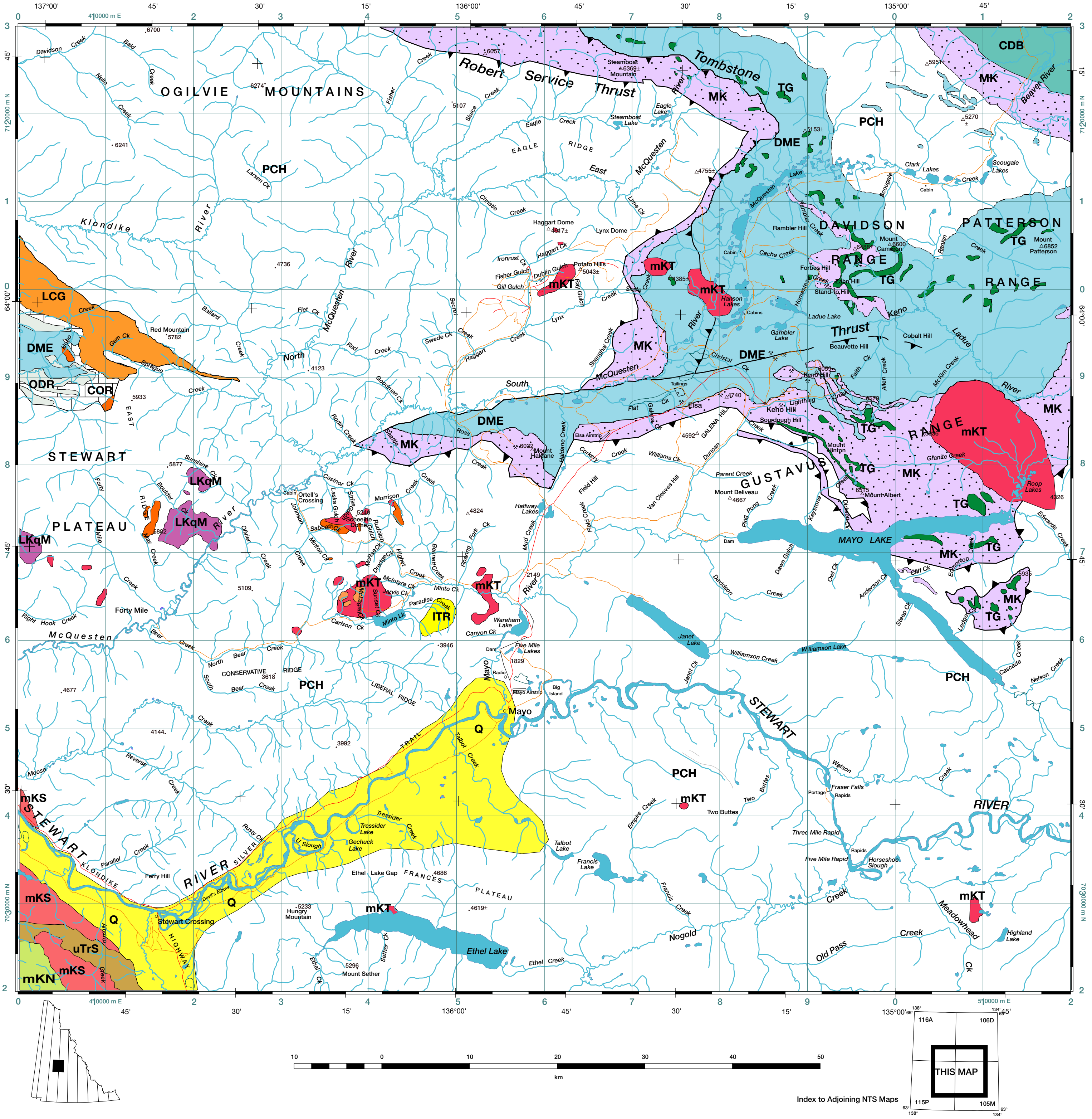


Figure 4. *Generalized bedrock geology (after Roots and Murphy, 1992; legend on adjacent page).*

Quaternary

Q	unconsolidated glacial, glaciofluvial and glaciolacustrine deposits, fluviatile sediments and local volcanic ash.

Tertiary

lTR	Ross mixed basalt and rhyolite and terrestrial local shale, sandstone and conglomerate, dominantly along or near Tintina Fault.

Cretaceous

LKqM	McQuesten Suite biotite ± muscovite granite and quartz monzonite.
mKN	Mount Nansen andesite to dacite flows, breccia and tuff; felsic lapilli tuff; rhyolite and quartz-feldspar porphyry plugs, dykes, sills and breccia.
mKS	Selwyn Suite plutonic suite of intermediate to more felsic composition (quartz monzonite, granodiorite and granite) and rarely syenitic.
MKT	Tombstone Suite syenite, quartz syenite; minor granite, monzogranite, diorite.

Triassic

uTrS	Synorogenic clastic rocks conglomerate with clasts of basalt, chert, mylonite, limestone, foliated hornblende granodiorite and quartz monzonite.
TG	Galena Suite diorite dykes.

Mississippian

MK	Keno Hill Quartzite quartz arenite with minor black shale or carbonaceous phyllite.

Devonian-Mississippian

DME	Earn Group black siliceous shale and chert with minor felsic volcanic rocks, chert-pebble conglomerate, barite and many occurrences of stratiform Pb-Zn.

Ordovician-Devonian

ODR	Road River - Selwyn black graptolitic shale and chert overlain by argillite and dolomitic siltstone or buff platy limestone.

Cambrian-Devonian

CDB	Bouvette Formation dolomite and limestone, minor argillaceous limestone, limestone conglomerate, and black shale.

Cambrian-Ordovician

COR	Rabbitkettle Formation silty limestone and calcareous phyllite and limestone conglomerate; local mafic flows, breccia and tuff.
LCG	Gull Lake Formation dominantly shale, siltstone and mudstone with minor quartz sandstone; basal limestones (conglomerate); phyllite to quartz-muscovite-biotite schist.

Proterozoic

PCH	Hyland Group coarse turbiditic clastics, limestone and maroon and green shale; layered micaceous quartzose rock; gritty phyllite; quartzite and metaconglomerate; rare calc-silicate rock.

***Figure 4** (continued)**.** Legend.*

stock intrudes metasedimentary rocks of the Late Proterozoic-Early Cambrian Hyland Group. The deposit consists of gold-bearing quartz veins and stockwork cutting the granite. Most veins strike northeast and range in width from a few centimetres to over 2 m, although the arsenopyrite-rich section is usually restricted to widths of 10 to 25 cm near the centre. Minor amounts of pyrite occur with the arsenopyrite (Yukon MINFILE, 1997).

The vein on the Victoria claims assayed 8.6 g/t Au and 13 g/t Ag over a width of 0.6 m for the 23-metre length of the drift. Similar assays were obtained from other veins (Yukon MINFILE, 1997).

Based on the trenching and drilling programs conducted by Amax Gold and Ivanhoe in 1991, a resource of 90 million tonnes grading between 0.93 g/t Au and 1.24 g/t Au has been identified on the Dublin Gulch property, presently owned by New Millenium Mining Ltd (Yukon MINFILE, 1997).

A tungsten skarn deposit known as Ray Gulch also occurs on the margin of the Potato Hills stock with drill-indicated reserves of 5.4 million tonnes at 0.82% WO_3 (Brown et al., 2002).

Highet Creek area

The Scheelite Dome (Yukon MINFILE 1997, 115P 004) gold-tungsten property lies at the headwaters of Highet Creek, where a porphyritic Cretaceous biotite-quartz monzonite is in contact with Hyland Group marble and amphibolite. The mineralization consists of wollastonite and actinolite skarn with disseminated pyrrhotite, scheelite and chalcopyrite (Yukon MINFILE, 1997).

The Scheelite Dome stock is cut by a shear zone 300 to 500 m wide, which extends northwest from the Hawthorne stibnite-arsenopyrite-gold quartz veins exposed in Harvey Gulch and Swede Gulch (Yukon MINFILE, 1997, 115P 003). A network of 0.5 to 5 cm wide quartz-feldspar veins, striking north and east, cuts quartz monzonite within the shear zone. Traces of arsenopyrite, molybdenite and scheelite occur along the edges of the veins (Yukon MINFILE, 1997).

A variety of other tin-silver veins and breccias, as well as several tungsten gold veins and skarns, are also associated with Cretaceous granites in the McQuesten River area (Yukon MINFILE, 1997).

SOILS AND PERMAFROST

The dominant soil in the study area is a Holocene brunisolic soil (>40%), which in central Yukon is known as the Stewart Neosol. Brunisols are poor to well-drained, yellowish-brown mineral soils that develop in forest, alpine, and tundra environments. Temperature regimes for brunisols range from temperate/cool to arctic, while moisture regimes conducive to brunisol development are generally per-humid to semi-arid (Clayton et al., 1977). The solum, or soil profile, ranges in thickness from 37 to 49 cm; it contains limited pedogenic weathering and little to no illuviated clay or other soil structures (Tarnocai et al., 1985). Other soil types in the Mayo area include cryosols (>20%) where permafrost is prevalent, and fibrisols (thick, organic-rich, weakly decomposed soils; 10 to 20% of surface area in poorly drained areas; Clayton et. al., 1977).

The Mayo area lies within the extensive discontinuous permafrost zone. Under this classification, approximately 50 to 90% of the land area is underlain by permafrost (Burn, 1994). Variations in permafrost distribution within this zone are controlled by surface sediments, soil moisture, aspect, and snow depth (Burn, 1987). Permafrost occurs typically on north- and east-facing slopes, highlands above 1372 m elevation, and poorly drained valley bottoms. Permafrost features, such as sorted stone polygons and solifluction lobes, are common near most plateau summits especially in the Gustavus Range. Open-system pingos, although rare, also occur in the Mayo area. These are large mounds of soil-covered ice, which form in part by the hydrostatic pressure of water below the permafrost. One example of pingo development is found at the headwaters of Swede Creek (Fig. 2), where two open-system pingos occur at the base of a north-facing slope. This area was last glaciated during the Reid glaciation and the surficial deposits likely consist of fine-grained material and organics derived from McConnell periglacial weathering, as well as from recent Holocene surface alluviation. Massive ice bodies such as those found in the Dawson area are rare in Mayo surficial deposits. This is attributed to the predominance of well-drained, coarse alluvium, typical within the limits of the Cordilleran glaciations.

VEGETATION

The Mayo area lies in the Mayo Lake-Ross River ecoregion within the northern boreal forest, as described by Oswald and Senyk (1977). A northern mixed deciduous and coniferous forest is dominant, but vegetation type in the study area varies strongly according to slope, aspect and surficial sediments. Black spruce (Picea mariana), paper birch (Betula papyrifera), willow (Salix sp.) and mountain alder (Alnus crispa) characterize north-facing slopes. In contrast, well drained, south-facing slopes in valley bottoms contain a mix of white spruce (Picea glauca), aspen (Populus tremuloides) and various grasses. South-facing slopes on plateaus and mountains have a denser tree growth than valley bottom sites and are dominated by white spruce, paper birch, aspen and grasses. Mountain alder, willows and white spruce occur locally along drainages. The diverse vegetation in the broad valley bottoms reflects a wide range of surficial deposits. Poorly drained alluvial and glacio-lacustrine sediment is typically vegetated by black spruce, sedges and sphagnum tussocks. White spruce, aspen, paper birch, and less commonly, lodgepole pine (Pinus contorta), dominate well-drained areas such as alluvial and glacial terraces. Subalpine regions are characterized by a mix of subalpine fir (Abies lasiocarpa), willows, dwarf birch (Betula nana L.) and mosses. Ericaceous shrubs, willows, dwarf birch, lichens and mosses are common in alpine regions. Disturbed sites are initially vegetated by fireweed (Epilobium angustifolium) and willow species.

QUATERNARY AND GLACIAL HISTORY

The Yukon has been subjected to several major episodes of glaciation, generally known as the pre-Reid (early Pleistocene), Reid (middle Pleistocene), and McConnell (late Pleistocene) glaciations. Table 3 shows simplified Late Cenozoic stratigraphy of the Mayo area.

In the central Yukon, each subsequent glaciation was progressively less extensive. The study area was completely glaciated during the pre-Reid and Reid glaciations, but only partly glaciated by the McConnell ice sheet (Fig. 3). The pre-Reid glaciation consisted of multiple episodes, the earliest being at least >2.58 Ma (Froese, 1997). Only the Reid (approximately 300 000 years ago) and the

Table 3. *Mayo area Late Cenozoic stratigraphy (modified from Roots, 1997)*

QUATERNARY

Holocene - post-McConnell and recent

Age: <10.3 Ka (interglacial)

Organic deposits and soils, permafrost and cryoturbation deposits
soils, fenland, peat, 'muck,' pingos, thermokarst ponds and lakes, cryoturbation wedges, casts, surfaces, loads, diapirs, and cryoplanation terraces

Alluvial deposits
alluvial gulch, canyons, valley, plain, terrace, fans, deltas, lacustrine, and complexes

Colluvial deposits
colluvial veneer, felsenmeer, rock fall, talus, blanket, and complexes

Eolian deposits
eolian dunes, veneer, blanket, and complexes

PLEISTOCENE

Late Pleistocene - Late Wisconsinan-McConnell

Age: <29 - 10.3 Ka (glacial)

Glaciofluvial and glaciolacustrine deposits
alluvial outwash valley, plain, terrace, fans, eskers, fan-deltas, lake-bottom blankets, and complexes

Glacial deposits
moraine (till) ridges, hummocky stagnation moraine, veneer, blankets, and complexes

Eolian deposits
loess veneer and blanket

pre-Late Wisconsinan - pre-McConnell

<200 - 29 Ka (interglacial)

Organic deposits and soils

Alluvial deposits
alluvial gulch, valley, plain, terrace, overbank, fans, fan-deltas, lacustrine, and complexes

Colluvial deposits
colluvial veneer, felsenmeer, rock fall, talus, blanket, and complexes

Middle Pleistocene - Illinoisan-Reid

Age: <311 - >190 Ka (Huscroft et al., 2001)

Glaciofluvial and glaciolacustrine deposits
alluvial outwash valley, plain, terrace, fans, eskers, fan-deltas, lake-bottom blankets, and complexes

Glacial deposits
moraine (till) ridges, hummocky stagnation moraine, veneer, blankets, and complexes

Illinoisan - Reid (interglacial)

Organic deposits and soils

Alluvial deposits
alluvial gulch, valley, overbank

Colluvial deposits
colluvial veneer, felsenmeer, rock fall, talus, blanket, and complexes

Early Pleistocene - undifferentiated pre-Reid

Age: <2.58 Ma >1.4 Ma

pre-Reid (glacial)

Glaciofluvial and glacial deposits
alluvial outwash valley, plain, terrace, moraine (till) ridges, morainal blanket, and complexes

pre-Reid (interglacial)

Alluvial deposits
alluvial gulch, valley, overbank

Colluvial deposits
colluvial veneer, felsenmeer, rock fall, talus, blanket, and complexes

PLIOCENE- EARLY PLEISTOCENE

undifferentiated

Age: >2.58 Ma

Alluvial deposits
alluvial gulch, valley, overbank

Colluvial deposits
colluvial veneer, felsenmeer, rock fall, talus, blanket, and complexes

Cryoturbation deposits
cryoturbation wedges, casts, surfaces, loads, diapirs, and cryoplanation terraces

McConnell (approximately 20 000 years ago) glaciations have left significant surficial deposits in the Mayo area.

While the timing of the interglacial prior to the Reid is uncertain, the Koy-Yukon interglacial prior to the McConnell glaciation lasted approximately 170 000 years (Berger, 1994). The modern (Holocene) interglacial began approximately 11 000 years ago.

The build-up of ice in the Yukon consisted of glaciers originating from multiple accumulation zones in the Ogilvie, Selwyn, Pelly, Cassiar, and St. Elias Mountains. Ice from these centres combined as they followed the trend of major drainages and flowed toward the central plateau region. Ice from the Selwyn Mountains was largely responsible for glaciating the Stewart Plateau, south of, and including the Stewart River valley. Ice from the Ogilvie and Wernecke mountains glaciated the McQuesten drainage system and the Mayo Lake valley. Local alpine ice developed in the Gustavus Range and mixed with Cordilleran ice in the Duncan, Lightning and Granite creek valleys during the Reid and pre-Reid glaciations (Fig. 3).

Pre-Reid glaciations

The pre-Reid episode consisted of multiple undifferentiated glaciations that occurred between approximately 2.58 Ma and >300 Ka. In the present study, the pre-Reid ice limits were not mapped primarily because of minimal evidence of pre-Reid glaciations. Such evidence is limited to erosional scars on slopes and plateaus (Fig. 5), glacial erratics above the Reid glacial limit, and the rare exposure of pre-Reid sediments lying below Reid glacial sediments. Despite these limitations, pre-Reid diorite erratics have been found at 1370 m (4500 ft) on Steamboat Mountain and 1495 m (4900 ft) on Haggart Dome (Fig. 6). A possible pre-Reid glacial diamict was noted in the Potato Hills between 1370 m (4500 ft) and 1400 m (4600 ft) elevation. Pre-Reid erratics were also noted up to 1460 m (4800 ft) on the Potato Hills, and numerous occurrences were found at 1250 m (4100 ft) in the North McQuesten map area, south of upper Ballard Creek. The upper limit of pre-Reid erratics on Keno Hill was between 1620 m (5300 ft) and 1650 m (5400 ft). In the Gustavus Range, pre-Reid ice reached at least 1555 m (5100 ft), connecting the Granite Creek drainage with tributaries of upper Duncan Creek. Reworked pre-Reid interglacial deposits have been identified in an exposure on Dublin Gulch (Weston, 1999).

Reid glaciation

The Reid glaciation ended at least 200 000 years ago (200 Ka), and may have begun by 300 Ka, according to cold cycles recognized in oxygen isotope ratios from

Figure 5. *Meltwater channel scars are found at the tops of many hills in the Mayo area.*

Figure 6. Claire Wilson excavated a pre-Reid glacial erratic near Haggart Creek in 1996. Erratics are some of the limited evidence of the pre-Reid glaciations in the Mayo area.

North Atlantic deep sea cores (Barendregt and Irving, 1998). The 200 Ka date was derived from loess bracketing the Sheep Creek tephra, which overlies Reid-age glaciofluvial sediments in the Stewart River valley at the Ash Bend section (Berger, 1994; Bond, 1996). More recent investigations by Huscroft et al. (2001) give a maximum age of 311 Ka for the Reid glaciations. This is based on an Ar-Ar date from Selkirk volcanics that underlie Reid outwash. Ice-flow directions during the Reid glaciation were similar to those of pre-Reid glaciations, but in the study area the ice was at least 300 m (1000 ft) thinner during the Reid glaciation. Reid glacial landforms are better preserved than pre-Reid glacial landforms, thus permitting mapping of the Reid ice limit throughout the North McQuesten (115P/16) and Dublin Gulch (106D/4) map areas (Figs. 2 and 3, Bond, 1999, in pocket). In the Keno Hill map area, the Reid glacial limit is evident on the slopes of Galena Hill, on the west side of Keno Hill, in Duncan Creek valley, and sporadically on the north side of Mayo Lake. The Reid glacial limit is less apparent in areas of steeper terrain, such as in Gustavus Range cirques and along the south flank of the Ogilvie Mountains in Eagle Creek valley.

During the Reid glaciation, Cordilleran ice may not have reached its maximum extent at the same time as local alpine ice. The glaciers in the Gustavus Range had a smaller, more local source than the ice from the Ogilvie Mountains, making them more sensitive to climate fluctuations and resulting in a quicker response to both glacial and deglacial climate changes. When Upper Duncan Creek ice had reached its maximum northwest extent near the confluence with the main valley, Keno-Ladue ice was only just entering the area and had not yet reached its maximum level. Keno-Ladue ice advanced into upper Duncan Creek after local ice began retreating into the cirques. This timing is demonstrated by the overlapping fabrics of two glacial diamicts in upper Duncan Creek, where a local montane till was found below a till containing fabrics suggestive of an up-valley flow (F. Hein, pers. comm., 1996). Alternatively, this stratigraphic sequence may suggest that local ice and Cordilleran ice coalesced for some period until the local ice began to retreat. Cordilleran ice could then have subsequently advanced into the montane valleys of the Gustavus Range. Similarly, ice continuing down the Duncan Creek drainage would have collided with ice advancing up Duncan Creek from the Mayo River valley (Fig. 7). Where the ice lobes met is uncertain, but this blockage from the south may have encouraged ice and meltwater to flow into the headwaters of Williams Creek. High-level outwash benches preserved between the Williams Creek and Field Creek drainages support this glacial history.

Figure 7. Leyla Weston and Lisa Mackinnon document the stratigraphy of an exposure on Upper Duncan Creek.

McConnell glaciation

The timing of McConnell ice in the study area remains uncertain. The McConnell glaciation had begun by 29.6 Ka according to a ^{14}C date and a paleoenvironmental reconstruction using detrital organics found below McConnell till near Mayo (Matthews et al., 1990). Ice-free conditions, however, still persisted near Ross River at 26.3 Ka (Matthews et al., 1990; Jackson and Harington, 1991). Dated organic material near Jake's Corner (south of Whitehorse) suggest McConnell ice had disappeared from the lowlands of southern Yukon by 11.3 Ka (GSC-3831, McNeely, 1991). These dates suggest the McConnell glaciation had 15 Ka to reach a maximum and then retreat back to accumulation zones.

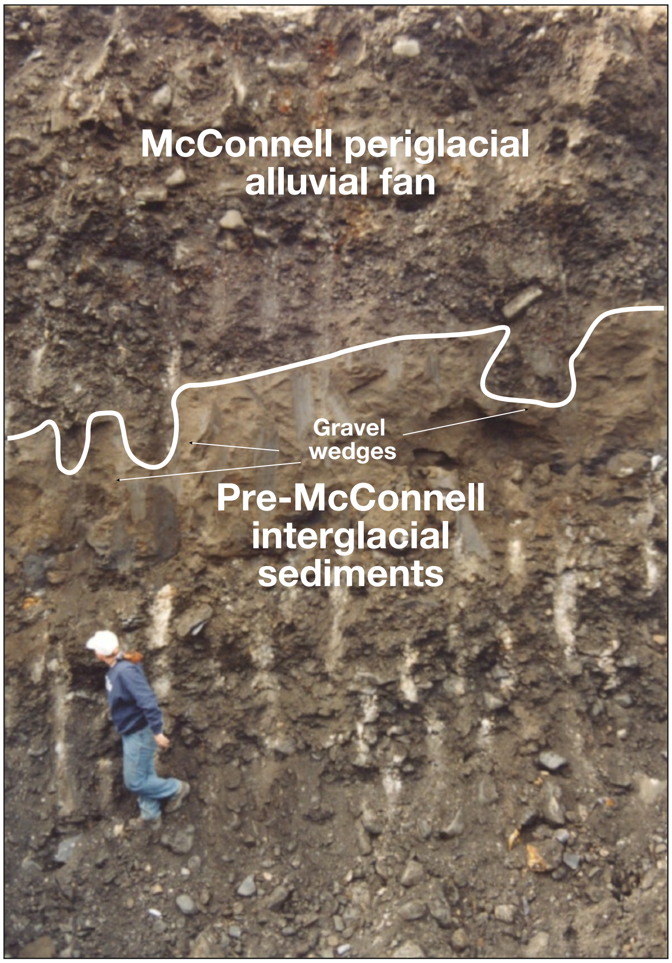


Figure 8. Exposure showing sediments from a McConnell periglacial fan with gravel wedges developed into interglacial sand and gravel on Upper Duncan Creek.

Figure 9. Alpine moraines at the McConnell ice limit were deposited by a local cirque glacier on upper Granite Creek. R=recessional moraine; E=end moraine

Above the canyon on Upper Duncan Creek (just outside the McConnell ice limit), a sample of wood was ^{14}C dated at 27.4 Ka ± 220 a B.P. (Beta-109148). This sample of wood, as well as ice-wedge casts found stratigraphically higher in the section (Fig. 8), suggest that the Keno area was exposed to McConnell periglacial conditions as much as 1000 years prior to the arrival the Cordilleran ice sheet. Organic material in alluvial fan sediments on Gill Gulch, just above a paleochannel bench of Haggart Creek, was ^{14}C dated at 12.3 Ka ± 120 a B.P (Beta-109150). This suggests periglacial conditions had waned by that time, as McConnell ice had retreated far enough to allow vegetation to re-establish itself.

McConnell glacial landforms are easily recognized in the study area, especially in the Dublin Gulch and the Keno Hill map areas (Fig. 9; Bond, 1998d,f, 1999, in pocket). McConnell ice did not extend to the North McQuesten River map area, although meltwater deposits are present in the valley bottom. Depositional landforms are well preserved in valley bottoms and sides, particularly in moderate to gently sloped valleys aligned parallel with the regional glacial flow. Depositional landforms at the McConnell end moraines are particularly prominent throughout the Mayo area.

PALEOGEOGRAPHY

Glacial flow patterns

The pre-Reid glaciation was the most extensive and advanced the farthest into the Mayo area, glaciating most of the uplands to their summits. Few pre-Reid deposits have been identified because of erosion or burial by more recent glaciations. Pre-Reid interglacial deposits were identified in exposures at Dublin Gulch, Highet Creek and Duncan Creek, and were most commonly preserved outside or near the limits of the McConnell glaciation.

Scattered pre-Reid erratics were documented above the Reid glacial limit, however; only two pre-Reid deposits were exposed at the surface in these areas. It seems likely, considering the deep valleys, that the pre-Reid glacial ice flow was topographically controlled throughout the area. If this were the case, then it is assumed that the more recent glaciations followed a similar path.

The Reid ice sheet entered the Mayo area from the north and east (Fig. 3, Bond 1999, in pocket). The main conduits for Reid ice emanating from the Ogilvie Mountains were the McQuesten Lakes valley and the North and East McQuesten River valleys. Ice entering the Mayo area from the east originated primarily from the Selwyn Mountains, with the main conduits being the Mayo Lake area, Janet Lake valley, and the Stewart River valley. The largest valley glacier was contained in the Stewart River valley, and it advanced the furthest to the west. The McQuesten River valley was also an important conduit for ice sheets, and during the Reid glaciation, ice advanced to the Tintina Trench. The McConnell glaciation appears to have followed similar flowlines to the Reid glaciers. The important difference was that the McConnell glaciation was less extensive and terminated in the Mayo area. McConnell ice from the McQuesten Lakes and Keno-Ladue river valleys advanced to Mount Haldane, and then split into two lobes on either side of the upland; the glacier then terminated shortly after (Bond, 1999, in pocket). Ogilvie Mountain ice also advanced down the East McQuesten River valley and terminated along the east flank of Eagle Ridge (Bond, 1999, in pocket). A second major ice lobe entering the area came through the Mayo Lake system. The glacier advanced beyond the present day extent of the lake and terminated approximately 6 km west of the Duncan Creek valley. The lake owes its origins to the deposition of end moraine sediments west of the lake. Glacial lake sediments exposed at the west end of the lake suggest a lake level at the end of the last glaciation approximately 15 m above the present level. The outlet has since been downcut by the Mayo River during the present interglacial period. The Mayo area has a number of other lakes that owe their origins to excess glacial sedimentation associated with the nearby McConnell limit. These lakes include Steamboat, McQuesten, Hanson, Gambler, Halfway, Mayo, and Janet Lakes. Ice in the Stewart River valley is responsible for glaciating the Janet Lake valley during the last glaciation.

Stretching beyond the McConnell ice limit in the Mayo area are broad outwash plains, primarily in the Stewart, Mayo, and McQuesten River valleys. The outwash plains form abandoned terraces along the margins of the valleys. In the Mayo River valley, between Field Creek and Duncan Creek, the outwash plain is largely slumped where thick deposits of glacial sediments are deeply incised. Glaciolacustrine deposits may underlie the valley at that point, creating an unstable surface upon which the later till and outwash sediments were deposited.

Late Tertiary to Holocene drainage pattern

The regional drainage pattern within the Mayo Mining District is generally to the west-southwest (Fig. 2). Most water courses within the Mayo Mining District lie within the Stewart River basin except for in the northern part of Sprague Creek map area, which lies within the Klondike River drainage basin.

Prior to the last glaciation, the McQuesten drainage basin most likely included the Beaver River. It appears that glacial sedimentation in the McQuesten Lakes area and valley erosion to the east of McQuesten Lakes caused the diversion of the Beaver River into the upper Stewart River. Likewise, the Keno-Ladue River was also diverted from the McQuesten drainage basin in a similar manner. The paleo-drainage pattern of the combined McQuesten and Beaver Rivers likely followed the modern McQuesten River drainage basin. It is possible however, that this combined flow once occupied the Haldane Creek valley, to the east of Mount Haldane. Haldane Creek valley is largely oversized and the current divide into the Mayo River drainage basin at Halfway Lakes is only 200 m above the McQuesten River. The morphology of the McQuesten River drainage basin, downstream of Mount Haldane, becomes narrower and increasingly incised towards the Tintina Trench. Tributaries to this part of the McQuesten River have become noticeably incised. In the Sprague Creek map area, upper Sprague Creek and upper Forty Mile Creek were captured from the Little South Klondike River drainage basin due to the large amount of glacial erosion in the McQuesten River valley. Tributaries to the McQuesten River in this area have very steep slopes and a v-shaped morphology, which differs from the more gentle slopes in the upper Little South Klondike River drainage basin (Bond, 1999, in pocket).

The Mayo River drainage basin likely follows its pre-glacial pattern. Mayo Lake is a product of the McConnell glaciation and may not have existed during the last interglacial. Like Halfway, Janet and the McQuesten lakes, Mayo Lake developed as a result of a glacial sediment dam in the valley. The Mayo River canyon below Wareham reservoir is also a feature of the last glaciation. Stewart valley ice impinging north into the Mayo valley appears to have diverted the river into the side slope of a bordering upland, causing it to become entrenched into bedrock.

The Minto Creek drainage appears to have been captured by the Mayo River. The eastward flow of this water course into the Mayo River is anomalous to the regional southwest drainage pattern. This is supported by the trend of upper Highet Creek, which is aligned with a southwest paleo-flow into the Moose Creek drainage basin. The effects of large valley glaciers pushing into the Minto Creek drainage basin have likely eroded the paleo-divide between Minto Creek and the Mayo River. During the McConnell glaciation, ice advanced into Minto Creek and terminated just west of the valley mouth. McConnell meltwater flowed westerly into Moose Creek and temporarily rearranged the drainage picture. Following retreat of the McConnell glacier from the Mayo area, alluvial sedimentation blocked Minto creek near Minto Lake and diverted the creek into the Mayo River drainage basin.

The pre-glacial drainage pattern of the Stewart River would have been through Nogold Creek and into the Ethel Lake area. During either the Reid or McConnell glaciation, the Stewart River was diverted from the Ethel Lake valley and into the Mayo River valley, perhaps via the Frances Lake area. This suggests that the present Stewart River valley, from Mayo to Stewart Crossing, was the Mayo River valley in pre-glacial time. During the last glaciation, McConnell ice terminated at the eastern end of Ethel Lake in what is now Nogold Creek valley. As the McConnell ice stagnated in Nogold Creek valley, a meltwater channel was cut into the Watson Creek area (Fraser canyon). The meltwater channel eventually captured the Stewart River and diverted it north around the Talbot Plateau (Fig. 10).

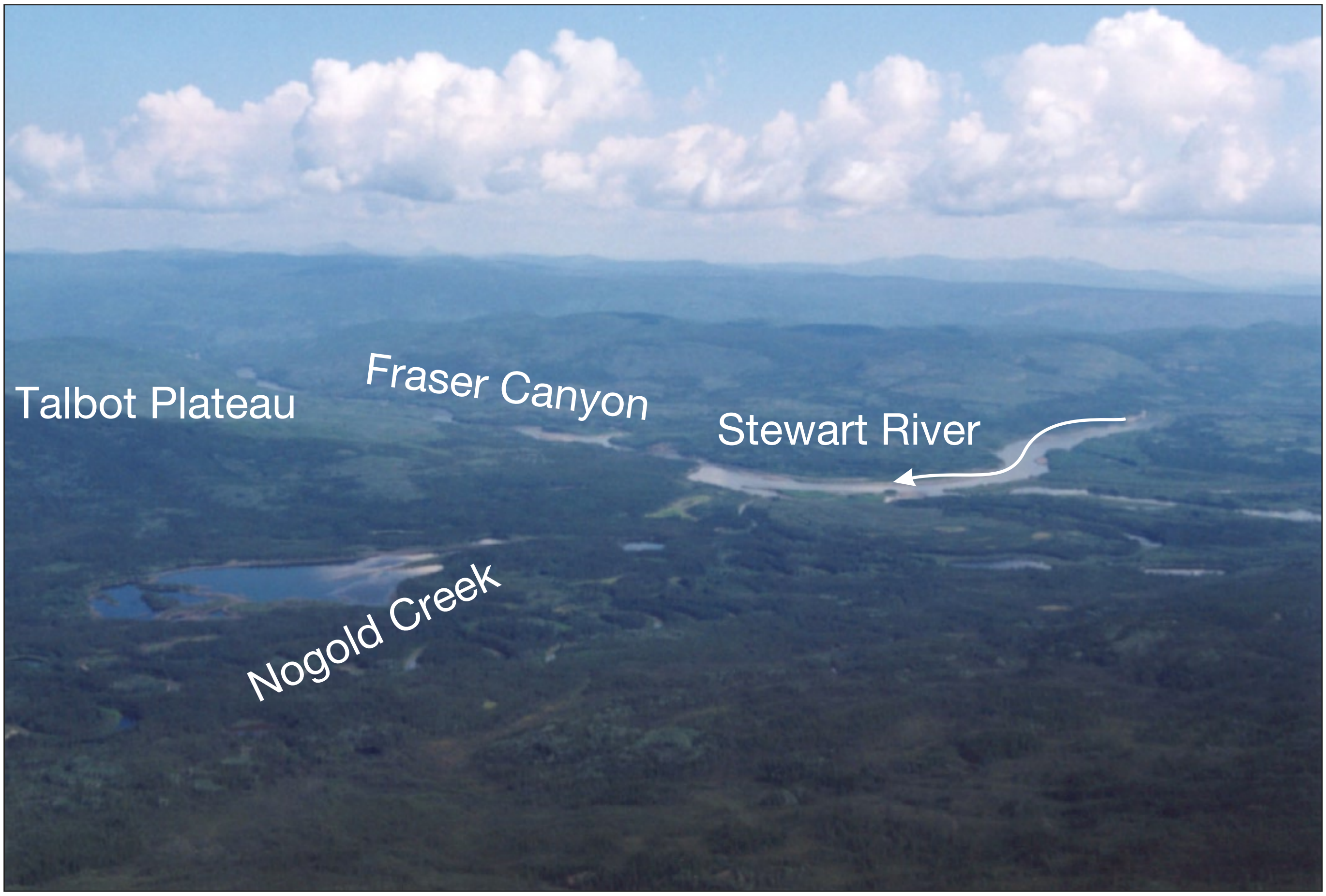


Figure 10. *The pre-glacial drainage of the Stewart River was westward in the direction of Ethel Lake. During either the Reid or McConnell glaciation, the Stewart River was diverted from the Ethel Lake valley northward into the Mayo River valley, and a meltwater channel was cut forming Fraser canyon. The meltwater channel eventually captured the Stewart River and diverted it north around the Talbot Plateau.*

SURFICIAL SEDIMENT: SEDIMENTOLOGY AND STRATIGRAPHY

In order to determine sedimentary environments and to construct paleogeographic models for an area, it is necessary to develop a classification of sediment types that incorporates the physical and biological aspects of the sediment as observed in the field. Mappable units of sediment, classified according to specific lithological, structural and diagenetic aspects, are termed 'facies.' Once the facies are identified and mapped, it is then possible to group facies into a higher order classification of facies associations or lithostratigraphic assemblages, which designate environmentally or genetically related facies. The higher order lithostratigraphic assemblages are the basis for the paleogeographic models and paleoenvironmental interpretations of the sediments, which, in turn, are the basis for understanding the geological and geomorphological evolution of a landscape through time.

The first step in understanding the paleogeographic history of an area relates to the identification and mapping of facies. In the present study, surficial sediment exposures were measured in detail, with classification into sedimentary facies after section measuring was completed. A unified facies classification for the area was developed, that incorporated the range of facies as observed in the entire study area. Although a number of criterion were used in the definition of facies (see Field and Laboratory Methodology, page 3), the major features were grain size or lithology and physical sedimentary structures. A summary of the facies scheme used in given in Table 4, which is followed by a more explicit description and interpretation of the facies. Larger scale lithostratigraphic assemblages are described and interpreted in later sections, following the basic description and interpretation of individual facies.

FACIES DESCRIPTIONS

Facies 1: Massive boulder-cobble diamict (Dmm)

Diamict is a very poorly sorted mixture of sediment that ranges widely in size from clay to boulders. These types of sediment mixtures are matrix-supported with varying amounts of clay, silt and/or sand. In the Mayo area, the diamict is massive and resistant and composed of, on average, 15-25% silt and clay and clasts generally 75-85%. Maximum boulder size is 3 m. Bed thickness ranges from 1.1 to 9.0 m. In beds with a sand-clay matrix there is a prominent blocky fracture. Diamicts with a fine sand-clay matrix tend to be more compact, tightly packed, and apparently cemented. Individual clasts within diamicts may be locally derived, very angular to subrounded; or extrabasinal erratics, that are subangular/subrounded to rounded.

In the drainage basins of Thunder Gulch, Upper Duncan and Duncan creeks, resedimented clay-intraclasts or wood debris are incorporated within the diamict units. In some cases there may have been some dewatering or liquefaction of the sediment, as shown by the occurrence of vertically oriented, iron-stained, openwork patches; by

***Table 4**. Facies scheme developed for the Mayo area.*

Facies number	Code	Facies description	Facies interpretation
1	Dmm	massive boulder-cobble diamict	lodgement till, meltout till, resedimented till
2	Dms	weakly stratified boulder-cobble-pebble diamict	debris flows, slumps, colluvial slope and solifluction deposits, resedimented till
3	Gms	weakly stratified/imbricated boulder gravel	fluvial gravel bars or diffuse gravel sheets under high traction flows
4	Ggh	graded or graded-stratified gravel	hyperconcentrated flood flows
5	Ghpt	stratified/cross-stratified gravel	high traction flows gravel bedforms
6	Sh	massive to stratified pebbly-fine sand	high traction flows upper flow regime
7	Sp	planar tabular cross-bedded pebbly to fine sand	fluvial sand bars under high traction flows
8	St	trough cross-bedded pebbly sand	high traction flows pebbly sand bedforms
9	Sr	ripple cross-bedded sand	traction flows lower flow regime, ripple bedforms
10	Fm	massive very fine sand/silt	mass wasting or windblown loess
11	Flr	laminated/rippled sand, silt and mud	suspension fallout, waning flood flows
12	Flo	massive to laminated organic silt	paleosols

the presence of fluid-escape tubes; or by prominent internal load-structures or convolute lamination. However, in general, there is a notable absence of primary sedimentary structures in this facies, with little or no reworking of sediment. In sections on Upper Duncan Creek, blocks of grey schistose bedrock are thrust up to 1.5 m into the overlying diamict units. Colour of the diamict is generally a tan, buff or yellowish-grey.

Heavy-mineral accessories include gold, pyrite, ilmenite, garnet and magnetite with a trace of zircon. Although heavy-mineral yields tend to be low, locally, for example in Upper Duncan Creek, gold concentrations are economic.

Facies 1 is commonly in contact with bedrock or it may occur higher upsection, such as in Duncan and Highet creeks. It occurs as isolated occurrences on bedrock at the base of an alluvial fan sequence in Upper Duncan Creek (Fig. 11); on bedrock on Haggart Creek and Dublin Gulch; and as other isolated occurrences within glacially-modified valleys in the Gustavus Range, Stewart Plateau and Ogilvie Mountains.

Facies 2: Weakly stratified boulder-cobble-pebble diamict (Dms)

This facies is distinguished from Facies 1 (massive boulder-cobble diamict - Dmm) by the presence of a weak, poorly defined, parallel stratification, and rarely the occurrence of convolute lamination along with inverse grading at the base of the diamict unit. As with Facies 1, these types of sediment mixtures are matrix-supported with varying amounts of clay, silt and/or sand. The matrix in the diamict comprises coarse sand (35-40%), granules (30-40%), fine sand (5-25%), medium sand (5-10%), and silt and clay (5-10%). Individual clasts within diamicts are locally derived and very angular to angular, or more widely travelled, subangular/subrounded to rounded. Maximum boulder size is 1.5 m. Bed thickness ranges from 1.1 to 9.5 m. Clasts are disorganized, or with a notable vertical to near-vertical fabric. Weak diffuse stratification occurs as banding that is parallel and, where discernable, is coincident with local slope directions. Individual beds may be ungraded, or inversely graded

Figure 11. *Facies 1 - Dmm, massive boulder cobble diamict, occurs throughout the study area, commonly in contact with bedrock. The above photos from measured section UD9703 on Upper Duncan Creek illustrate the massive, compact and disorganized nature of this facies. Bedrock slivers intrude the unit at the basal contact. This example is interpreted to be either a lodgement till or resedimented lodgement till of Reid age. Field notebook in left photo is 18 cm long.*

(coarsening-upwards). The basal and topmost contacts of weakly-stratified diamict are abrupt and non-gradational. Locally the base of individual diamicts may be wavy and loaded into the underlying material. Colour of the diamict is variable, generally a function of the colour of the underlying bedrock and the colour of locally derived clasts. Clast lithologies are variable, containing predominantly local bedrock lithologies, including quartz-mica schist, vein quartz, quartzite, metasandstone; and more distantly derived intrusive rocks and banded ironstones.

Heavy-mineral accessory occurrences are extremely variable, ranging from those that are barren to units that include gold, magnetite, ilmenite, and traces of scheelite, zircon and cassiterite. Heavy-mineral yields, when they occur, are variable, from low to moderate. Locally, gold concentrations in the stratified diamict may be economic where the diamict directly overlies gold-bearing veins in bedrock, or where it overlies and reworks paleoplacer deposits. Such occurrences have been noted in the following valleys: Highet Creek, Parent Creek, Gill Gulch, Haggart Creek, Ledge Creek, Hope Gulch, Seattle Creek, as well as benches along Upper Duncan Creek.

Weakly stratified diamict occurs along the basal unconformity with bedrock or higher upsection. This facies directly overlies bedrock at Seattle Creek (Fig. 12); sits on bedrock or occurs higher upsection in Duncan Creek and Highet Creek; is downvalley from bedrock canyons that feed fan-deltas along Mayo Lake, for example, Ledge Creek; is the basal unit of prograding side-valley alluvial fans in Hope, Faith, Crystal, Gill gulches, Parent and Williams creeks, on and across from Forty Pup; may be isolated as aprons flanking bedrock benches in Upper Duncan Creek and on Galena Hill; is associated with Facies 1 (massive diamict - Dmm) within cirques cut in bedrock or within glacially-modified valleys, such as Thunder Gulch and other drainages in the Gustavus Range; and may occur higher upsection associated with glaciolacustrine sediment in the Upper Duncan, Minto and Haggart creek areas.

Figure 12. *Facies 2 - Dms, weakly stratified boulder cobble-pebble diamict, is similar to Facies 1, but distinguished by weak parallel stratification which follows the inclination of the slope. Clasts are somewhat disorganized and may be vertical in orientation. On measured sections SEA9701 and SEA9702 on Seattle Creek, Facies 2 is interpreted to be a periglacial debris flow, which marks the onset of the McConnell glaciation.*

Facies 3: Weakly stratified/imbricated boulder gravel (Gms)

This facies differs from Facies 1 (massive diamict - Dmm) with the presence of a variable, poorly to moderately defined, parallel stratification, along with a well-defined clast fabric (imbrication), and a general lack of fine sediment content (clay content 1-2%). Gravel of Facies 3 are clast-supported, consisting of pebble- to cobble-sized clasts with rare boulders. Imbrication is variably developed, poor in coarser-grained lower bed portions, to moderate and well developed in finer, upper bed portions. Sorting is poor to moderate. Matrix-infill between clasts contains very little clay-size material, predominantly coarse sand and granule-size material. In most cases individual clasts within the gravel is locally derived and subangular to well rounded. Less common are scattered boulders of angular, locally derived bedrock. Maximum clast size is 3 m, although these boulders are rare and always rest on bedrock. Bed thickness ranges from 0.5 to 15 m. Clasts are poorly to very well organized, or with a notable b- (intermediate) axis imbrication. Stratification is better defined than in Facies 2 (stratified diamict - Dms). In this facies the crude stratification is defined by variations in clast size, or by discontinuous, rippled sand lenses (<50 cm thick). Less commonly are ice-wedge casts and reworked organic debris. The basal contacts are abrupt and erosional, with upper bed contacts either abrupt or gradational. Colour of the gravel is variable, generally a function of the colour of the underlying bedrock, the colour of locally derived clasts, and/or dependent upon the presence of Fe- and/or Mn-staining within matrix surrounding the clasts. Lithologies consist of local quartzite and diorite, sandstone, limestone, quartz-mica schist, vein quartz, metasandstone, phyllite and rare conglomerate. Local organic detritus may be recovered from gravel, and ice-wedge casts occur locally, most notably in the Duncan Creek area.

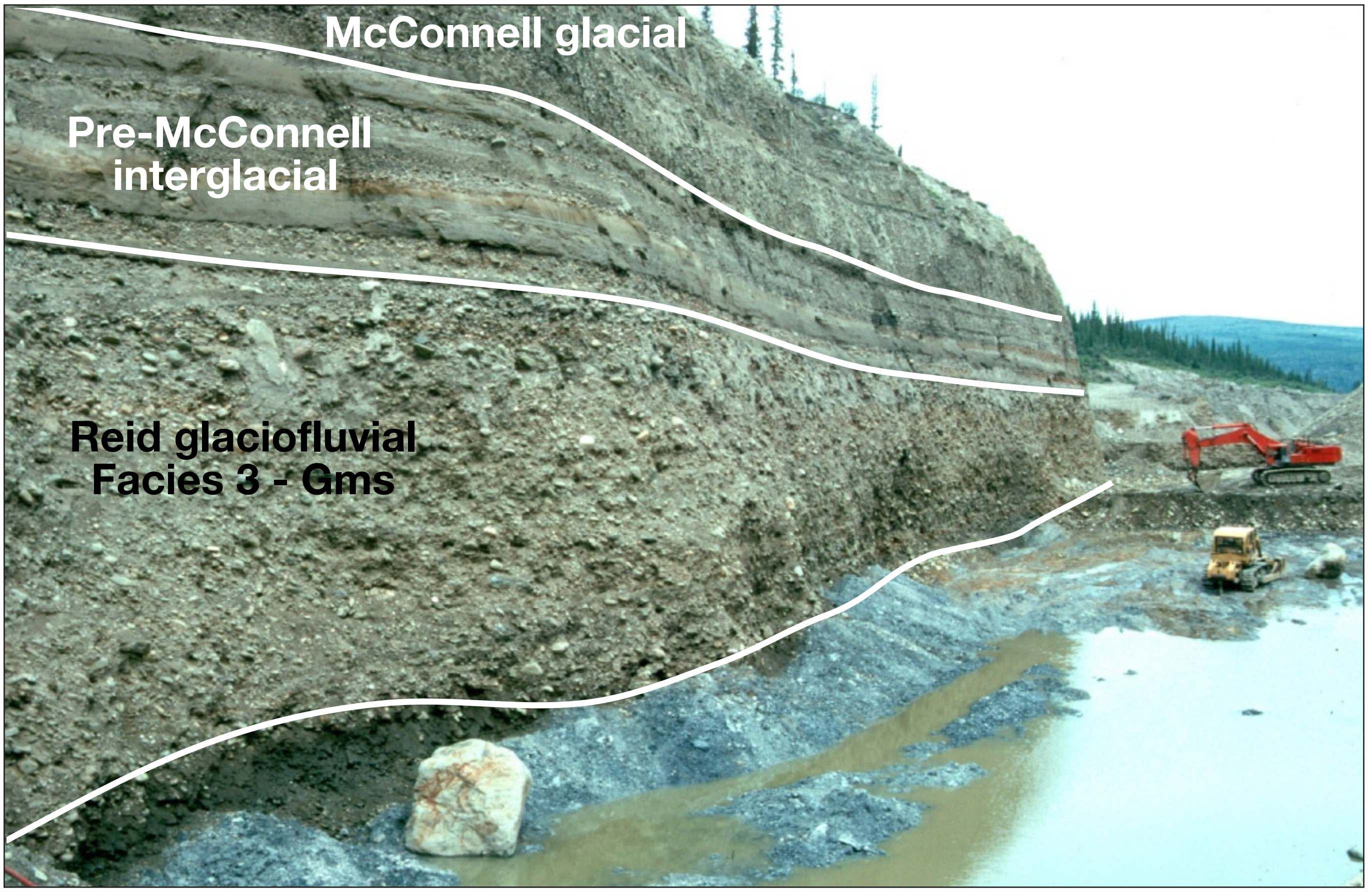


Figure 13. *Facies 3 - Gms, weakly stratified/imbricated boulder gravel, is commonly crudely stratified with moderate to well-developed b-axis imbrication. Parallel stratification is defined by variations in clast size and localized discontinuous sand lenses. On Duncan Creek, this facies is the main pay gravel, with grades throughout but increasing with proximity to bedrock. This photo shows measured sections FT2-95 and FT3-95, where Facies 3 is interpreted to be a Reid outwash gravel buried by interglacial alluvium and McConnell glacial drift.*

Heavy-mineral accessory occurrences are extremely variable, ranging from those that are barren to units that include gold, native silver, hematite, magnetite, garnet, pyrite, ilmenite, cassiterite and traces of scheelite or zircon. Heavy-mineral yields, when they occur, are variable, from low to high. Locally, gold concentrations in the weakly stratified gravel may be economic where the gravel directly overlies gold-bearing bedrock veins, or incorporates pre-existing sediments such as paleoplacers deposits. This facies is the main pay unit on Duncan Creek, where gold concentrations occur throughout but increase in grade near bedrock (Fig. 13).

Weakly stratified/imbricate gravel occurs along the basal unconformity with bedrock or higher upsection. This facies is associated with most landforms, including glacial moraines and meltwater channels; alluvial canyons and valleys, side-entry alluvial fans and fan-deltas. Such occurrences have been noted in most of the study area, with the more economic occurrences in the following valleys: Anderson, Davidson, Dirksen, Duncan, Upper Duncan, Empire, Haggart, Highet, Goodman, Ledge, Lightning, Minto, Rodin and Seattle creeks; Gill and Thunder gulches. Other potentially economic high-bench gravel deposits of this facies are in the valleys of Upper Duncan, Duncan and Upper Davidson creeks.

Facies 4: Graded or graded-stratified gravel (Ggh)

This facies differs from Facies 3 (weakly stratified boulder gravel - Gms) with the occurrence of normal grading (fining-upsection). Beds of this facies may also be horizontally stratified. Gravel of Facies 4 is clast- or matrix-supported, consisting of pebble- to cobble-sized clasts with rare boulders. Imbrication is variably developed, poor in coarser grained lower bed portions to moderate and well developed in finer upper bed portions. Sorting is very poor to poor. Matrix-infill between clasts is a very poorly sorted mixture of sand-silt-clay, or is sand-dominated. In most cases, individual clasts within the

Figure 14. *Facies 4 - Ggh, graded or graded stratified gravel, is distinguished by normal (fining upward) grading. It can be matrix or clast-supported with variably developed a- or b-axis imbrication. On Rudolph gulch this facies is the main pay gravel. This photo shows measured section RUD9701, where Facies 4 is interpreted to be a Holocene gulch gravel. Each division on the pole is 20 cm.*

gravel are locally derived and subangular to subrounded, with the smaller clasts being more angular, and the boulders subrounded. Maximum clast size is 1.5 m. Bed thickness ranges from 0.5 to 1.9 m. Clasts are moderately organized, with a notable a- (long) axis imbrication or near-vertical orientation. Stratification is better defined than in Facies 2 (stratified diamict – Dms). In this facies the stratification is defined by variations in clast size, or by alternations of clast- and matrix-supported layers. Less common are ice-wedge casts and reworked organic debris. The basal contacts are abrupt and erosional, with upper bed contacts either abrupt or gradational. Colour of the gravel is variable, but it is generally a function of the colour of locally derived clasts and matrix. Lithologies consist of local quartzite and diorite, sandstone, limestone, quartz-mica schist, vein quartz, metasandstone, with phyllite and rare conglomerate.

Heavy-mineral accessory occurrences are extremely variable, ranging from those that are barren to units that include traces of gold, along with magnetite, garnet, pyrite, ilmenite, and traces of scheelite or zircon. Depending upon local bedrock mineralization, ilmenite may dominate the heavy-mineral concentrates. Heavy-mineral yields vary from low to high. Locally, gold concentrations in the graded/stratified gravel may be economic where the gravel directly overlies gold sources such as bedrock veins or has reworked paleoplacer deposits. This facies overlies the main pay unit on Highet Creek and accessories within the graded-stratified gravel are dominated by ilmenite. Pay gravel of this facies occur in Rudolph Pup, where flat gold was recovered at the base of the unit (Fig. 14), and from Empire Creek, where very large gold nuggets (up to 10 oz, 300 g) were found in this basal unit sitting on bedrock.

Graded-stratified gravel occurs along the basal unconformity with bedrock. It is a rare facies, and has only been mapped along the upper tributaries of Haggart Creek, along the flanks of Galena Hill, at Rudolph Pup, and at Empire Creek. Despite this rare occurrence, its close association with the basal unconformity along bedrock, along with recovered gold in a few cases, suggests that locally significant pay may be recovered from this facies. It must be noted that a very similar facies of gravel contained significant placer gold at Trail Hill in the Klondike area (cf. Morison and Hein, 1987; Morison, 1989). This facies may have similar economic potential, however it is a relatively unexplored unit in the Mayo district.

Facies 5: Stratified/cross-stratified boulder-pebble gravel (Ghpt)

This facies differs from Facies 4 (graded/graded-stratified gravel - Ggh) with the occurrence of well-defined stratification and cross-stratification, and a general lack of fine sediment content. This facies consists of clast-supported, cobble-pebble gravel with 75-80% clasts and 20-25% matrix. In general units are clast-supported; less commonly they are matrix-supported. The matrix is mainly coarse granule (33-65%) to coarse sand (26-49%), with lesser amounts of fine-grained sand, and rare silt/clay fines. The gravel ranges from tightly packed, compact units to loose, openwork gravel. Imbrication is moderately to well developed. Sorting is moderate to excellent. In most cases, the larger clasts within the gravel is subrounded to rounded, with the smaller clasts being somewhat more subangular to rounded. Maximum clast size is 2.5 m. Bed thickness ranges from 1.0 to 7.5 m. Clasts are moderately to well organized, with a notable b- (intermediate) axis imbrication, or less commonly an a- (long) axis imbrication for the smaller clasts. Stratification is well defined. Planar tabular and trough cross-stratification is less common. In this facies the stratification/cross-stratification mainly is defined by variations in clast size, or, less commonly, by alternations of clast- and matrix-supported layers. Ice-wedge casts and reworked organic debris occur locally. The basal contacts are abrupt and erosional, with upper bed contacts either abrupt or gradational. Colour of the gravel is typically a light to medium grey, but is also dependent upon the colour of locally-derived clasts and matrix. Lithologies consist of local quartzite and diorite, sandstone, limestone, quartz-mica schist, vein quartz, metasandstone, with more distantly derived sedimentary rocks including phyllite, conglomerate, and banded ironstone.

Heavy-mineral accessory occurrences are extremely variable, ranging from those that are barren to units that include traces of gold, magnetite, garnet, pyrite, and traces of hematite and ilmenite. Heavy-mineral yields vary from low to high. Locally, gold concentrations in the well-stratified/cross-stratified gravel may be economic where the gravel has reworked paleoplacers or overlies bedrock gold sources such as veins. This facies overlies the main pay unit on Duncan Creek (Fig. 15). At Minto and Seattle creeks, pay gravel of this facies were found in this basal unit sitting on bedrock. In test pits along Minto Creek, the gold is flat and concentrated along the base of the unit, sitting on top of bedrock.

Well-stratified/cross-stratified gravel occurs along the basal unconformity with bedrock or higher upsection. This facies is very common in the Mayo district, and is associated with fluvial and glaciofluvial landforms, including meltwater channels, alluvial canyons and valleys, side-entry alluvial fans and fan-deltas. Such occurrences have been noted in most of the study area, with the more common occurrences in the following valleys: Anderson, Davidson, Dirksen, Duncan, Upper Duncan, Haggart, Highet, Ledge, Minto, Seattle creeks and Thunder Gulch.

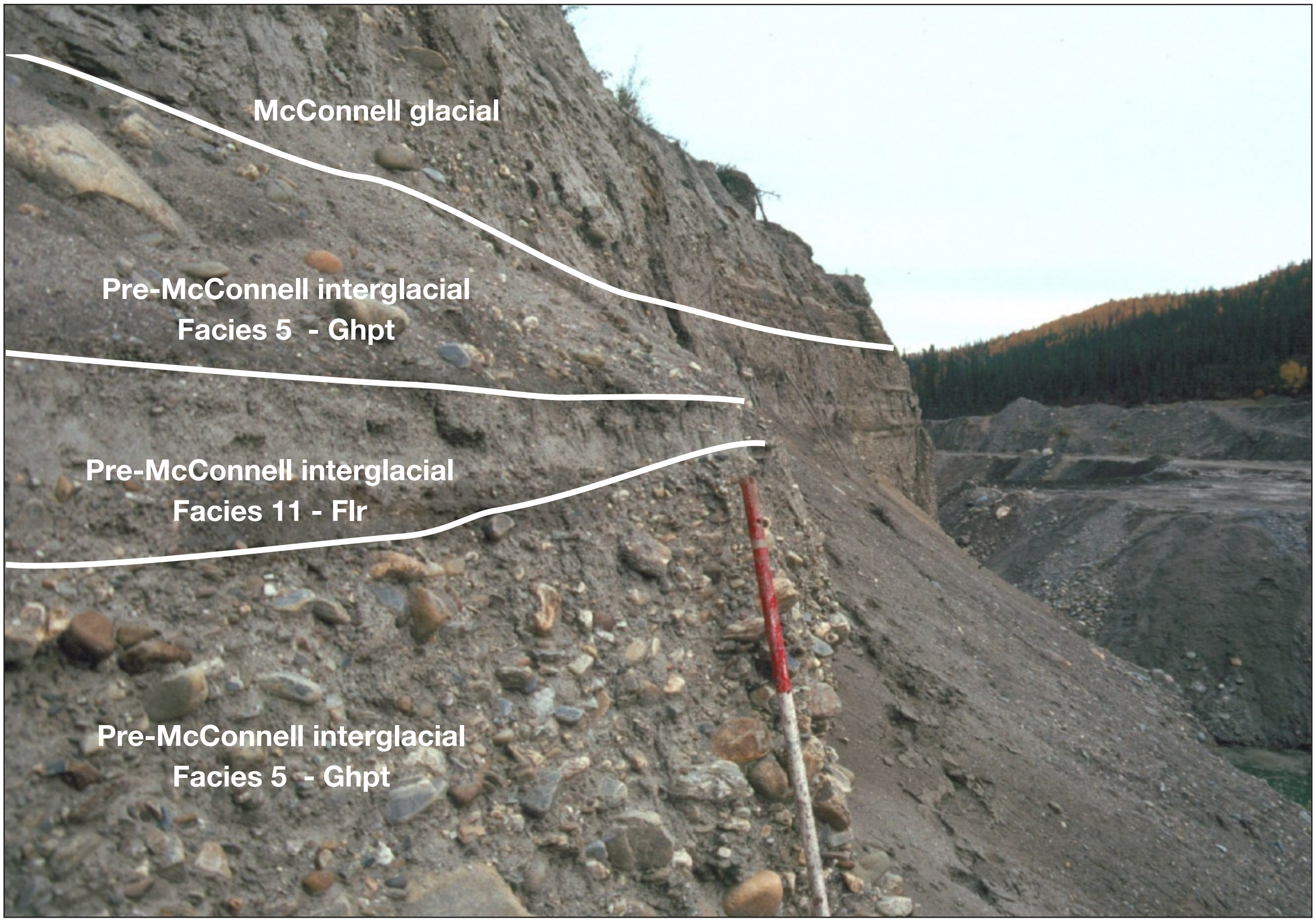


Figure 15. *Facies 5 - Ghpt, stratified/cross stratified boulder pebble gravel is overlain by Facies 11 - Flr (laminated and rippled sand, silt and mud) at this locality on Duncan Creek (measured section FT2-95), forming a fluvial channel gravel/ overbank silt (fining upward) couplet. This is interpreted to be an interglacial alluvial sequence deposited between Reid glaciofluvial outwash and McConnell glacial drift. Divisions on pole are 50 cm.*

Facies 6: Massive to stratified pebbly fine sand (Sh)

This facies consists of horizontally stratified pebbly fine sand with less common massive pebbly medium sand interbeds. Sorting is moderate to excellent. Maximum bed thickness is approximately 0.5 m. This is a relatively rare facies, and is commonly associated with Facies 7 (cross-bedded pebbly fine sand - Sp) described below. Although it is a rare facies, it is important because it can help us interpret many of the other more massive gravel units, of which this facies is a small component. In addition, much of the recovered woody material is preferentially better preserved in the finer sand facies, and thus affords an opportunity for ^{14}C dating. No heavy minerals were recovered from this facies. Accessories include woody material and organic laminations. Figure 16 shows a woody sample within a massive medium sand on Duncan Creek, which was radiocarbon dated at 32 320 a ± 1270 a B.P. (Beta-86851). A similar sample found within a stratified pebbly medium sand on Upper Duncan Creek was radiocarbon dated at 27 440 a ± 220 a B.P. (Beta-109148).

Thin interbeds of this facies are common in most sections with the reworked stratified diamict (Dms) or the stratified boulder-cobble-gravel (Gms) facies. Thicker accumulations of this facies are less common, and occur in areas with a better preserved interglacial or glaciofluvial section. These include: lowermost stratigraphic units at Highet Creek; middle stratigraphic units at Duncan Creek and Thunder Gulch; higher stratigraphic units in Seattle, Goodman, and Upper Duncan creeks; and, interbedded throughout the section at Rodin Creek.

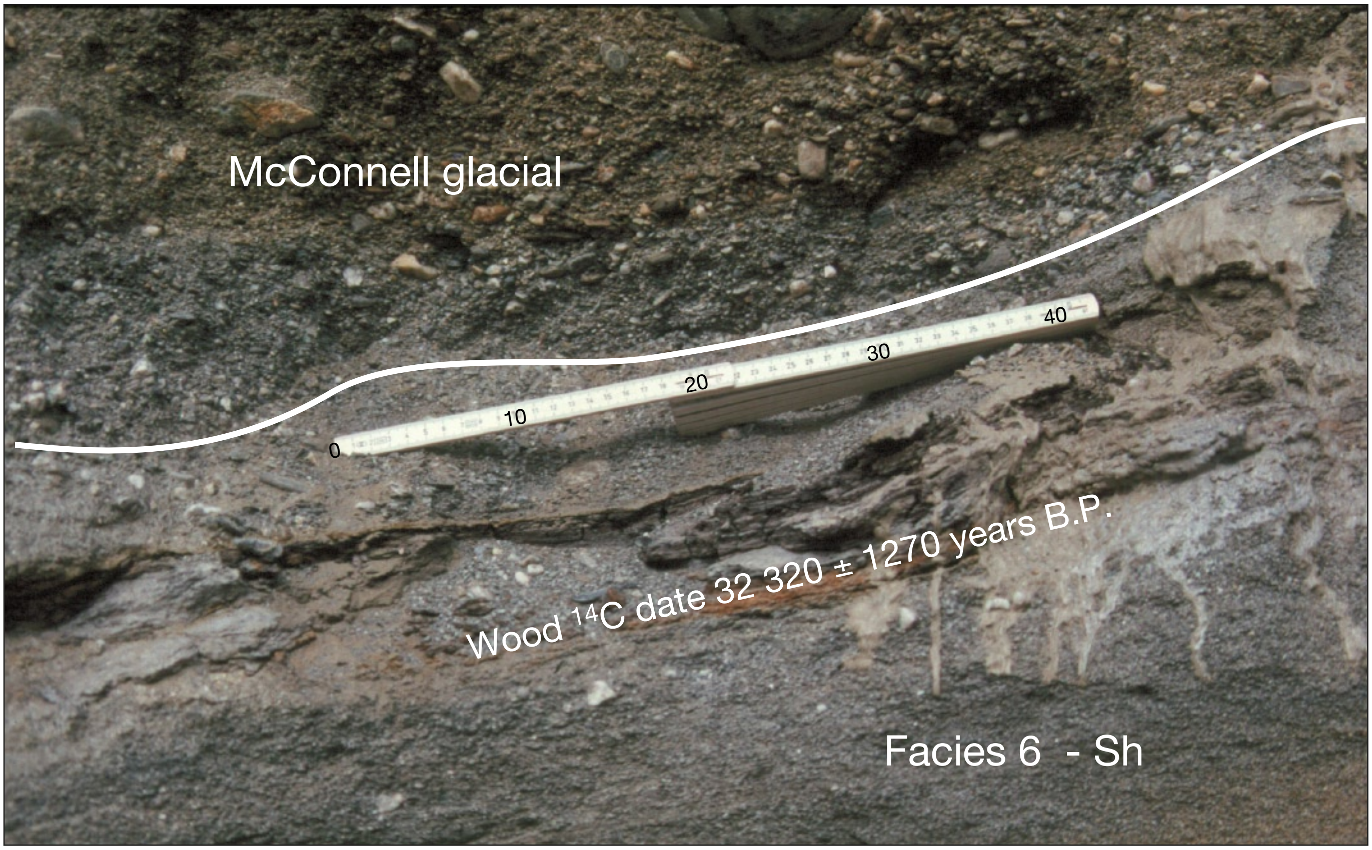


Figure 16. *Facies 6 - Sh, massive to stratified pebbly fine sand, consists of horizontally stratified pebbly fine sand with less common massive pebbly medium sand interbeds. Sorting is moderate to excellent. This photo from measured section FT95-2 (Duncan Creek), shows a sample of wood within a massive medium sand which was radiocarbon dated at 32 320 a ± 1270 a B.P. (Beta-86851). Scale is in centimetres.*

Facies 7: Planar tabular cross-bedded pebbly fine sand (Sp)

This facies consists of planar tabular cross-bedded pebbly fine sand. Sorting is moderate to excellent. Maximum bed thickness is approximately 0.5 m. This is a relatively rare facies, and is commonly associated with the previous Facies 6 (massive-stratified pebbly fine sand - Sh) described above. As with Facies 6, although it is a rare facies, Facies 7 is important because it can help interpret many of the associated more massive gravel units. No heavy minerals were recovered from this facies.

Thin interbeds of this facies are common in most sections with well-stratified boulder-cobble-gravel (Ghpt) facies. Thicker accumulations of this facies are less common, and occur in areas with better preserved interglacial or glaciofluvial sections. These include lowermost stratigraphic units at Rodin Creek (Fig. 17) and Highet Creek and middle stratigraphic units at Duncan Creek and Thunder Gulch.

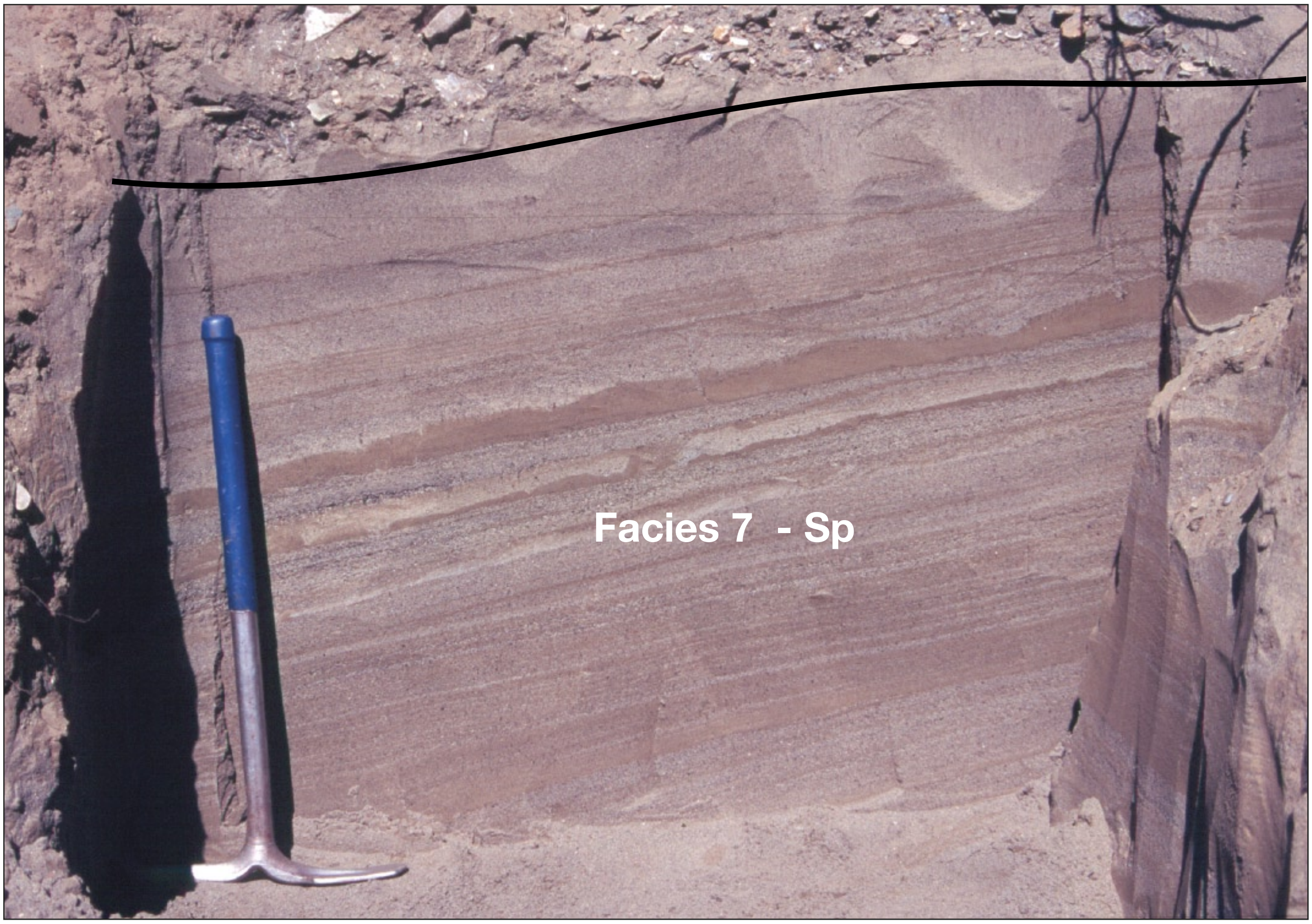


Figure 17. *Facies 7 - Sp, planar tabular cross-bedded pebbly fine sand, consists of planar tabular cross-bedded pebbly fine sand. Sorting is moderate to excellent. Maximum bed thickness is approximately 0.5 m. Thick accumulations of this facies may occur in proglacial or deltaic glaciofluvial paleoenvironments, such as at this section at Rodin Creek (measured section ROD97-01).*

Facies 8: Trough cross-bedded pebbly fine sand (St)

This facies consists of trough cross-bedded pebbly fine sand. Sorting is moderate to excellent. Maximum bed thickness is approximately 0.5 m. This is a relatively rare facies, and is commonly associated with the previous Facies 6 (massive-stratified sand) and Facies 7 (planar-tabular cross-bedded sand) described above. As with these other rare sand facies, Facies 8 is important because it helps in paleoenvironmental interpretation. No heavy minerals were recovered from this facies.

Thin interbeds of this facies may occur in some sections associated with well-stratified boulder-cobble-gravel (Ghpt) facies, and with ripple cross-bedded medium to fine sand (Facies 9). This unit occurs in middle stratigraphic units on Seattle Creek, Duncan Creek (Fig. 18) and Upper Duncan Creek.

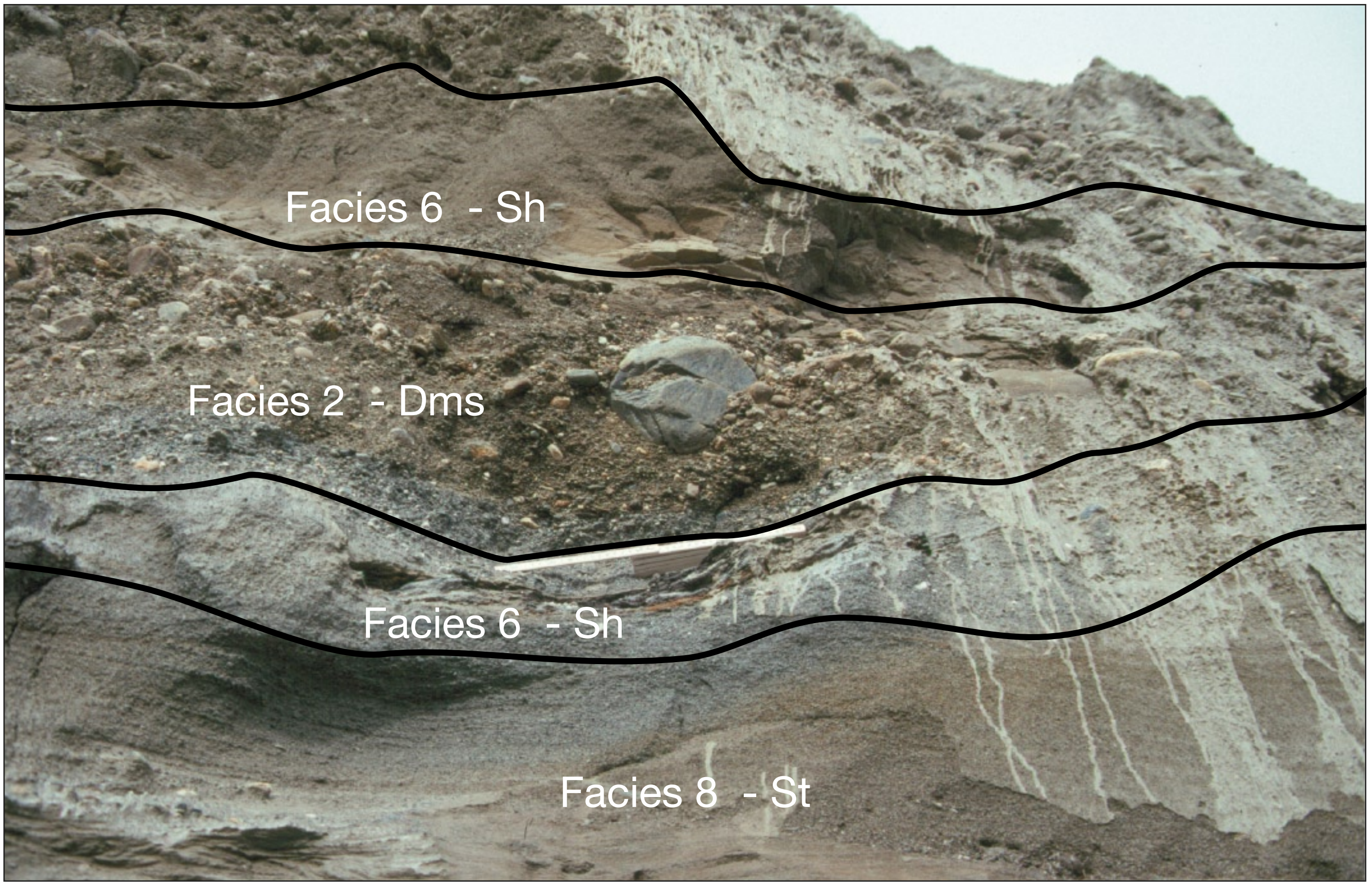


Figure 18. *Facies 8 - St, trough cross-bedded pebbly fine sand and Facies 6 - Sh, massive to stratified pebbly fine sand may occur together, such as in measured section FT2-95 on Duncan Creek. Facies 6 reflects more rapid deposition and higher flow rates than Facies 8, which is deposited under waning tractive flow conditions. This is common in fluvial interglacial settings, which is the interpretation of this part of the exposure.*

Facies 9: Ripple cross-bedded medium to very fine sand (Sr)

This facies consists of ripple cross-bedded medium to very fine sand. Sorting is moderate to excellent. Maximum bed thickness is approximately 0.25 m. This facies is commonly associated with the previous Facies 6 - 8 (stratified and cross-bedded sand) described above. As with these other rare sand facies, Facies 9 is important to aid in paleoenvironmental interpretation, and in recovery of woody and organic material for biostratigraphic and absolute age dating. No heavy minerals were recovered.

This facies was noted in those areas with better preserved fine-grained interglacial sections and some glaciofluvial sections, including Rodin Creek, Duncan Creek and Seattle Creek (Fig. 19).

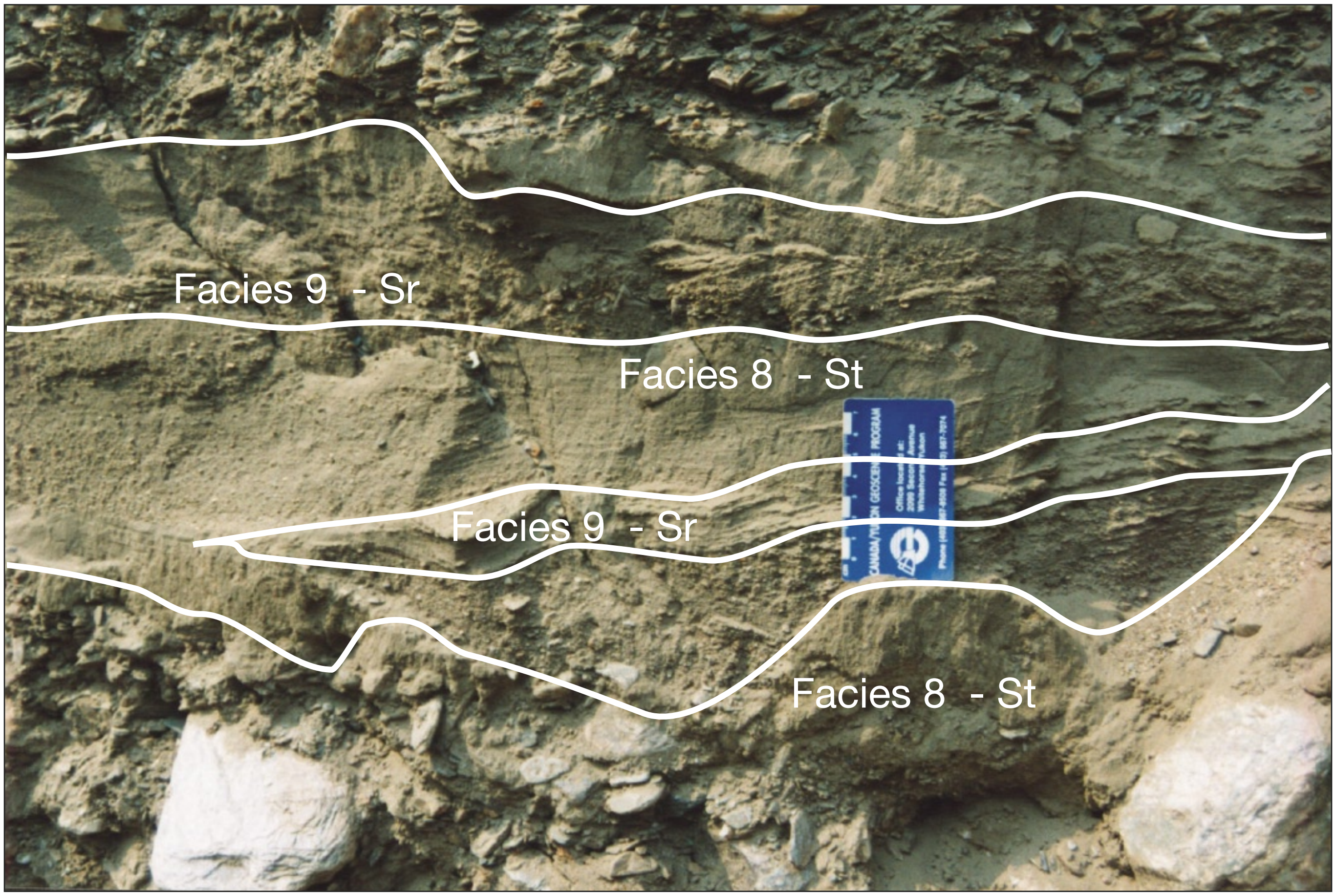


Figure 19. *Facies 8 - St, trough cross-bedded pebbly fine sand and Facies 9 - Sr, ripple cross-bedded medium to very fine sand commonly occur together, such as in this measured section SEA 9704 on Seattle Creek. A transition from Facies 8 to Facies 9 is interpreted as a reflection of gradually declining tractive flow. This type of depositional environment is more common in fluvial or distal alluvial fan systems than in glaciofluvial settings.*

Facies 10: Massive very fine sand/silt (Fm)

This facies consists of massive very fine sand/silt. Sorting is moderate to excellent. It is difficult to discern individual beds in this facies, but maximum thickness of this unit is over 5.0 m. Dispersed woody debris for finely comminuted organics occur within the massive sand/silt of this facies. Ice-wedge casts commonly occur in this facies. Colours of units from this facies vary from buff-tan grey, or light olive grey, dusky yellow, and yellowish grey, depending upon the composition of clasts and matrix, and the percentage of admixed organics.

Locally the massive very fine sand/silt facies grades vertically and laterally into Facies 1 or 2 massive or weakly stratified boulder-cobble diamict (Dmm, Dms). Massive very fine sand/silt is also associated with Facies 11 laminated and rippled fine sediment (Flr), and Facies 12 massive organic-rich silt (Fo). This unit was not studied in detail, and only sampled for heavy minerals in one or two cases. Heavy mineral yield is low, but garnet and ilmenite are present along with traces of magnetite and cassiterite. No gold was recovered from this facies.

This facies was noted in those areas with aeolian and mass-flow deposits, commonly with lacustrine, proglacial or glaciolacustrine sections. These include middle stratigraphic units at Ledge Creek and topmost stratigraphic units at Duncan Creek, Seattle Creek and Highet Creek (Fig. 20).

Facies 11: Laminated and rippled sand, silt and mud (Flr)

This facies consists of stacked units of sand, silt and mud that are planar laminated with common to rare rippled interlaminae. Silt is more dominant near the bottom of

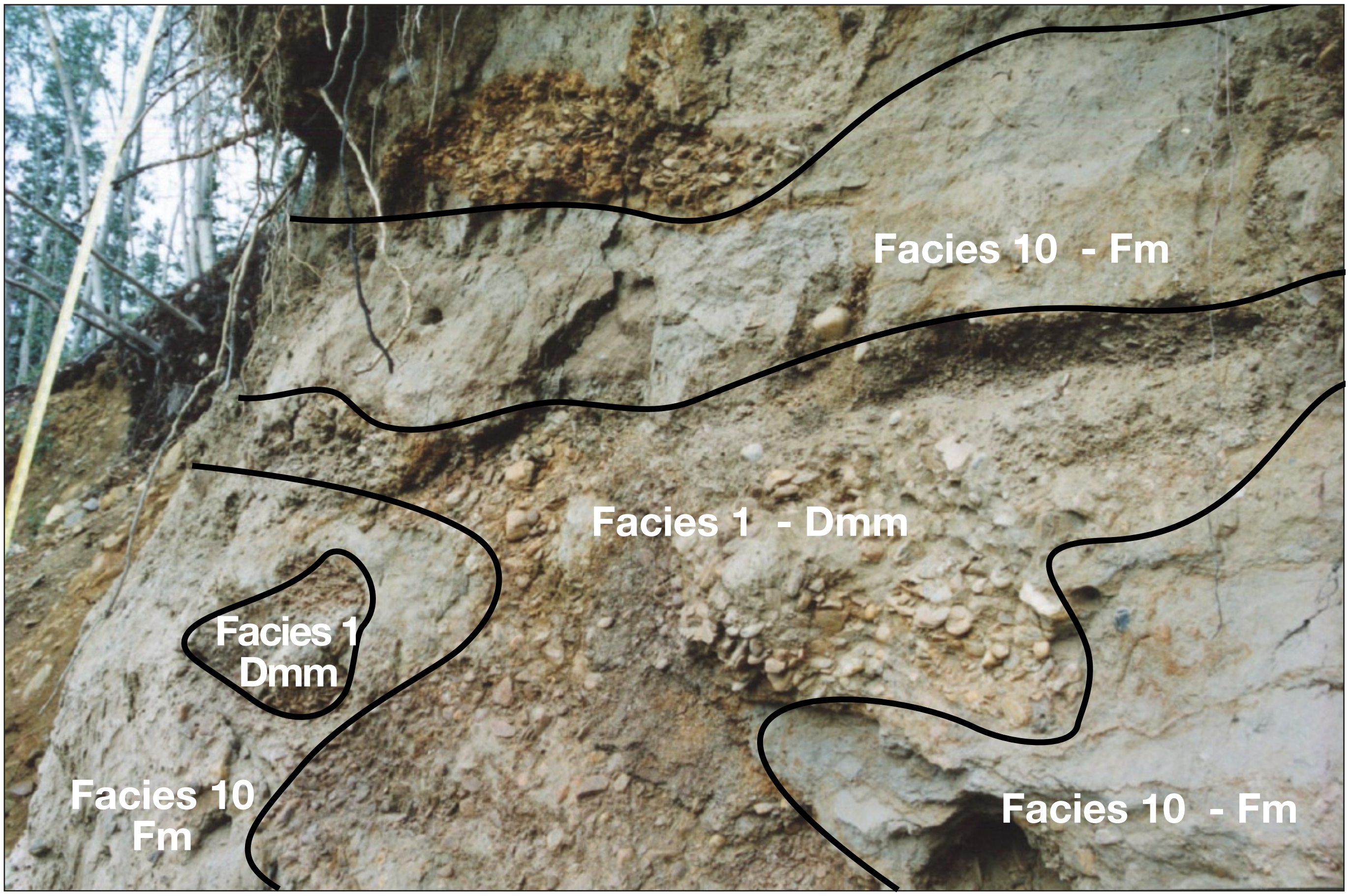


__Figure 20.__ Facies 10 - Fm, massive very fine sand/silt, has moderate to excellent sorting, and individual beds may be difficult to discern. Accessories include woody debris and organic sediments as well as localized ice-wedge casts. Locally, this facies grades vertically and laterally into Facies 1 (Dmm), massive diamict or Facies 2 (Dms), weakly stratified boulder-cobble diamict. Local facies associations also include Facies 11 (Flr), laminated and rippled fine sediment, and Facies 12 (Fo), massive organic-rich silt. This photo shows measured section HCR9701 on the Highet Creek road, where Facies 10 is interpreted to be a fine-grained mass flow deposit originally derived from windblown silt (loess).

units, which are often capped by thin clay layers. In some cases, the laminations show variable grading, including normal (fining-upwards), inverse (coarsening-upwards), and inverse-to-normal. Within the graded-laminites are rare intrabeds of massive sand, pebble-cobble diamict, and dropstones. Cryogenic features such as ice-cast sand wedges commonly occur in the lower 3-4 m of the units belonging to this facies. The laminated/rippled and graded-laminated fine sediment of this facies is associated with Facies 10 massive very fine sand/silt. Graded-laminites ('rhythmites') tend to be preserved in thicker units, up to 6.75 m; whereas the laminated fines with rare discontinuous interbeds of pebble-granule/cobbles are at most 3.75 m thick. Stacked units of graded-laminites ('rhythmites') are up to 20 m thick in the measured sections. Accessories such as woody material are generally absent in those units with graded-laminations and dropstone structures. Organics and woody debris are more common in the laminated and rippled very fine sand and silt. The exception is in the sections at Duncan and Upper Duncan creeks that yielded woody detritus in the graded-laminites with dropstone structures. Colours of units from this facies vary from medium to dark grey, or light olive grey, dusky yellow, and yellowish grey, depending upon the composition of clasts and matrix, and the percentage of admixed organics.

As with Facies 10, this unit was not studied in detail, and only sampled for heavy minerals in one or two cases. Despite the low representation of this facies, there is a low heavy mineral yield, with garnet, ilmenite, along with traces of magnetite and cassiterite. The pay zone at Davidson Creek is from this facies. This facies is rare or less common and was noted in those areas with better preserved finer grained interglacial lacustrine, or proglacial glaciolacustrine sections. These include middle stratigraphic units at Duncan Creek, Thunder Gulch, Ledge Creek, Highet Creek, and Lower Highet Creek (Fig. 21); and, topmost stratigraphic units at Duncan Creek, Goodman Creek and Rodin Creek.

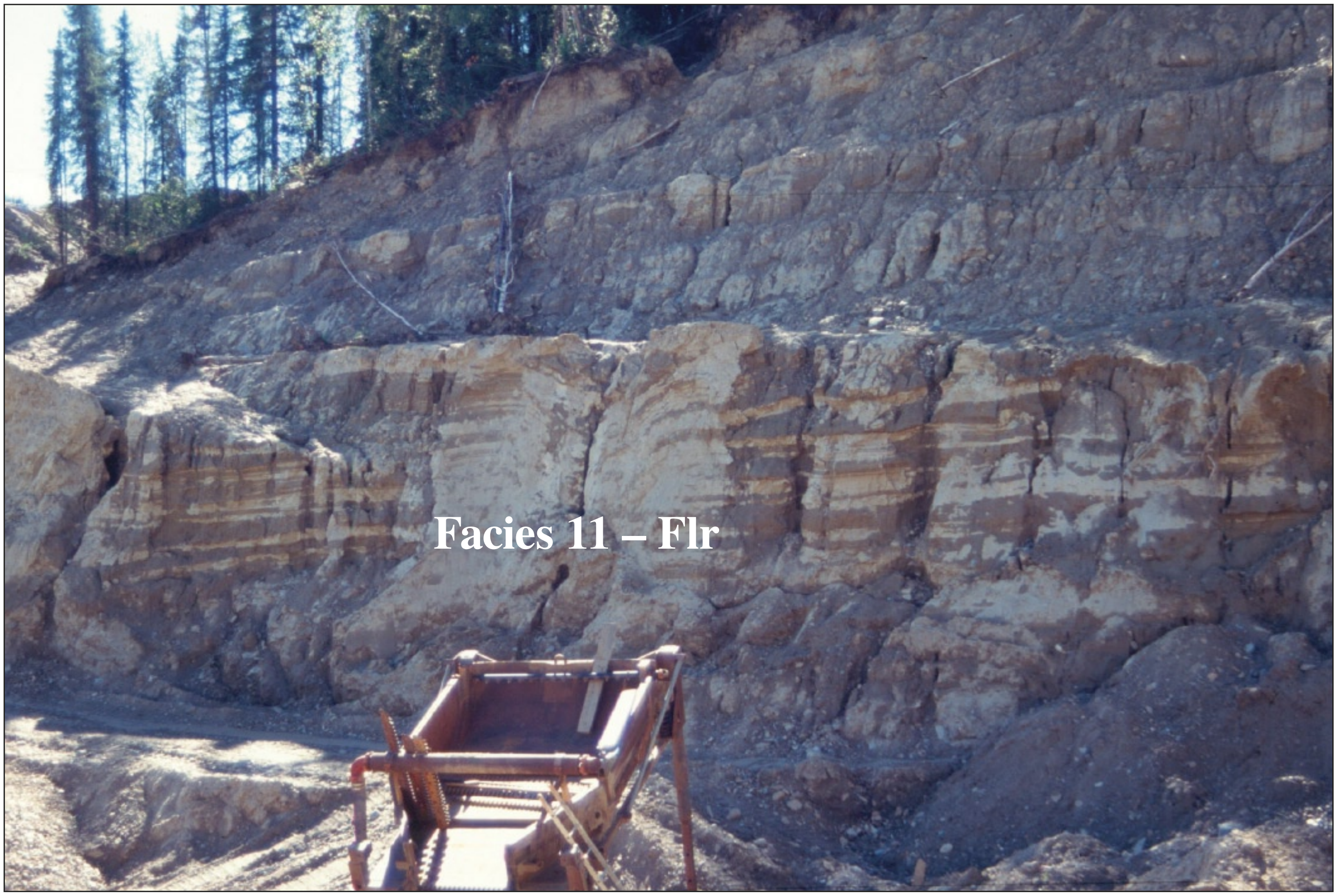


Figure 21. *Facies 11 - Flr, laminated and rippled sand, silt, and mud, consists of stacked units of sand, silt and mud that are planar laminated with common to rare rippled interlaminae. This photo shows measured section HT2/3-95 on Highet Creek, which is interpreted to be a Reid glaciolacustrine sequence overlying interglacial alluvium and underlying Reid glacial till.*

Facies 12: Massive to laminated organic-rich silt (Flo)

This facies consists of very fine sandy silt or silt with a very high content of macerated organics and woody organic debris. Units of this facies range from thin partings to more composite units up to 1 m thick. Faint to distinct parallel lamination may be present. This facies is recognized by its high organic content, with colours varying from greyish-orange to brownish-grey or dark grey, depending upon the organic content and the occurrence of any secondary diagenetic Fe- or Mn-staining. Local clasts from boulder to pebble size occur in this facies in addition to accessories such as macro-organics and volcanic ash (e.g., measured section FT98-1-2, Fig. 22). As with the other fine-grained units, this facies was not studied in detail, with samples analysed from Duncan and Highet creeks. In the Duncan Creek samples, heavy mineral yields were low to medium, in one case dominated by ilmenite, less commonly by pyrite, garnet and magnetite. In the other Duncan Creek sample with low heavy mineral yields, there was a trace of magnetite and zircon. The Highet Creek sample had a low heavy mineral yield, dominated by ilmenite. No gold was recovered from samples of this facies.

This facies is rare and was noted in those areas with better-preserved finer grained interglacial sections, commonly underlying Holocene to Recent organic mats, rooted soil horizons, and locally highly organic 'mucks.' These include topmost stratigraphic units at Seattle, Duncan Creek, Upper Duncan, Thunder Gulch, Goodman Creek, Rodin Creek and Seattle Creek. In interglacial and Holocene settings, woody material can be radiocarbon dated.

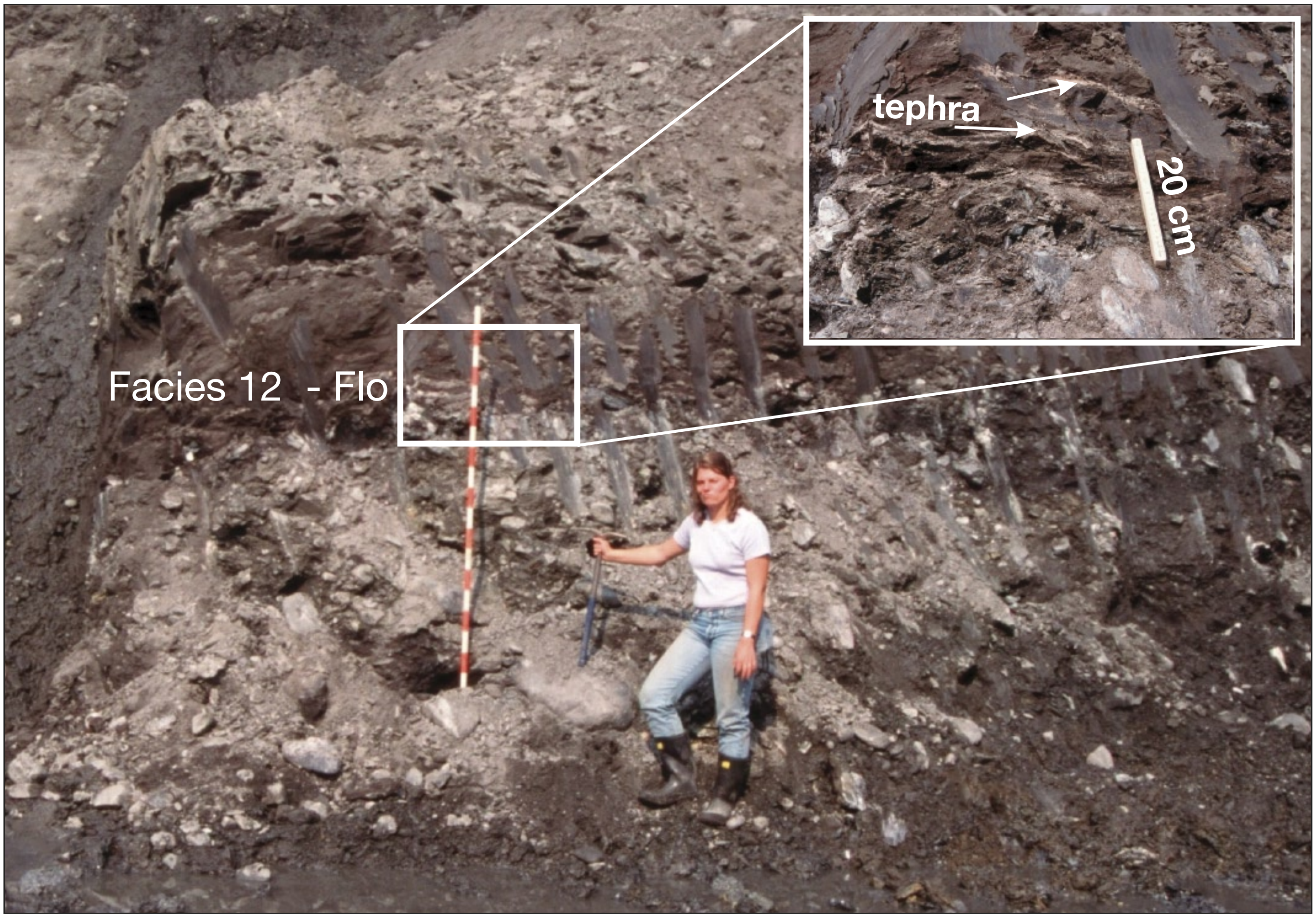


Figure 22. Facies 12 - Flo, massive to laminated organic rich silt, consists of very fine sandy silt or silt with a very high content of macerated organics and woody organic debris. Local clasts from boulder to pebble size occur in addition to accessories such as macro-organics and volcanic ash (e.g., measured section FT98-1-2, pictured here). In interglacial and Holocene settings, woody material can often be radiocarbon dated. A wood sample from this unit was ^{14}*C (AMS) dated at >50 030 years B.P.*

FACIES INTERPRETATIONS AND LITHOSTRATIGRAPHIC RELATIONSHIPS

The basic interpretation of the origin and processes of deposition of individual facies is given in Table 4. In the following section, these processes are briefly discussed along with a brief outline of the lithostratigraphic relationships that form the basis for the Lithostratigraphic Assemblages discussed in the next section.

Facies 1 (massive boulder-cobble diamict - Dmm) is interpreted to be a lodgement till or a resedimented lodgement till. Facies characteristics such as the very poor sorting, high mud-matrix content, disorganized or chaotic fabrics, and bullet-shaped or flat-iron clast morphologies are typical of glacial till deposits. The compact nature and high matrix content, along with a maximum clast size of 3 m, implies that the deposit is either morainal material or lodgement till. Such deposits are common in ice-contact settings such as u-shaped valleys, proximal glaciofluvial environments, terminal and recessional moraines, and stagnation morainal complexes.

Facies 2 (massive to weakly stratified boulder-cobble diamict - Dms) is interpreted as proximal debris flows, colluvial slope, slump or solifluction deposits. The high percentage of mud-matrix, basal inverse grading, disorganized structures with vertical fabrics, along with the presence of a diffuse horizontal stratification that parallels local slopes, are typical of debris flows or other mass-wasting deposits in proximal high-slope and/or high-discharge areas. Such deposits are common in proximal glacial settings, where glacial tills are reworked by catastrophic meltwater flows; in high discharge proximal glaciofluvial/meltwater channel settings; on high-angle colluviated alluvial slopes; or in steep slope permafrost areas susceptible to solifluction. Local debris flow deposits may form where glacial ice and meltwater discharges into glaciolacustrine margins.

Facies 3 (stratified/imbricated boulder gravel - Gms) is indicative of high traction flows of gravels in a proximal fluvial setting, such as progradation of gravel bars or diffuse gravel sheets. This type of deposit is common in glaciofluvial outwash or meltwater channel settings, although similar facies develop in proximal alluvial canyon-gulch, or alluvial-fan environments under very high discharges or flood conditions. In boulder beds with clasts up to 3 m, the facies is interpreted as subglacial or proximal glaciofluvial outwash, either reworked morainal deposits or subject to extremely high discharge events associated with positions proximal to large glacial ice masses. This facies may occur in glacial or periglacial settings, but is not solely indicative of such environments.

Facies 4 (graded or graded-stratified gravel - Ggh) is interpreted as being deposited very rapidly from basal dispersions associated with high suspended-load flood flows, called ‘hyperconcentrated’ flood flows. These types of very high discharge, very high suspended load flows are similar to dilute, watery debris flows, and are capable of transporting very high loads of very coarse debris. Such flows may originate as very high seasonal discharge flood events in alluvial environments, or alternatively may record extreme discharges associated with glacial meltwater channel flow. Similar to Facies 3, this type of deposit is indicative of very high discharge-flood events, common in glaciofluvial outwash, glacial meltwater channels, proximal alluvial canyon-gulch, or alluvial-fan environments.

Facies 5 (stratified/cross-stratified gravel - Ghpt) indicates high traction flows that transported gravel as bedload. For horizontally-stratified gravel, transport occurs as traction on bar tops or within channels as tractive carpets, some of which may organize into coarse-grained lobate gravelly bedforms called ‘diffuse gravel sheets’. With bed buildup on bar tops or within channels these gravel sheets may develop into gravel bars, with development of foresets, that upon progradation form planar-tabular cross-stratification. Given high or extreme discharge events gravel may be molded into large-scale three-dimensional dune bedforms, that produce trough cross-stratification with downstream migration. Such coarse gravel dunes have been recorded in ‘jokulhaup’ events associated with failure of ice-dam lakes or with extreme seasonal flood flows in fluvial environments. Similar to the previous gravel facies, these type of deposits record high to very high discharge events, common in glacial meltwater and braided outwash channels, proximal alluvial braided channels, or medial to distal alluvial-fan environments.

Facies 6 massive to stratified pebbly sand (Sh) is a finer grained equivalent to Facies 5 (stratified gravel) deposits. As such the stratified pebbly sand of Facies 6 records either somewhat lower traction flows than that which deposited the coarser gravel of Facies 5, but still under upper flow regime conditions; or, alternatively, a change in sediment supply of coarse gravel debris. Facies 6 units are mostly associated with gravel of Facies 5, and as such, are similarly interpreted as a record of very high discharge events, common in proximal braided outwash or fluvial channels, or medial to distal alluvial-fan environments.

Facies 7, 8 and 9 reflect gradually declining tractive flow events. Facies 7 (planar tabular cross-bedded sand -Sp) units were deposited on braided sand bars under high traction flow events, with downstream progradation producing planar tabular cross-stratification. Facies 8 (trough cross-bedded pebbly sand - St) is a finer grained equivalent of the trough cross-bedded gravel of Facies 5 (Ghpt), whereas Facies 9 (ripple cross-bedded sand – Sr) units are lower flow regime deposits from ripple bedforms. The cross-bedded sand facies are indicative of declining or normal discharge events in braided outwash or fluvial channels, or medial to distal alluvial-fan settings.

Although there is less stratigraphic and sedimentologic control on Facies 10-11, the basic textural properties of these units indicate that they were likely deposited in overbank or alluvial settings distal from coarse-sediment channel environments. Facies 10 (massive very fine sand/silt - Fm) is either a fine-grained mass-flow deposit, or aeolian (windblown) loess. Facies 11 (laminated/rippled sand, silt and mud – Flr) originates as two types, those that are due to suspension waning flood-flows, as in overbank settings; or those that are deposited rhythmically as alternating silt and clay layers in lacustrine or glaciolacustrine settings. Deposits of Facies 12 (massive to diffusely laminated organic silts and muds – Flo) are interpreted to be paleosols that formed in overbank settings or on colluviated and vegetated slopes.

LITHOSTRATIGRAPHIC ASSEMBLAGES

Introduction

Sedimentological and stratigraphic data indicate eight lithostratigraphic assemblages, which are sedimentary facies grouped based on common lithology and stratigraphy. These assemblages occur repeatedly throughout the study area in similar geomorphic landforms and stratigraphic position, and are bounded by unconformable contacts. References to the surficial geology map units, where applicable, are listed in italics.

They are as follows:

1. Pre-Reid interglacial alluvium;
2. Early and Middle Reid glaciofluvial, glacial and periglacial sediments;
3. Late Reid glacial and periglacial sediments;
4. Post-Reid (Koy-Yukon) interglacial alluvium;
5. Early and Middle McConnell periglacial sediments;
6. McConnell glacial, glaciofluvial and glaciolacustrine sediments;
7. Late McConnell periglacial sediments; and
8. Holocene alluvial sediments.

Descriptions of assemblages

Lithostratigraphic Assemblage 1 – Pre-Reid interglacial sediments

Assemblage 1 consists of Pre-Reid interglacial fluvial, gulch and alluvial fan sediments that have been variably reworked and/or buried. It includes Facies 5 (stratified pebble-cobble gravel - Ghpt), Facies 6 (massive to stratified pebbly medium sand - Sh), Facies 7 (planar tabular cross-stratified pebbly medium sand - Sp), Facies 8 (trough-cross-bedded pebbly sand), Facies 9 (ripple-cross-bedded sand - Sr), Facies 11 (laminated/rippled silt and clay - Flr) and Facies 12 (massive to laminated organic silt - Flo). It occurs in the lowest stratigraphic position below Assemblage 2, however it is commonly preserved only in valleys transverse to paleo-ice-flow.

Lithostratigraphic Assemblage 2 – Early and Middle Reid glaciofluvial, glacial and periglacial sediments

Assemblage 2, associated with the Reid glacial advance and maximum (Early and Middle), consists mainly of glaciofluvial (*G^Rp, G^Rt, G^Rx*), glacial (*T^Rv, T^Rb, T^Rx*) and periglacial sediments (*A^Rf, A^Rx*) with local variably reworked pre-Reid interglacial fluvial sediments. The dominant facies are Facies 1 (massive boulder-cobble diamict - Dmm), Facies 2 (stratified boulder cobble diamict - Dms), Facies 3 (stratified/imbricated boulder-cobble gravel - Gms), Facies 4 (graded or graded/stratified gravel - Ggh) and Facies 11 (laminated/rippled silt and clay - Flr). This assemblage is usually preserved on slopes and plateaus in areas outside of the McConnell glacial limit.

Lithostratigraphic Assemblage 3 – Late Reid glaciofluvial, glacial and periglacial sediments

Assemblage 3, associated with deglaciation, is dominated by glaciofluvial (*G^Rp, G^Rt, G^Rx*) and periglacial sediments (*A^Rf, A^Rx*) with minor amounts of glacial sediments (*T^Rv, T^Rb, T^Rx*). The dominant facies are Facies 1 (massive boulder-cobble diamict - Dmm), Facies 2 (stratified boulder cobble diamict - Dms), Facies 3 (stratified/imbricated boulder-cobble gravel - Gms), and Facies 4 (graded or graded/stratified gravel - Ggh). This assemblage occurs mainly in a low stratigraphic position near bedrock, or lying unconformably in contact with Assemblage 2.

Lithostratigraphic Assemblage 4 - Post-Reid (Koy-Yukon) interglacial alluvium

Assemblage 4 consists mainly of fluvial, gulch and alluvial fan sediments that have been variably reworked and/or buried. It includes Facies 5 (stratified pebble-cobble gravel - Ghpt), Facies 6 (massive to stratified pebbly medium sand - Sh), Facies 7 (planar tabular cross-stratified pebbly medium sand - Sp), Facies 8 (trough-cross-bedded pebbly sand), Facies 9 (ripple-cross-bedded sand - Sr), Facies 11 (laminated/rippled silt and clay - Flr) and Facies 12 (massive to laminated organic silt - Flo). It mainly occurs in the middle stratigraphic position above Assemblages 2 and 3, however it is rarely preserved.

Lithostratigraphic Assemblage 5 – Early and Middle McConnell periglacial sediments

Assemblage 5, associated with the McConnell glacial advance and maximum, consists mainly of sediments deposited under periglacial climatic conditions ($A^{M}f$, $A^{PM}p$, $A^{PM}t$, $A^{PM}f$), either outside of the McConnell glacial limit or within the limit but immediately prior to the arrival of the McConnell ice sheet. It includes Facies 1 (massive boulder-cobble diamict - Dmm), Facies 2 (stratified boulder-cobble diamict - Dms), Facies 6 (massive to stratified pebbly sand), Facies 7 (planar tabular cross-bedded sand) and Facies 10 (massive very fine sand/silt - Fm). It occurs either on bedrock or stratigraphically higher than Assemblage 4 along an unconformable contact; elements of both Assemblages 3 and 4 are mostly present including resedimented till and reworked organic material. Within the McConnell glacial limit, it lies disconformably beneath sediments of Assemblage 6.

Lithostratigraphic Assemblage 6 - Middle McConnell glacial, glaciofluvial and glaciolacustrine sediments

Assemblage 6, associated with McConnell glacial maximum, consists of well-preserved glaciofluvial ($G^{M}p$, $G^{M}t$), glacial ($T^{M}v$, $T^{M}b$, $T^{M}x$)and glaciolacustrine sediments ($L^{M}b$) of McConnell age. It includes intercalated Facies 1 (massive boulder-cobble diamict - Dmm), Facies 2 (stratified boulder-cobble diamict – Dms), Facies 3 (stratified/imbricated boulder-cobble gravel – Gms), Facies 4 (graded or graded/stratified gravel – Ggh), Facies 10 (massive very fine sand/silt - Fm) and Facies 11 (laminated/rippled sand, silt and clay - Flr). This package commonly rests disconformably over Assemblages 5, 4 and 3, generally at a high stratigraphic position on slopes, terraces and plateaus within the McConnell glacial limit. In valley settings, it is crosscut by sediments of Assemblage 8.

Lithostratigraphic Assemblage 7 – Late McConnell periglacial sediments

Assemblage 7, associated with McConnell deglaciation, consists of sediments deposited under periglacial climatic conditions ($A^{M}f$), either outside of McConnell glacial limit or within the limit, but immediately after the retreat of the McConnell ice sheet. It includes Facies 1 (massive boulder-cobble diamict - Dmm), Facies 2 (stratified boulder-cobble diamict - Dms), Facies 6 (massive to stratified pebbly sand), Facies 7 (planar tabular cross-bedded sand) and Facies 10 (massive very fine sand/silt - Fm). Outside of the McConnell glacial limit, this assemblage occurs either on bedrock or stratigraphically higher than Assemblages 2-5 along an unconformable contact; elements of these assemblages are usually present including resedimented till and reworked organic material. Within the McConnell glacial limit, this assemblage includes reworked elements of Assemblage 6, which were deposited during ice retreat.

Lithostratigraphic Assemblage 8 - Holocene alluvial, colluvial and eolian sediments

Assemblage 8 resembles Assemblage 4 however the sediments have been subjected to little burial or reworking (*Ap, At, Af, Ax, Cv, Ca, Ev*). It is dominated by fluvial, gulch and fan sediments including Facies 5 (stratified pebble-cobble gravel - Ghpt), Facies 6 (massive to stratified pebbly medium sand – Sh), Facies 7 (planar tabular cross-stratified pebbly medium sand - Sp), Facies 8 (trough cross-bedded pebbly sand), Facies 9 (ripple cross-bedded sand – Sr), Facies 11 (laminated/rippled silt and clay - Flr) and Facies 12 (massive to laminated organic silt – Flo). Scattered occurrences of Facies 4 (graded or graded/stratified gravel – Ggh) have been noted. As Facies 4 crosscuts and erodes previously existing sediments, it commonly contains elements of all other assemblages including reworked till, glacial boulders and organic material. It may be the only assemblage present especially in tributary gulches where it lies unconformably on bedrock.

PLACER MINING AREAS – DETAILED STUDIES

DUNCAN CREEK/KENO HILL

Introduction

Duncan Creek, a tributary of the Mayo River, was first prospected at the turn of the century and is historically one of the most actively mined drainages in the Mayo District. Since 1995, however, only two mining operations have been active, the Taylor family (Duncan Creek GoldDusters) on Duncan Creek (Fig. 23) and the Barchen family (Bardusan Placers) on Lightning Creek, Thunder Gulch and Upper Duncan Creek (Fig. 24). Gold production from Duncan Creek and its tributaries in the last 15 years is nearly 34,000 crude ounces (1 057 519 g), with historical production estimated to be at least twice that for the last 95 years.

Figure 24. *Aerial view of Bardusan Placers mining operation on Upper Duncan Creek in 1996. Wood found in two layers in measured section UD9602 was radiocarbon dated at 33 190 ± 880 years B.P. and 31 580 ± 620 years B.P.*

Figure 23. *Aerial view of Duncan Creek GoldDusters placer mining operation in 1996. The McConnell glacial ice advanced north from Mayo River valley up Duncan Creek valley, reaching approximately the lower left extent of this photo.*

Location and access

The Duncan Creek/Keno Hill area is located on NTS map areas 105M/13 and 105 M/14, between latitude 63° 45'N and 64°00'N and longitude 135°00'W to 136°00'W (Fig. 25). Access from the town of Mayo is via hard-surfaced road (the Silver Trail) and gravel road (Duncan Creek road), a distance of approximately 40 km. Duncan Creek road joins with the Silver Trail on both ends, forming a loop with the village of Keno City on the north intersection.

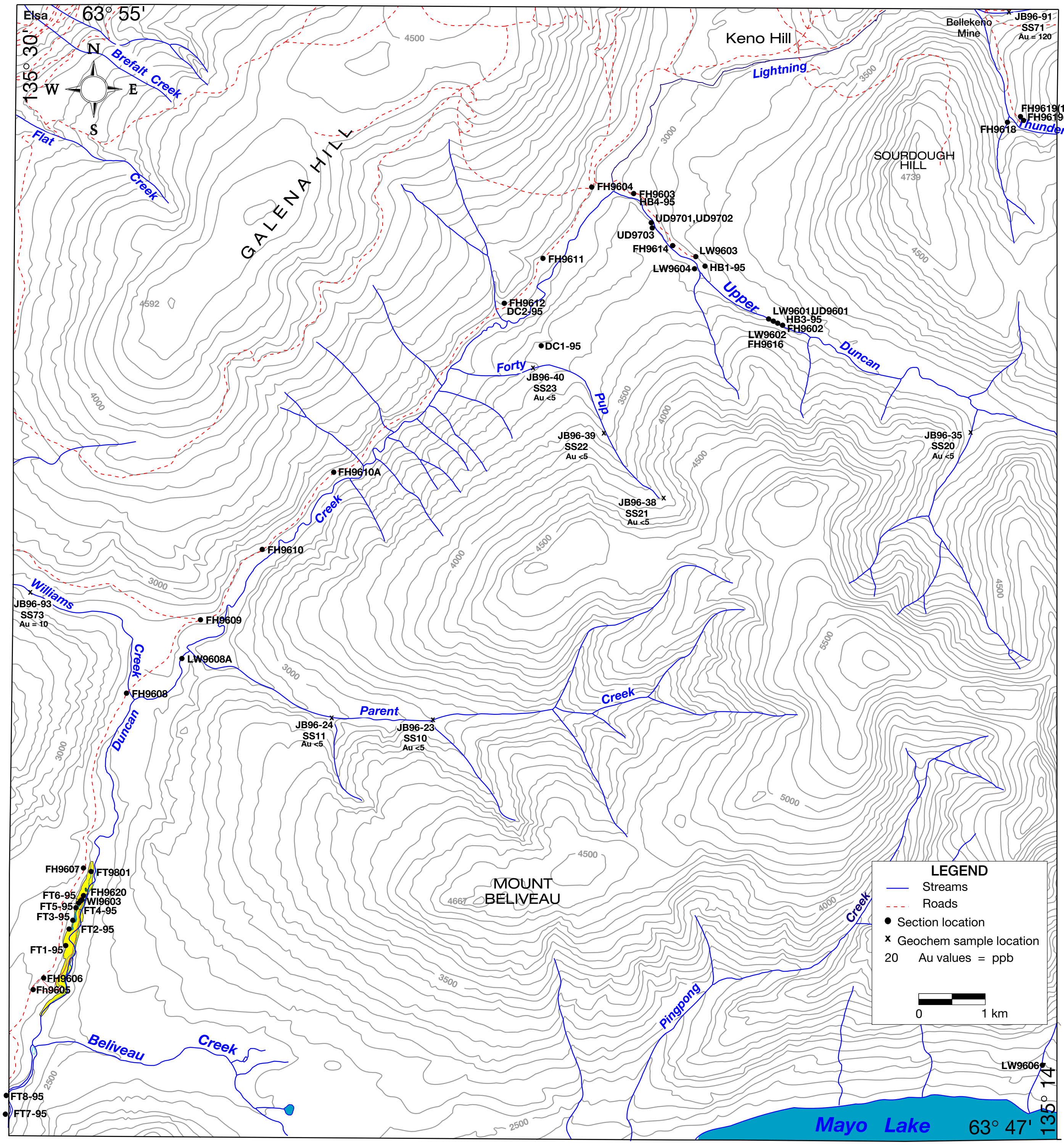


Figure 25. Measured section and geochemical sample locations, Duncan Creek area.

Physiography

The Stewart plateau is characterized by wide, flat-bottomed valleys, which separate blocks of broad, smooth uplands (Bostock, 1948). Near the centre of the field area is the Gustavus Range, which is bounded by wide valleys containing the Keno-Ladue River to the north, the South McQuesten River to the west, and Mayo Lake to the south (Fig. 2). The elevation of the valleys averages 2200 ft (670 m) while several peaks including Mt. Hinton, at the core of the Gustavus Range, lie above 6500 ft (2000 m). The uplands contain several cirques, which form the headwaters of many of the local streams including Duncan and Lightning creeks in the north, and Granite and Keystone creeks to the south.

Local geology

The Robert Service Thrust Fault traverses the field area, thrusting Upper Proterozoic to Lower Cambrian Hyland Group phyllite, psammite and marble over Mississippian Keno Hill Quartzite and Devono-Mississippian Earn Group graphitic schist, phyllite and sericite schist (Murphy, 1997). Triassic metadiorite sills intrude the Paleozoic sequence (Murphy, 1997).

Hosted within the Keno Hill Quartzite are over sixty silver-lead and gold vein deposits, nearly all of which have been mined for silver (Yukon MINFILE, 1997).

Surficial geology

Unconsolidated sediments in the Gustavus Range and the surrounding plateaus consist mainly of deposits from Cordilleran valley glaciers (continental ice sheet), alpine glaciers (local montane glaciers), colluvium, and minor alluvium (Bond 1998d, in pocket). Most of the upland areas are covered with a veneer of colluviated bedrock and scattered solifluction deposits. Exposed bedrock is common in the headwalls of cirques, along ridge-tops, and where frost weathering has carved out nivation hollows on north-facing slopes. Most glacial deposits in the area are McConnell age alpine and Cordilleran deposits. Deposits from the Reid and pre-Reid glaciations were noted above the McConnell limit on the uplands flanking the Gustavus Range, particularly near Duncan, Williams, and Field creeks (Bond 1998d). A natural section on lower Duncan Creek has exposed Reid or older till under McConnell sediments (Fig. 26), which suggests that large trunk valleys may also contain stacked deposits of older glacial sediments (Fig. 27). A Reid till blanket was identified in Parent Creek, and in Upper Duncan Creek a Reid till blanket and resedimented till overlie gold placers. Reid till and outwash were also mapped at the summit of Galena Hill and at a divide between Thunder Gulch and upper Duncan Creek. Overall, slope processes have eroded much of the evidence of older glaciations at the higher elevations.

McConnell Cordilleran deposits line the valleys of the Keno-Ladue River, South McQuesten River, Mayo River, and Duncan Creek and include sequences of meltout till, basal till, outwash plains, and outwash channel deposits. McConnell alpine glacial deposits are found in Faro Gulch, McNeill Gulch, McMillan Gulch, Allen Creek, Granite

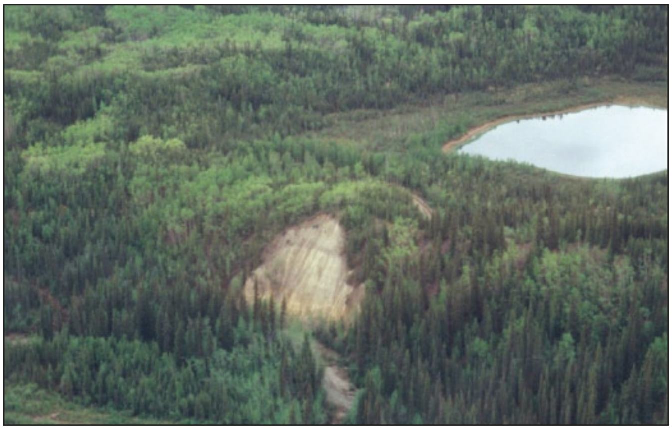


Figure 26. *Measured section FT95-08, a natural exposure at the mouth of Duncan Creek near its confluence with Mayo River. This sequence of weathered pre-McConnell (possibly Reid) till beneath two distinct McConnell tills suggests that large trunk valleys throughout the Mayo area may contain stacked deposits of older glacial sediments in addition to the surface McConnell deposits.*

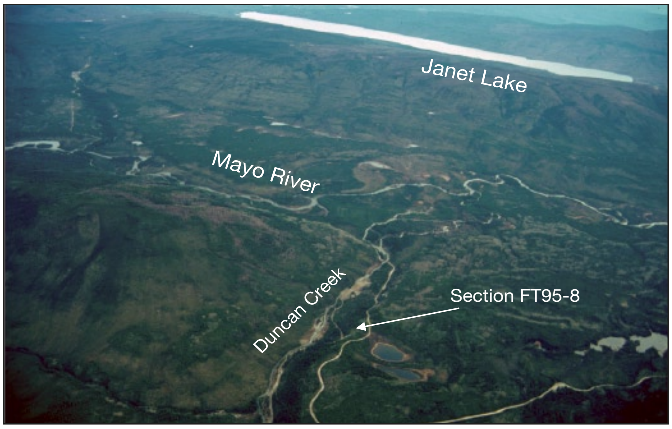


Figure 27. *Duncan Creek flows south into Mayo River which drains Mayo Lake in a large glacially-scoured valley. Multiple tills are exposed in a natural exposure (measured section FT95-8) on Duncan Creek.*

Creek, upper Duncan Creek, and in three other unnamed valleys in the Gustavus Range (Bond 1998d, in pocket). The glacial deposits remain intact in the valley bottoms, however they are commonly draped with a colluvial apron. Large terminal moraines were deposited at the mouth of McNeill and McMillan Gulches, which nearly join with a Cordilleran moraine in Faith Creek. Outwash terraces on the north side of Lightning Creek were deposited by meltwater exiting to the west into the Duncan Creek drainage. In Granite Creek valley, thick deposits of Cordilleran till blanket the lower part of the drainage and nearly merge with local alpine moraines originating from Mount Hinton.

Sedimentology

Introduction

Fifty-three sections were examined in detail in the Duncan Creek area between 1995 and 1998. Sections were located at active mining cuts and stream cutbanks on Duncan, Upper Duncan and Lightning Creeks, Thunder Gulch, and other Duncan Creek tributaries. Figure 24 shows the location of the sections; this information is also summarized in Appendix 1a.

Dominant facies and interpreted environments of deposition

Duncan Creek lies at the margin of the McConnell glaciation; some portions of the creek and tributaries lie within the ice limit and some lie outside of the glacial limit. In addition, the drainage is completely within the Reid glacial limit, which deposited thick sequences of till and outwash in the Duncan Creek valley. Consequently, glacial, glaciofluvial and glaciolacustrine sediments are dominant, which includes Facies 1 to 3 and Facies 11. Facies 1 (massive boulder-cobble diamict – Dmm) occurs mainly in contact with bedrock on Duncan Creek, Upper Duncan Creek and Thunder Gulch. It is interpreted as a Reid age glacial till. Facies 2 (weakly stratified boulder-cobble-pebble diamict -Dms) is found throughout the area either on bedrock or higher in the section, commonly in association with Facies 1. This unit is interpreted as deposited by proximal debris flows associated with the reworking of glacial deposits (Facies 1), typical in ice marginal settings. Facies 3 (weakly stratified/imbricated boulder gravel - Gms) is the main pay unit on Duncan Creek where it is associated with Facies 1 and 2. It is interpreted as Reid age proximal glaciofluvial outwash. Thick sequences of Facies 11 (laminated and rippled sand, silt and mud - Flr) are preserved in the main valley of Duncan Creek where they overlie Facies 1 to 3. This sediment was deposited as a proglacial lake during the McConnell glacial episode.

Stratigraphy

Representative stratigraphic sections

Figure 28 is a panel diagram showing typical stratigraphy in the main valley of Duncan Creek (measured section FT98-1-1). Additional stratigraphic sections are located in Appendix 4.

Lithostratigraphic assemblages

Seven lithostratigraphic assemblages are found in the Duncan Creek area; a representation of these is shown in Figure 29, which is a schematic cross-valley profile of Duncan Creek.

They are as follows:

- Assemblage 2 – Early and Middle Reid glaciofluvial, glacial and periglacial sediments;
- Assemblage 3 – Late Reid glacial and periglacial sediments;
- Assemblage 4 – Post-Reid (Koy-Yukon) interglacial alluvium;
- Assemblage 5 – Early and Middle McConnell periglacial sediments;
- Assemblage 6 – McConnell glacial and glaciofluvial sediments;
- Assemblage 7 – Late McConnell periglacial sediments; and
- Assemblage 8 – Holocene alluvial sediments.

Stratigraphic relationships

Lithostratigraphic Assemblage 2 – Early and Middle Reid glaciofluvial, glacial and periglacial sediments

In Duncan Creek, this assemblage is most commonly preserved on slopes and plateaus in areas outside of the McConnell glacial limit, for example, the Reid outwash on the divide between Williams Creek and Field Creek.

Lithostratigraphic Assemblage 3 – Late Reid glaciofluvial, glacial and periglacial sediments

Along the main valleys of Duncan and Upper Duncan creeks this assemblage occurs in the lowest stratigraphic position on bedrock, lying unconformably in contact with Assemblage 2.

Lithostratigraphic Assemblage 4 – Post-Reid (Koy-Yukon) interglacial alluvium

This assemblage is relatively well preserved in Upper Duncan Creek, where it forms alluvial fans overlying periglacial or glacial sediments of Reid age (Assemblages 2 and 3, radiocarbon dates in Table 5). In the main valley of Duncan Creek, this assemblage is locally preserved between Reid outwash and McConnell lacustrine sediments and till.

Lithostratigraphic Assemblage 5 – Early and Middle McConnell periglacial sediments

Assemblage 5 occurs either on bedrock or stratigraphically higher than Assemblage 4 along an unconformable contact; elements of Assemblages 2, 3 and 4 are commonly present including resedimented till and reworked organic material. Within the McConnell glacial limit, it lies disconformably beneath sediments of Assemblage 6, as it was deposited prior to ice advance. This assemblage was noted in several locations in mining exposures on Duncan Creek, and is especially well exposed in Section FT98-1.

Lithostratigraphic Assemblage 6 – McConnell glacial and glaciofluvial sediments

Assemblage 6 lies disconformably over Assemblages 5, 4 and 3, generally at a high stratigraphic position on slopes, terraces and plateaus within the McConnell glacial limit. In Duncan Creek valley, it is reworked and cut by sediments of Assemblage 8.

Lithostratigraphic Assemblage 7 – Late McConnell periglacial sediments

McConnell periglacial alluvial fan sediments were noted outside of McConnell ice limit along Duncan Creek; these fans were probably deposited continuously throughout the McConnell glaciation, depositing sediments of Assemblage 7 on top of Assemblage 5.

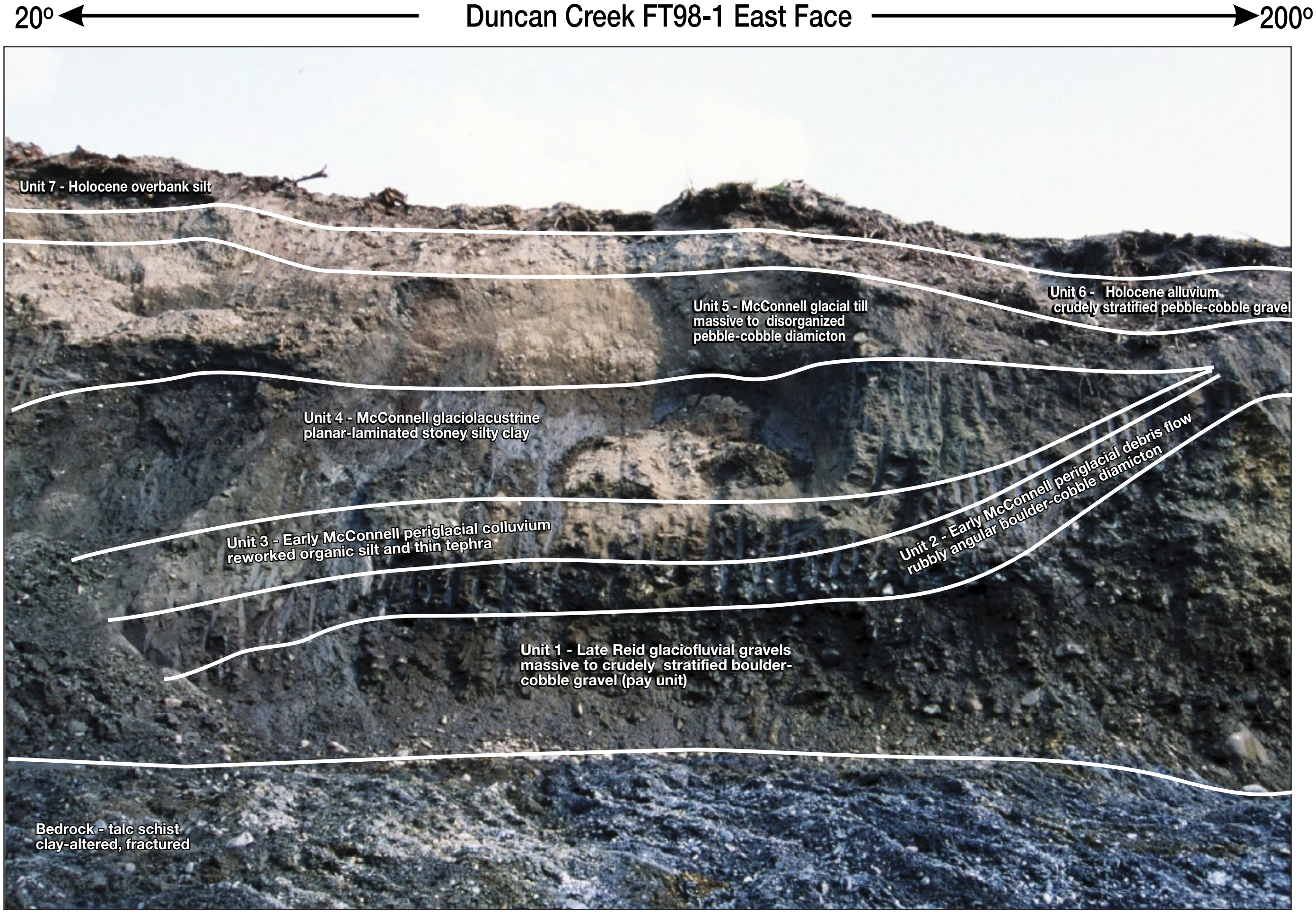


Figure 28. *Panel diagram showing typical stratigraphy on Duncan Creek. Reid glaciofluvial outwash is unconformably overlain by periglacial and glacial sediments of McConnell age.*

Lithostratigraphic Assemblage 8 – Holocene alluvial, colluvial and eolian sediments

Along the left limit on the lower reaches of Duncan Creek, Holocene alluvial gravels (Table 6) are in contact with the bedrock rim on the valley side. On the valley centre and right limit, Holocene alluvial gravels lie in contact with McConnell glaciolacustrine silt and glacial till.

Paleogeographic history

Evidence of the pre-Reid glaciations in Duncan Creek area is limited to erratics that are found at elevations of up to 5400 ft (1600 m) and a remnant cirque on Thunder Gulch. Paleoflow of Cordilleran ice likely initially followed topography before merging with alpine glaciers and overtopping the hills.

Table 5. *Radiocarbon dates for Koy-Yukon Interglacial, Duncan Creek*

Unit number	Sample number	Location	^{14}C Date (type)	Comments
FH9602	Beta-102614	Upper Duncan	>41 000 (conventional)	midway fines
UD9602-1	Beta-102620	Upper Duncan	33 190 ± 880 (conventional)	lower organics
UD9602-2	Beta-102621	Upper Duncan	31 580 ± 620 (conventional)	upper organics
UD97-02-04	Beta-109148	Upper Duncan	27 400 ± 220 (conventional)	organic silt
FT2-95-09	Beta-86851	Duncan Creek	32 320 ± 1270 (conventional)	wood
FH96012-1	Beta-102613	Duncan Creek	36 080 ± 1600 (conventional)	unit 1
FH9620	Beta-102617	Duncan Creek	>47 870 (Conventional)	Taylors W side organics
FH96012-8	Beta-111598	Duncan Creek	30 800 ± 500(ams)	unit 8
FT97-01-02	Beta-111600	Duncan Creek	>46 610 (conventional)	Taylors fall ’97 cut
FT98-1-02	Beta-127492	Duncan Creek	>50 030 (ams)	organic with tephra

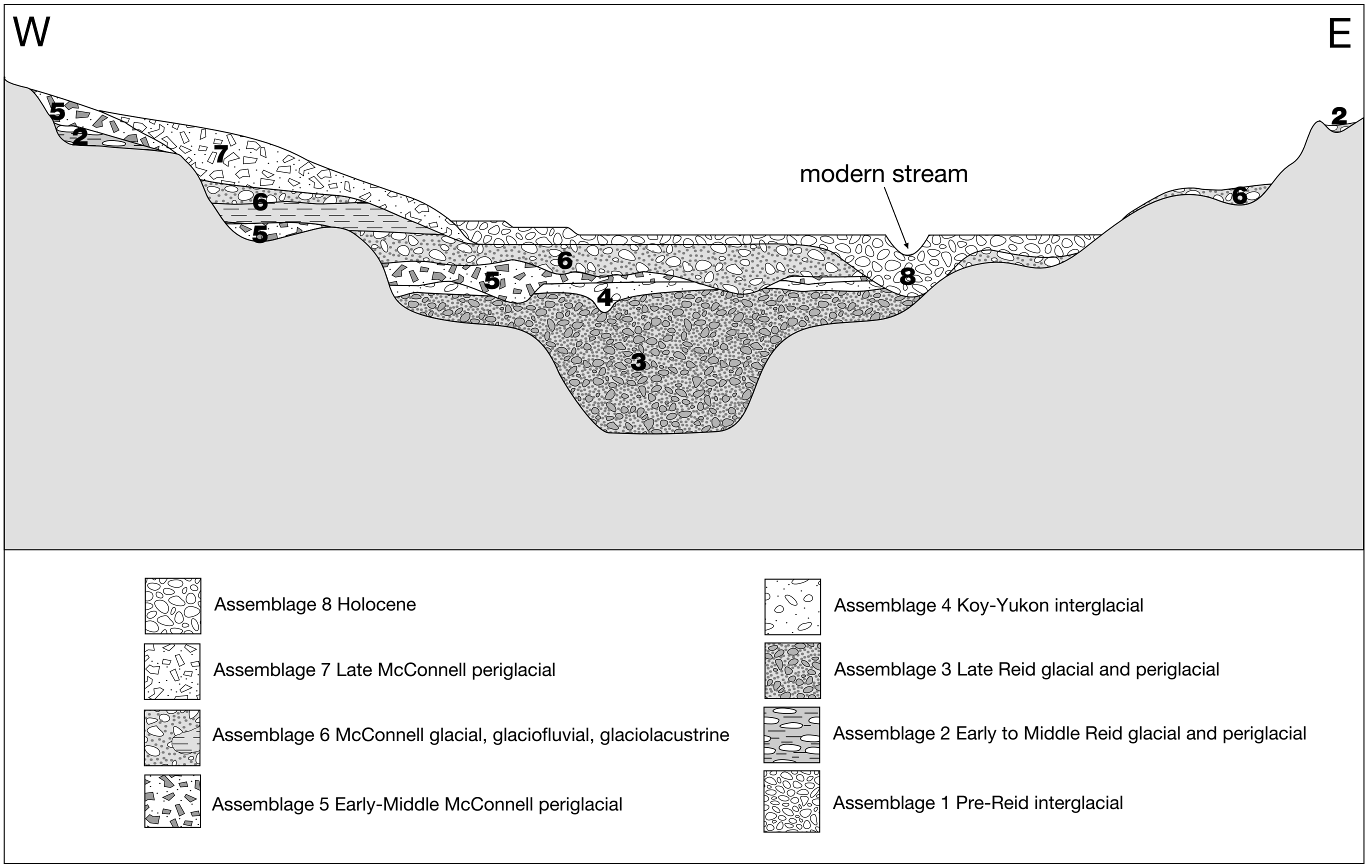


Figure 29. *Schematic cross-valley profile of Duncan Creek, showing relations between lithostratigraphic assemblages. Not to scale.*

Table 6. *Radiocarbon dates for Holocene sediments, Duncan Creek.*

Unit number	Sample number	Location	^{14}C Date (type)	Comments
FH9602-6	Beta-102615	Upper Duncan	5420 ± 70 (conventional)	Unit 6 wood
FH9601-3	Beta-111599	Upper Duncan	5110 ± 40 (conventional)	Unit 3 organics

During the Reid glaciation, ice filled most valleys to elevations of at least 1280 m, spilling outwash gravel over ridges including the divide between Williams and Field creeks, and the divide between Upper Duncan Creek and Thunder Gulch. Duncan Creek hosted a large glacial ice sheet, which deposited morainal drift and glaciofluvial outwash gravel. During the following interglacial (Koy-Yukon), fluvial systems stabilized and placer deposits formed while slope processes eroded much of the evidence of the older glaciations in the higher elevations.

Climatic cooling brought the McConnell glaciation to the area, although it was not as extensive as previous glaciations. Glacial ice advanced only a few kilometres up Duncan Creek valley from the south. McConnell glacial ice also blocked the northern extent of Duncan Creek valley, advancing to near its confluence with Lightning Creek. An extensive pro-glacial lake formed as a result of the ice blocking the drainage of the valley. Glaciolacustrine and glaciofluvial sediments inundated the valley to depths of up to 40 or more metres. In many areas along the McConnell ice margin these sediments buried pre-existing interglacial placers. Cordilleran ice also advanced into the valleys of Crystal, Faith, McKim, and Granite creeks. Near Keno City, Cordilleran outwash breached the divide into Duncan Creek and truncated a periglacial fan emanating from Upper Duncan Creek. McConnell alpine glaciers formed in Faro Gulch, McNeill Gulch, McMillan Gulch, Allen Creek, Granite Creek, upper Duncan Creek, and in three other unnamed valleys in the Gustavus Range (Bond 1998d).

Ice advancing from the mouth of McNeill and McMillan Gulches nearly coalesced with a Cordilleran ice lobe in Faith Creek. Most of the meltwater exited to the west into the Duncan Creek drainage. In Granite Creek valley Cordilleran ice nearly merged with alpine ice originating from Mount Hinton. The timing of the Cordilleran ice entering the range and alpine glaciers reaching their maximum may not have coincided. Because alpine glaciers had a local source they responded to climatic changes faster than the Cordilleran glaciers, which had distant accumulation zones in the Ogilvie and Selwyn Mountains. Lateral moraines from an unnamed alpine glacier originating from Mount Albert appear to be crosscut by lateral moraines from the Cordilleran glacier that advanced up Granite Creek. This supports the inferred timing for this area that alpine glaciers often reached their maximum limit prior to the Cordilleran ice sheet entering the region. The moraines also indicate a re-advance by both glaciers following retreat from the glacial maximum.

In the Keno-Ladue and South McQuesten river valley, glacial deposits were subjected to little post-glacial fluvial erosion. In contrast, the Mayo River valley glacial deposits were intensely eroded by outwash from the Mayo Lake valley glacier as it retreated. This base level change triggered downcutting that reached into Duncan Creek valley, partially re-excavating the valley fill. Post-glacial erosion by Lightning and Duncan Creek left the outwash surface as a high bench in the valley.

Placer geomorphology

The most significant gold-bearing gravel in the Duncan Creek area is the Reid outwash gravel (Lithostratigraphic Assemblage 3), which, in the lower reaches, lines most of the valley floor on bedrock. This outwash gravel likely incorporated a pre-existing (pre-Reid interglacial) placer deposit, which resulted in the dispersion of high-grade interglacial pay gravel into large volumes of glaciofluvial sediment. During the late stage of the Reid glaciation, meltwater erosion was sufficient to rework some of the dispersed gold into higher-grade concentrations near bedrock. This gravel may represent the largest potential buried placer gold deposit in the Mayo District.

After the Reid glaciation, high-discharge, sediment-laden glaciofluvial systems changed to non-glacial fluvial systems with lower, more constant flow rates and less sediment. Significant reworking of valley alluvium allowed the formation of high-grade placer deposits in the interglacial period.

During the McConnell glaciation, ice advanced into Duncan Creek from both ends, effectively burying pre-existing interglacial placers under 40 or more metres of glaciolacustrine and glaciofluvial sediments.

Post-McConnell downcutting significantly changed the morphology of the Duncan Creek drainage. Downcutting by the Mayo River, following the last glaciation, triggered a base level change in Duncan Creek and increased erosion throughout the main valley of the drainage. Duncan Creek eroded through McConnell glacial sediments in the lower part of the drainage and continued into the placer gold-bearing Reid outwash gravel. The influence of the base level change continued upstream as far as Lightning Creek and McNeill Creek. Upper Duncan Creek was not downcut as quickly as Duncan Creek and consequently was left as a hanging valley. Upper Duncan Creek has since eroded a canyon at the junction of the two valleys, which is where placer gold was first discovered in the Mayo district in 1898. This deposit consisted of sediment reconcentrated from a higher surface that represented the former mouth of Upper Duncan Creek. In Duncan Creek valley, post-glacial fluvial reworking of gold-bearing alluvium and bedrock sources created modern gulch and valley-floor placers on top of McConnell glacial drift and schist bedrock.

The development of local glaciers may have played a significant role in liberating lode gold into the placer environment. Glacial movement at the head wall of the cirque erodes bedrock into the glacial system, which eventually works its way into the fluvial environment following the glaciation. A lengthy post-glacial fluvial reworking period is then critical for placer development. It appears that the north-facing glacial valleys in the Gustavus Range, despite having considerable glacial activity, have not been exposed to sufficient post-glacial reworking to form placers. All north-trending valleys have actually produced fewer placers than valleys that were last glaciated during the pre-Reid and/or Reid glaciations. Viable placers may be found in sections of the recently glaciated valleys, but would largely consist of immature deposits. West-facing valleys like Upper Duncan Creek and Thunder Gulch have experienced long periods of hydrological reworking and subsequently have produced more abundant and coarser gold placers. Some of the placer deposits in Upper Duncan Creek may have actually been reworked to the mouth of the valley during the McConnell glaciation by meltwater from small alpine glaciers. This is discussed further in the section on “Regional Investigations.”

MAYO LAKE/DAVIDSON CREEK

Introduction

Many of the streams in the Mayo Lake area including Ledge, Davidson, Cascade, Anderson and Steep creeks have seen historical placer prospecting and mining activity since 1903. In recent years, modern mechanized placer mining has taken place on Davidson, Steep, Ledge, Anderson and Dirksen creeks. Recorded placer gold production for Mayo Lake tributaries from 1903 to 2000 totals 8432 crude ounces (263 819 g), however as this figure is derived only from incomplete placer royalty records, the total gold production is likely much higher.

Location and access

Mayo Lake lies on NTS map sheets 105M/10, 105M/11, 105M/14 and 105M/15. Access from Mayo is via the Silver Trail highway and the Duncan Creek road, a distance of approximately 45 km (Fig. 2). A narrow road intersects Duncan Creek road and winds southeast along the northern shoreline of Mayo Lake as far as Keystone Creek. A four-wheel drive road and a narrow bridge crossing Mayo River join Davidson Creek to the Mayo Lake road. Mayo Lake tributaries Anderson and Ledge creeks are accessed in winter by an ice road while in the summer access is restricted to boats, barges and aircrafts, which can utilize a small airstrip on Ledge Creek.

Physiography

Mayo Lake is the largest water body in central Yukon with a length of over 30 km (Fig. 30), and it consists of the West, Roop (east) and Nelson (south) arms. Several narrow streams occupy canyons above Mayo Lake and form alluvial fan-deltas where they empty into the water body. The main discharge point of Mayo Lake is through Mayo River from the West arm. Davidson Creek empties into Mayo River just west of the outlet from Mayo Lake. The Gustavus Range (including Mt. Albert at 6500 ft, 2000 m a.s.l.) rises steeply to the north while wide, glaciated valleys extend from each of the lake’s three arms.

Local geology

The Robert Service Thrust Fault crosses Mayo Lake from northwest to southeast, separating Upper Proterozoic to Lower Cambrian Hyland Group from Mississippian Keno Hill Quartzite and Devono-Mississippian Earn Group (Murphy, 1997). The Roop Lakes stock is Cretaceous hornblende-biotite granite, which subcrops a few kilometres north of the Roop arm (Murphy, 1997). Between the Roop and South arms, the Mayo Lake antiform dominates the Fork Plateau. A small galena vein

(Yukon MINFILE 1997, 105M 047) occurs on the north shore of Mayo Lake on Mt. Albert.

Surficial geology

Much of the topography surrounding Mayo Lake is covered by colluviated bedrock and till. Glacial erosion dominated in the Roop Arm (north arm) and no glacial deposits were observed in this area except near the McConnell glacial limit at 4000 ft (1200 m). A sizeable alluvial fan-delta developed at the mouth of Edmonton Creek and smaller fan-deltas were observed on the north shore. On the Nelson Arm to the south, a blanket of glacial till and meltwater deposits were noted near Ledge Creek to elevations of 2600 ft (790 m). The west shore of the Nelson Arm is generally steep with few surficial deposits other than colluviated bedrock. Well-developed alluvial fan-deltas form at the mouths of streams entering the lake. The west-end of Mayo Lake, after the confluence of the Roop and Nelson arms, has few surficial deposits until the valley widens at the west-end of the lake. An elevated ice-marginal outwash deposit (Kame terrace) parallels the north shore of the lake from Keystone Creek to Pingpong Creek (Bond 1998d, in pocket). A large alluvial fan-delta complex at the mouth of Keystone Creek

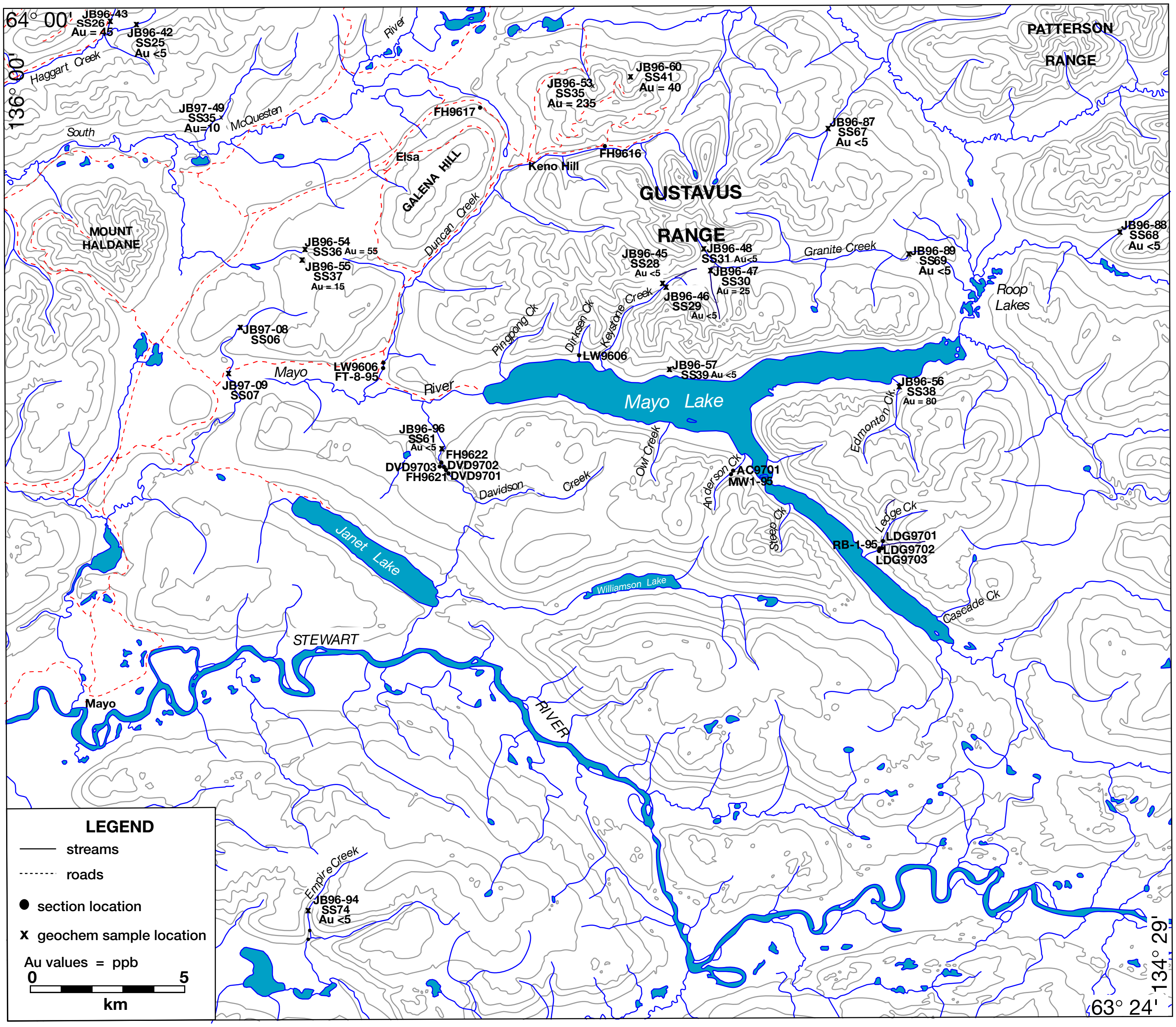


Figure 30. Section and geochemical sample locations, Mayo Lake area.

consists of two remnant fan-delta terraces on either side of the active fan-delta (Fig. 31). The abandoned fan-deltas mark a period closer to the end of the last glaciation when the lake level was higher. Evidence of a higher lake level is also preserved as elevated lake sediments at the west end of the lake. Till blankets and complexes of outwash gravel and meltout till line the Mayo River valley. Large alluvial plains dissect the glacial deposits and form broad floodplains and terraces in the base of the valley (Bond, 1998d, in pocket).

Sedimentology

Introduction

Thirteen sections were examined in detail in the Mayo Lake area between 1995 and 1998. Sections were located at active mining cuts and stream cutbanks on Anderson, Ledge, Dirksen and Davidson creeks. Figure 30 shows the location of the sections; these are summarized in Appendix 1b.

Dominant Facies and Interpreted Environments of Deposition

Mayo Lake lies completely within the Reid ice limit, and its tributary creeks were glaciated nearly to their headwaters during the McConnell. Anderson Creek, Ledge Creek and most of the other tributaries of Mayo Lake have formed alluvial fan-deltas into Mayo Lake. Dominant facies include glacially derived Facies 1 (massive boulder-cobble diamict – Dmm) and Facies 2 (weakly stratified boulder-cobble-pebble diamict - Dms), as well as glaciolacustrine and lacustrine-derived Facies 11 (laminated and rippled sand, silt and mud - Flr). Fan-delta sediments include Facies 3 (weakly stratified/imbricated boulder gravel – Gms), Facies 5 (stratified/cross-stratified gravel - Ghpt), Facies 6 (massive to stratified pebbly fine

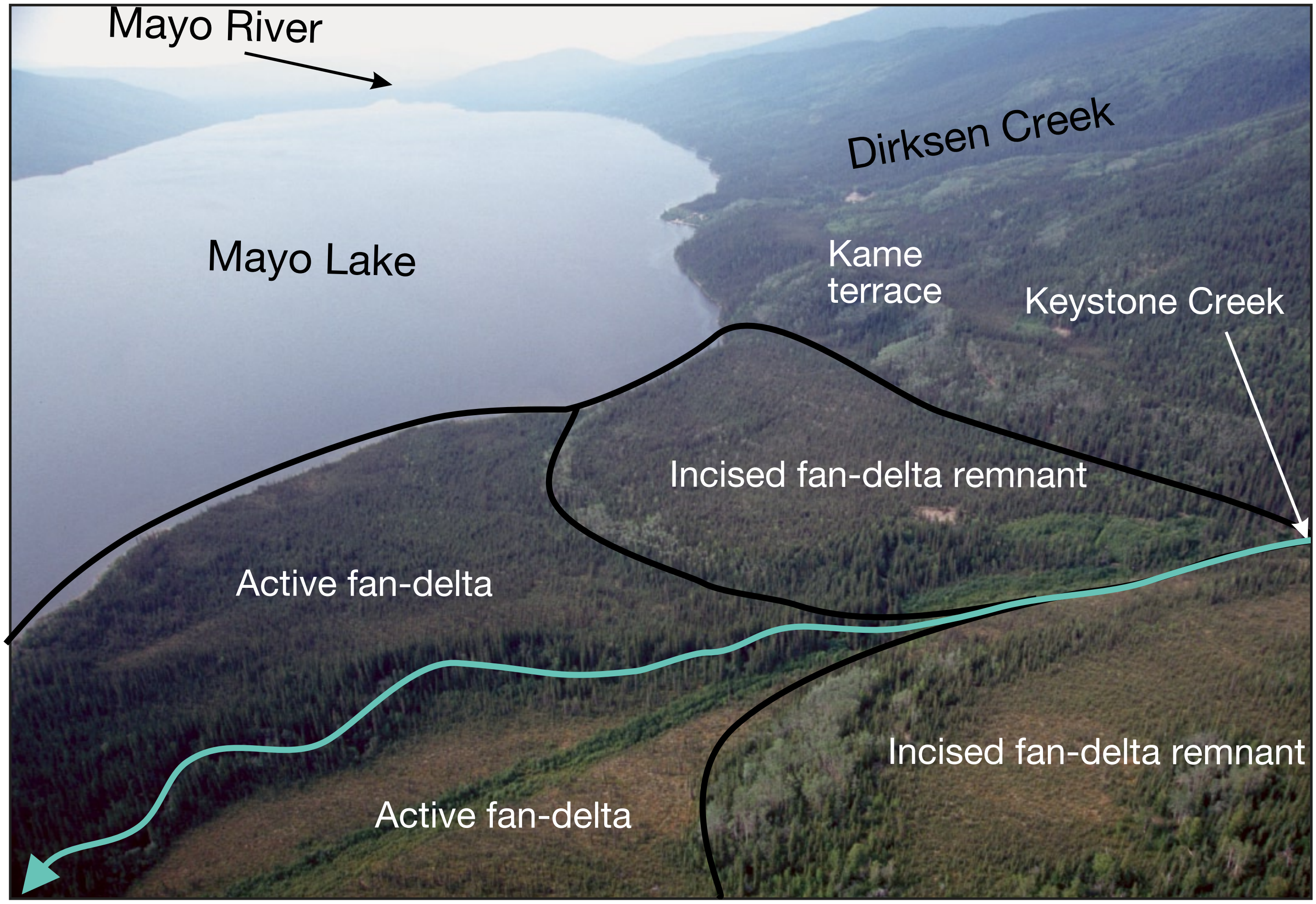


Figure 31. *View looking west of a large alluvial fan-delta complex at the mouth of Keystone Creek. Two fan-delta terraces are preserved as remnants on either side of the incised active fan-delta.*

sand – Sh), Facies 7 (planar tabular cross-bedded pebbly fine sand – Sp) and Facies 9 (ripple cross-bedded sand – Sr). On Ledge Creek Facies 3 is the main pay unit – it was interpreted to be an interglacial alluvial fan gravel which is overlain by McConnell glacial till (Facies 1) and glaciolacustrine sediments (Facies 11).

Stratigraphy

Representative stratigraphic sections

Figure 32 is a panel diagram depicting measured section AC9701 on Mayo Lake tributary Anderson Creek, while Figure 33 depicts measured section RB 95-1 on Mayo Lake tributary Ledge Creek. Additional sections are located in Appendix 4.

Lithostratigraphic asemblages

Five lithostratigraphic assemblages are found in the Mayo Lake area; a representation of these is shown in Figure 34, which is a schematic cross-valley profile. They are as follows:

- Assemblage 4 – Post-Reid (Koy-Yukon) interglacial alluvium;
- Assemblage 5 – Early and Middle McConnell periglacial sediments;
- Assemblage 6 – McConnell glacial sediments;
- Assemblage 7 – Late McConnell periglacial sediments; and
- Assemblage 8 – Holocene alluvial sediments.

Stratigraphic relationships

Lithostratigraphic Assemblage 4 – Post-Reid (Koy-Yukon) interglacial alluvium

This assemblage occurs mainly on bedrock in tributaries to Mayo Lake, where it forms part of the alluvial fans which build into Mayo Lake. On Ledge Creek, a wood sample (LDG 9703-01A) from a boulder gravel unit within this assemblage produced a ^{14}C date of 30 450 ± 340 B.P (see Table 7).

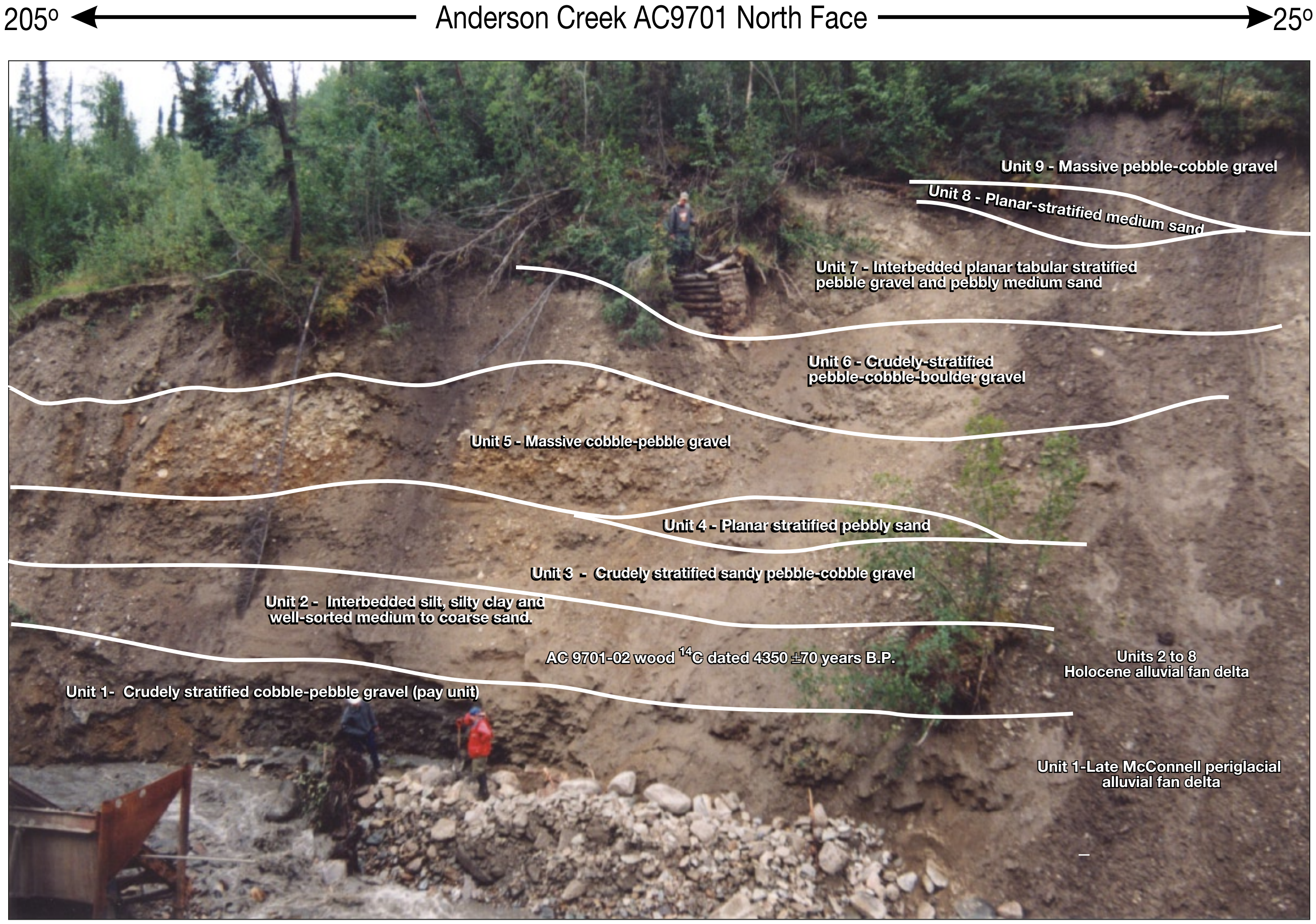


Figure 32. *Panel diagram of Anderson Creek mining section showing typical alluvial fan delta stratigraphy. Alternating units of fluvial channel gravel, overbank organic silt and sand, fine-grained lake sediments and deltaic sands are characteristic.*

Table 7. *Radiocarbon dates for organic sediments, Mayo Lake.*

Unit number	Sample number	Location	^{14}C Date (type)	Comments
LDG9703-01	Beta-109149	Ledge Creek	30 450 ± 340 (conventional)	Unit 1a organics
AC9701-02	Beta-109153	Anderson Creek	4350 ± 70 (conventional)	Unit 2 organics

Lithostratigraphic Assemblage 5 – Early and Middle McConnell periglacial sediments

On Mayo Lake tributaries, Assemblage 5 occurs either on bedrock or unconformably upon gravelly units of Assemblage 4. It may contain reworked elements of Assemblage 4, and lies disconformably beneath sediments of Assemblage 6, as it was deposited prior to ice advance.

Lithostratigraphic Assemblage 6 – McConnell glacial sediments

Assemblage 6 lies disconformably over Assemblages 5 and 4, generally on slopes, terraces and plateaus within the McConnell glacial limit. In Davidson Creek, silt and clay from this assemblage line the valley, where it is reworked and cut by sediments of Assemblage 8.

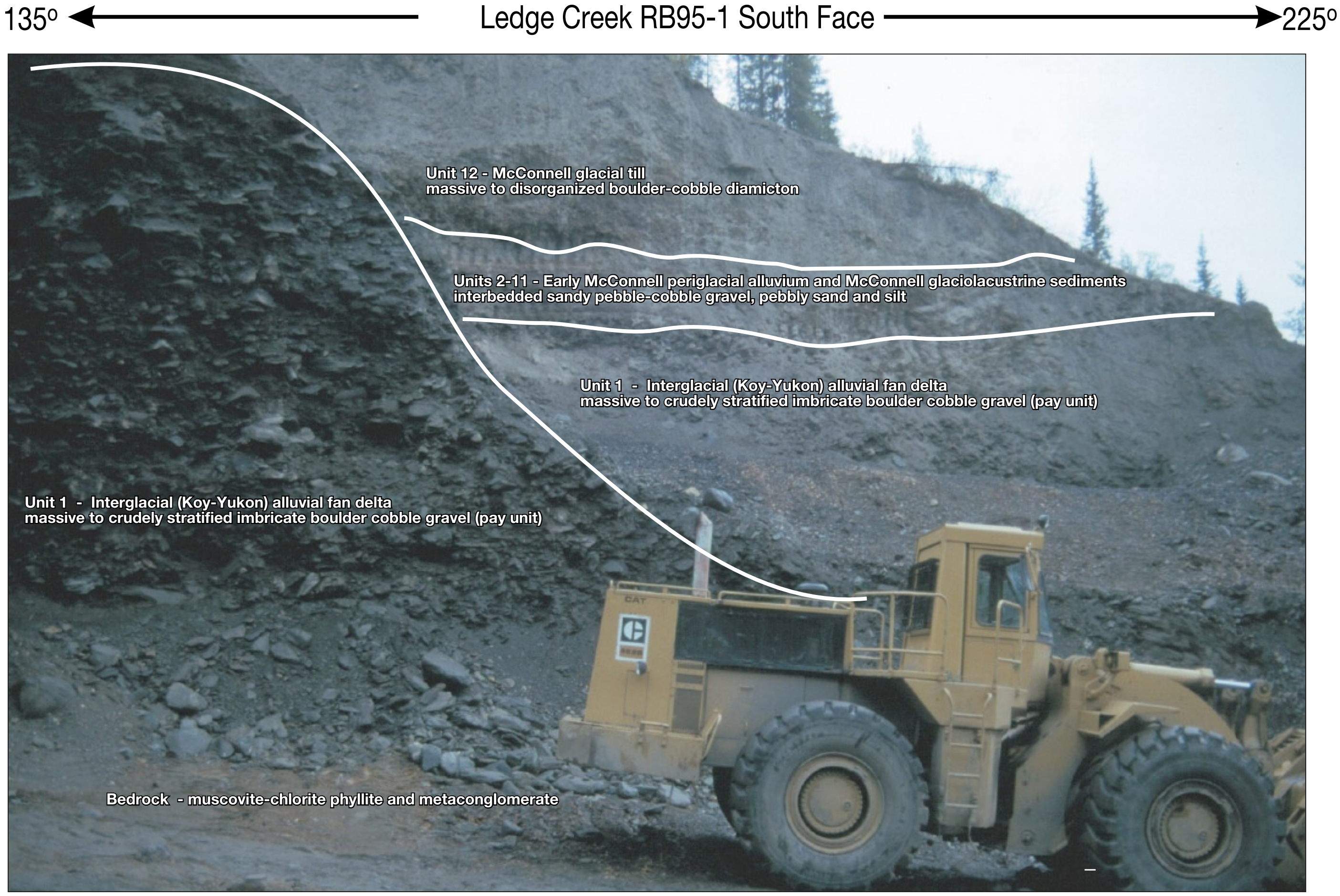


Figure 33. *Measured section RB1-95 on Ledge Creek showing interglacial (pre-McConnell) alluvial fan-delta gravel overlain by McConnell glaciolacustrine silt and glacial till. Interglacial gravel is typically gold-bearing, coarse grained and very poorly sorted.*

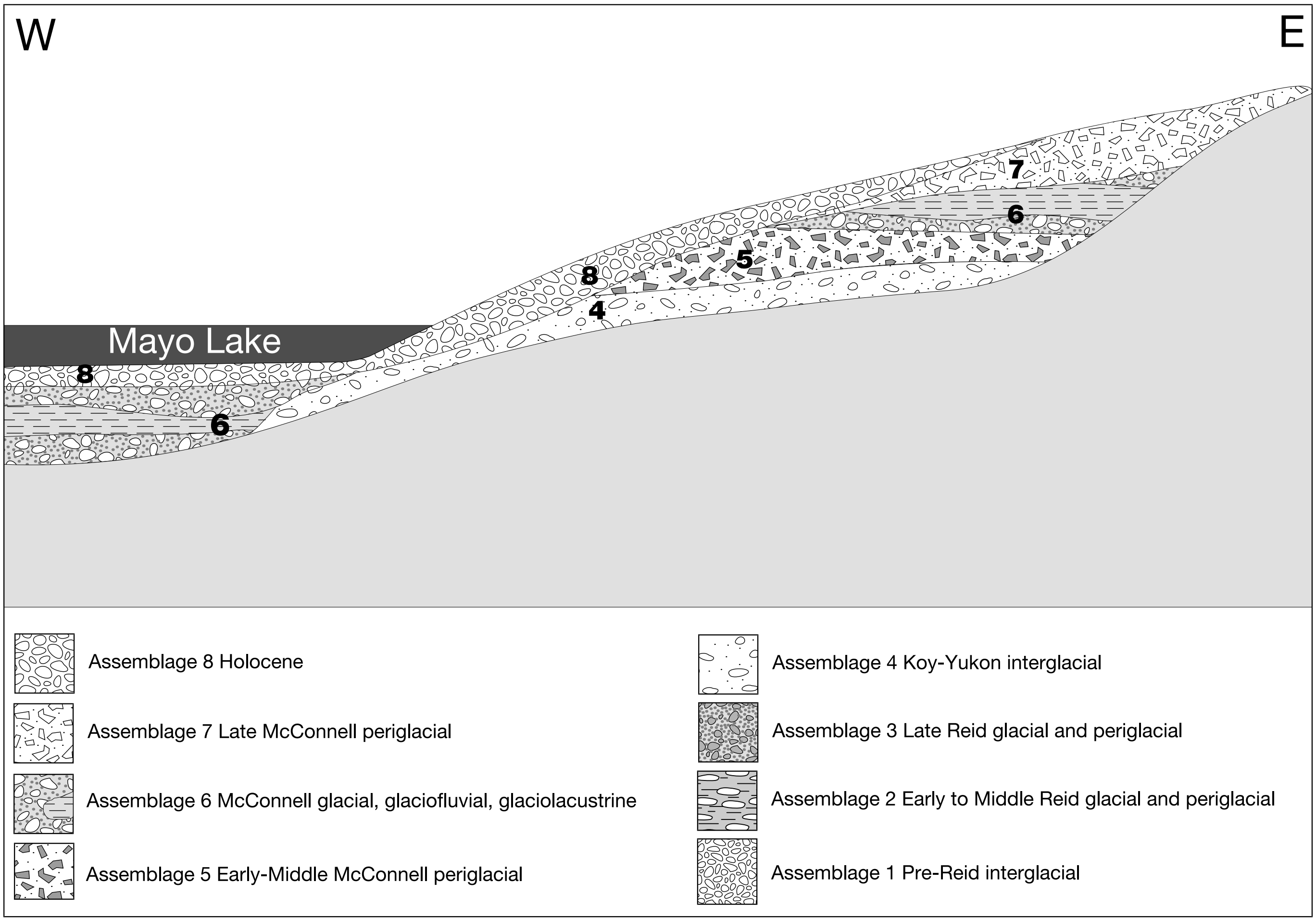


Figure 34. *Schematic cross-valley profile of Mayo Lake tributaries. Not to scale.*

Lithostratigraphic Assemblage 7 – Late McConnell periglacial sediments

McConnell periglacial alluvial fan sediments were noted outside of McConnell ice limits along Mayo Lake these fans were probably deposited continuously throughout the McConnell glaciation, depositing sediments of Assemblage 7 on top of Assemblage 6.

Lithostratigraphic Assemblage 8 – Holocene alluvial, colluvial and eolian sediments

In the canyon of Davidson Creek, Holocene alluvial gravel lies unconformably upon McConnell glacial sediments and bedrock (see also Fig. 35). On Mayo Lake tributaries, they crosscut or overlie all earlier assemblages including McConnell glacial and periglacial sediments and earlier interglacial alluvium. On Anderson Creek, organic debris from within alluvial fan delta sediments yielded a ^{14}C age of 4350 ± 70 years B.P (see Table 7).

Paleogeographic history

The glacial history of Mayo Lake was controlled by its confining physiography. Ice lobes entering the Roop and Nelson arms eroded the valley walls until deglaciation when meltout till and outwash were deposited on the lower flanks of the valleys. Erosional scars from meltwater channels occur on all the slopes bordering the lake and may contain minor outwash deposits. All streams flowing into Mayo Lake enter the lake at a transverse angle and have a v-shaped morphology, which suggests they were spared of glacial erosion. Small cirques at the headwaters of Edmonton Creek would have contained small glaciers during the last glaciation, however cirques at the headwaters of Steep Creek are likely Reid age, based on their orientation and amount of dissection. Glacial deposits are more abundant at the headwaters of Mayo River where the valley widens. Distinct lateral moraines can be traced from this point into Duncan and Davidson creeks. Excessive glacial deposition in Mayo River valley caused damming and the formation of Mayo Lake.

Figure 35. *In 1996, Rivest Mining had a placer operation just above the canyon on Davidson Creek. Placer gold-bearing gravels were found on a low terrace on bedrock, and within a silty clay layer which may be McConnell glaciolacustrine sediment.*

Placer geomorphology

The morphology of tributary valleys to Mayo Lake was influenced by glacial erosion, particularly in the Nelson and Roop arms. The sides of the main valley were selectively eroded by the glacier, creating a u-shaped valley, which contrasts with the v-shaped valleys of the tributaries. Widening of the trunk valley also makes the tributary valleys appear less incised. Above the glacial limit, or at least above the limit of glacial erosion, the tributary streams have an incised and well-confined drainage pattern, and within the glacial limit the drainage pattern is shallower and more exposed. Keystone Creek valley is the only tributary that has a well-incised morphology near its junction with Mayo Lake valley, and this is likely due to its length and a higher than average amount of discharge.

In spite of the glacial erosion in Mayo Lake valley, however, several placer deposits have been found in tributary valleys. These placers are of three types: interglacial (pre-McConnell) alluvium found in narrow valleys and canyons above the alluvial fan-deltas (Lithostratigraphic Assemblage 4, which was subsequently buried by McConnell glacial sediments); McConnell age periglacial alluvial fan deposits which formed placers on bedrock and at the apex of the alluvial fan-deltas (Lithostratigraphic Assemblage 7); and modern alluvium in tributary valley canyons and fan-delta apexes (Lithostratigraphic Assemblage 8).

Placer gold deposits occur on Anderson Creek at the apex of the fan-delta and on bedrock on the distal fan; and most, if not, the entire fan is comprised of sediments of Lithostratigraphic Assemblage 8 (Fig. 36). Conversely, Ledge Creek placer deposits also include interglacial sediments of Lithostratigraphic Assemblage 4, which were buried and preserved by McConnell glacial drift (Fig. 37). Several other alluvial fan-deltas extending into Mayo Lake may have similar settings; further exploration of these tributaries is warranted.

Davidson Creek lies partially within the McConnell glacial limit and the valley morphology is a result of a glacial diversion above the canyon. Prior to the last glaciation, upper Davidson Creek flowed south to Janet Lake (Fig. 30). Lower Davidson Creek at this time had a more local drainage pattern and the canyon was likely less developed or absent. When McConnell ice in Janet Lake Valley reached its maximum extent meltwater was diverted over the low divide northward into the Mayo River valley. More rapid erosion formed a canyon and ensured the northward course. Glacial outwash blankets upper Davidson Creek near the diversion.

The origin of gold in the canyon of lower Davidson Creek is unknown, although, its flattened morphology suggests that it is moderately travelled (Kreft, 1993). If placer gold were found near the point of diversion, just inside the canyon (meltwater channel), this would suggest an upstream source. Placer gold deposits do not normally originate in meltwater channels that were not previously occupied by an interglacial stream. If the gold originated in the headwaters of Davidson Creek, as current geomorphology suggests, then a large part of this drainage basin warrants exploration. The broad outwash plain near the head of the canyon was created by meltwater from the impinging Janet Lake ice lobe. Further prospecting should attempt to identify more locally derived gravel below the glacial outwash if it escaped McConnell erosion. If found, this paleochannel representing upper Davidson Creek prior to the McConnell diversion should extend southward toward Janet Lake.

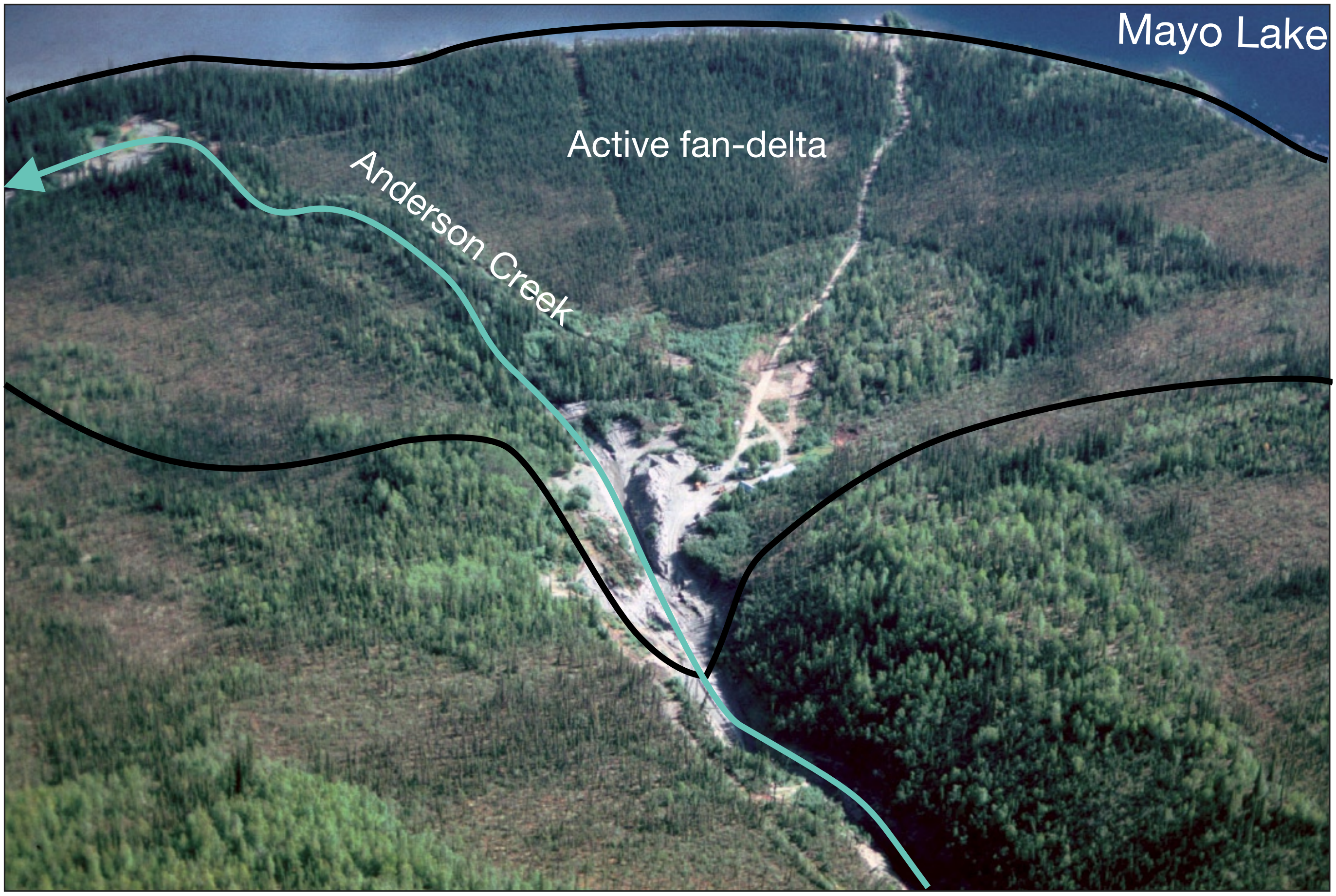


Figure 36. *This photo taken in 1995 shows a Holocene alluvial fan-delta which has formed on Anderson Creek, a Mayo Lake tributary. Most placer mining activity has been near the fan apex, and on bedrock farther down the fan.*

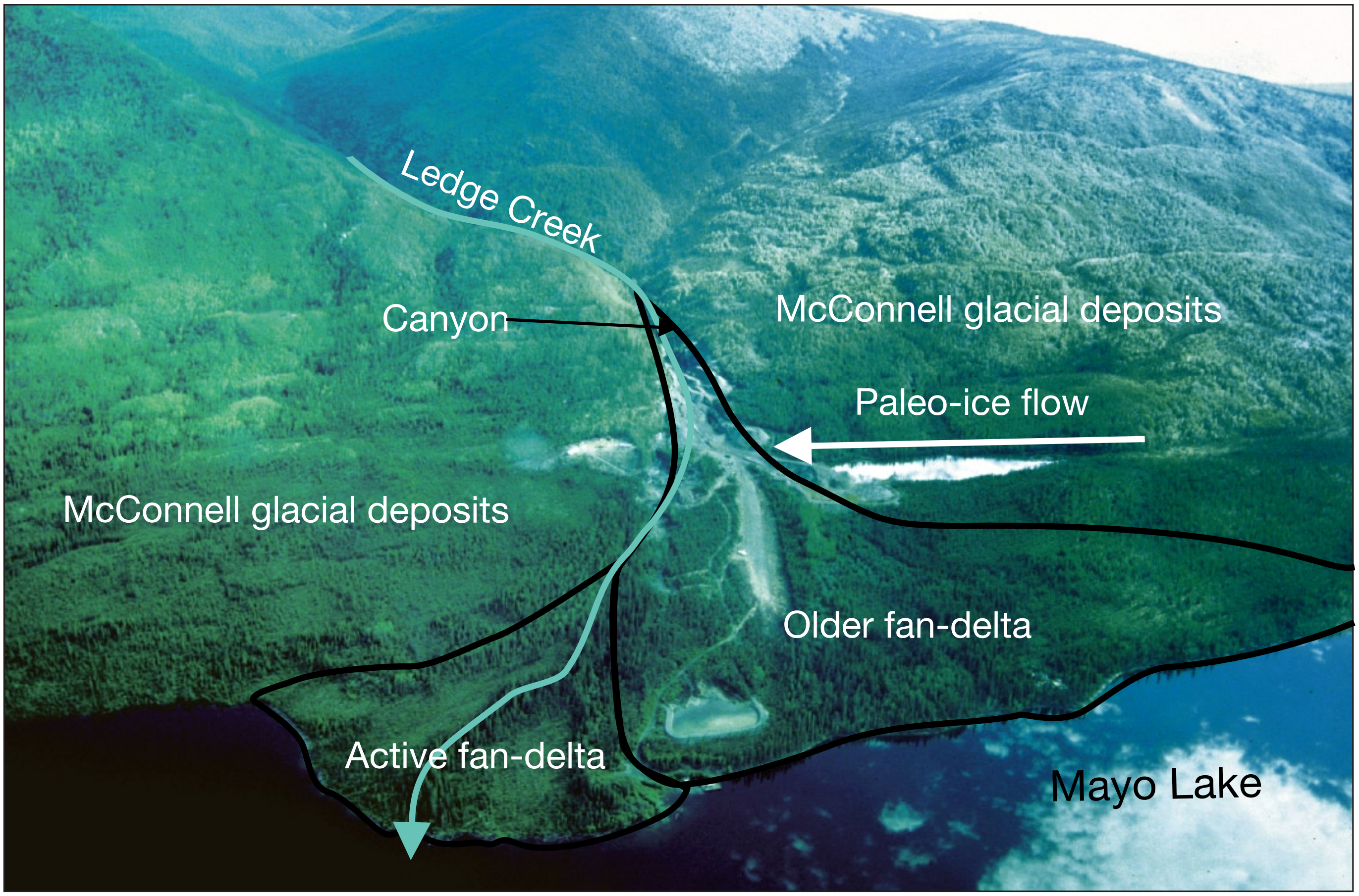


Figure 37. *On Ledge Creek, interglacial alluvial fan sediments, comprising an older fan-delta, were reworked and partially buried by McConnell glacial deposits. Since the canyon above the fan-delta is oriented transverse to paleo-ice flow, placer gold-bearing gravels were protected from glacial erosion. An active fan-delta has since formed after the glacier retreated.*

HIGHET CREEK/MINTO LAKE

Introduction

Although production was reported on Johnson Creek as early as 1894, the Discovery claim on Johnson Creek was staked by F. Johnson in 1898. This initiated a small stampede resulting in 38 prospectors staying the winter. Groundwater problems resulted in abandonment of the creek until a brief resurgence of activity in 1915. From 1958 to 1967, mining was conducted by Bardusan Placers, and in 1976, C. and H. Klippert Ltd. began mining. Bardusan Placers later returned, mining from 1980 to 1991. The total placer gold production from Johnson Creek is reported to be 13,280 crude ounces (411 700 g.).

Mining activity began on Highet and Minto creeks in 1903. The bench deposit on the right limit of Highet Creek proved to be the richest ground, especially near Rudolph Gulch, where over 6773 fine ounces (210 700 g) of gold were recovered. In 1920-21, an attempt was made to dredge Highet Creek, which was ultimately unsuccessful due to the large amount of boulders uncovered.

Recorded placer gold production from Highet and Minto creeks and their tributaries to 2000 is over 48,000 crude ounces (1.5 million g).

Location and access

The Minto Lake drainage area is located on NTS map sheets 115P/9 and 115P/16. The main drainages in the area are Minto, McIntyre, McLagan, Highet, Sabbath and Johnson creeks (Figs. 38 and 39). The road to Highet and Minto creeks begins 15 km along the Silver Trail, north of Mayo. It winds west for another 5 km before dividing into a northern road, which climbs the Highet Creek valley, and a southern road, which follows Minto Creek to Minto Lake. Both roads are two-wheel drive accessible in the summer months.

Physiography

The Highet Creek/Minto Lake area consists of a large incised plateau bounded by broad, u-shaped, glaciated valleys, including the South McQuesten River to the north. In the southern part of the field area near Minto Lake, North and South Bear creeks and Moose Creek, underfit streams flow in wide valleys that were modified during the Reid glaciation and subsequently filled with glaciofluvial outwash during the McConnell glaciation.

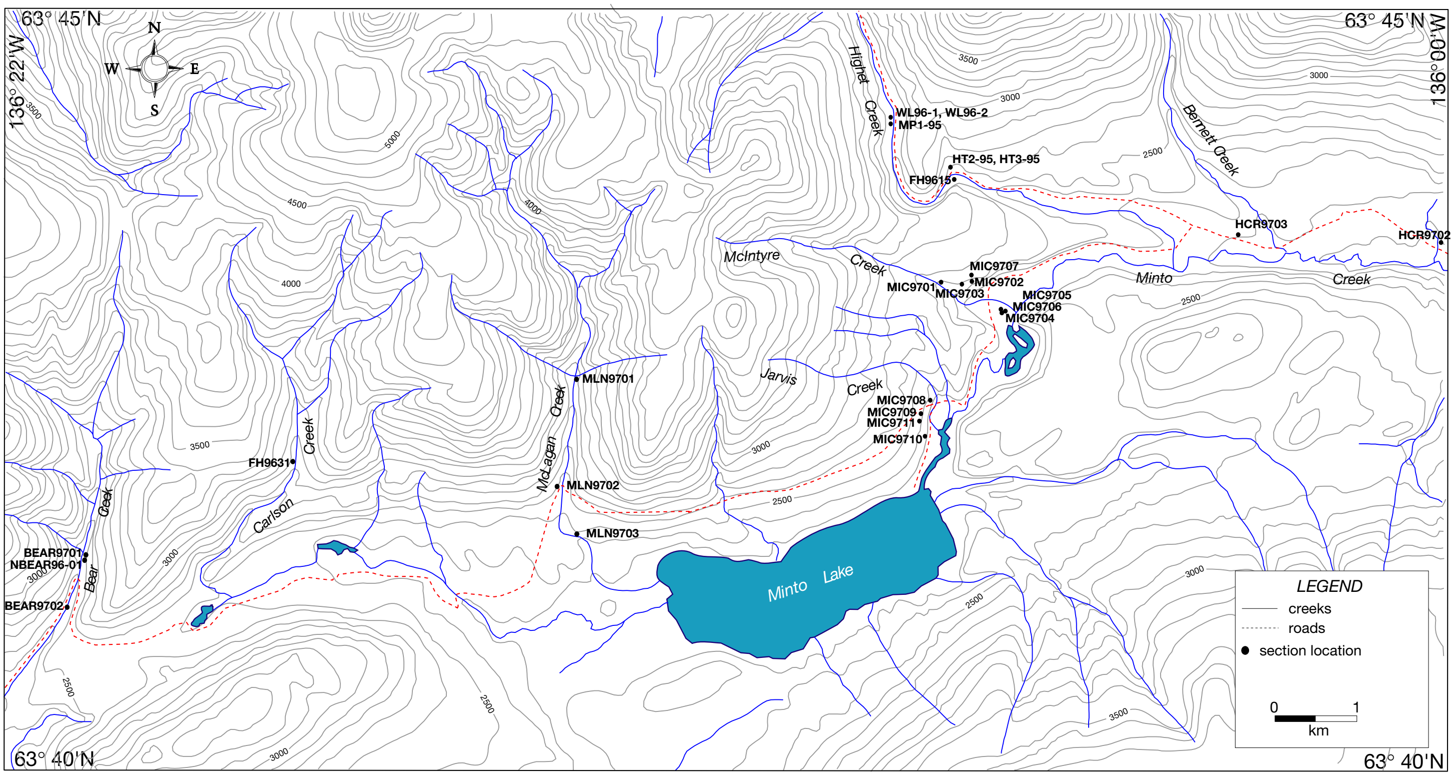


Figure 38. *Minto Lake and southern reaches of Highet Creek showing locations of measured sections.*

Local geology

The Robert Service Thrust Fault crosses north of the map area at Seattle Creek, where it divides Upper Proterozoic to Lower Cambrian Hyland Group from Mississippian Keno Hill Quartzite and Devono-Mississippian Earn Group (Murphy, 1997). Cretaceous hornblende granodiorite intrudes Hyland Group phyllite on the uplands between Highet Creek and Seattle Creek, and between Highet Creek and Minto Lake (Murphy, 1997).

The Scheelite Dome tungsten-gold skarn deposit and the Hawthorne Sb-Au vein ((Yukon MINFILE, 1997, 115P 004, 115P 003) are the main mineral occurrences in the headwaters of these two creeks.

Figure 40. *Measured section MIC9710 near Minto Creek, where a Diversion Creek paleosol is preserved on a Reid glaciofluvial terrace. This yellow-brown paleosol was subsequently buried by a McConnell age periglacial debris flow and protected from further erosion.*

Surficial geology

Thick deposits of glacial till, lacustrine and outwash sediments characterize the surficial geology of the Minto Creek valley. McConnell till lines the lower part of the drainage basin and McConnell outwash sediments extend west to Minto Lake. Reid glacial till, lacustrine and outwash sediments line the valley beyond the McConnell limit and form a distinct terrace between Minto Lake and Highet Creek (Fig. 40). All tributaries to Minto Creek are incised into the glacial deposits where they intersect the valley. Mining exposures in Highet Creek, a tributary to Minto Creek, reveal Reid glacial deposits on the lower

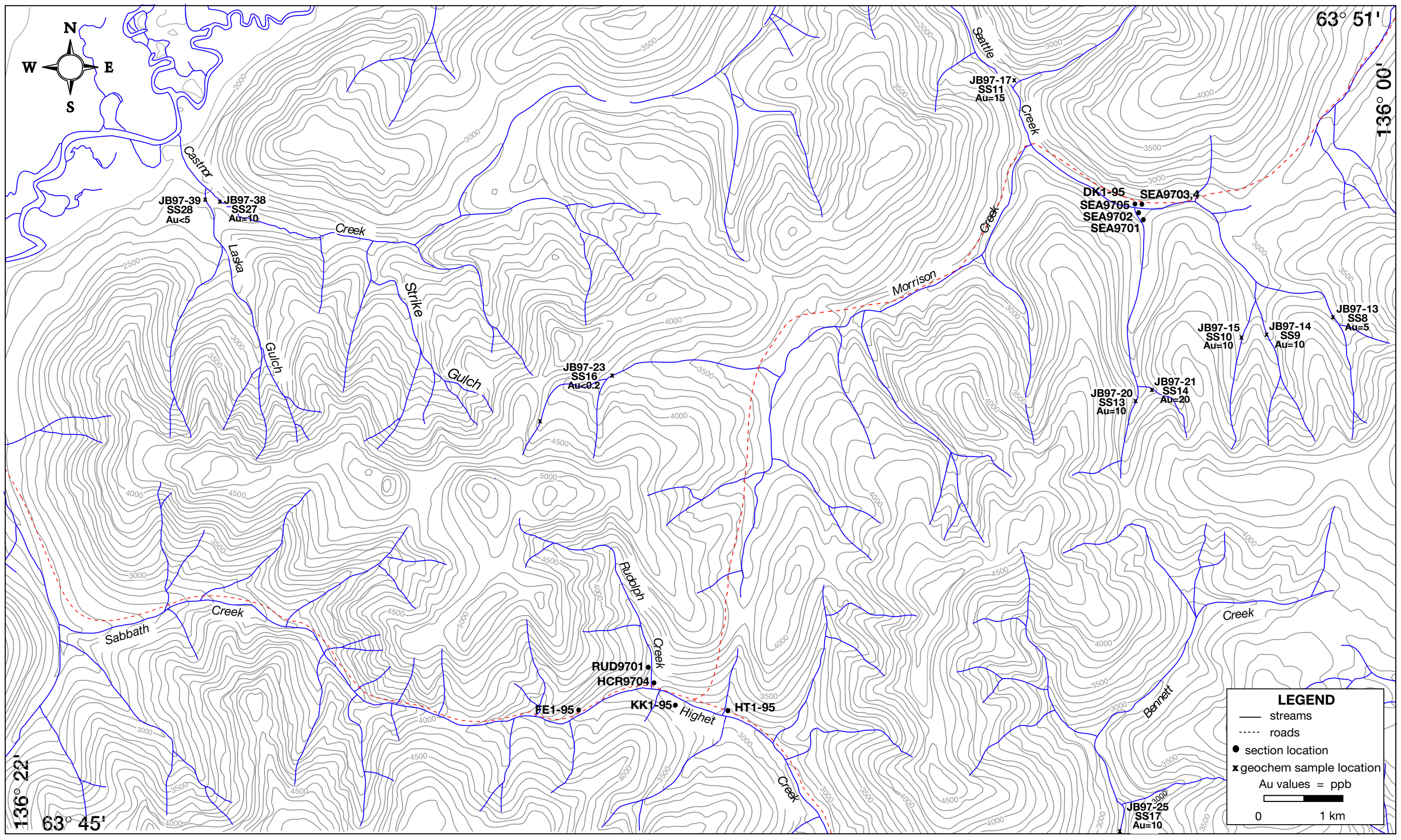


Figure 39. *Highet Creek and Seattle Creek showing locations of measured sections.*

slopes of the valley. Late or post-Reid downcutting and interglacial sedimentation have since emplaced younger sediments within the glacial maximum fill. Whether Bennett Creek and Roaring Fork Creek, the other two main tributaries to Minto Creek, have a similar stratigraphy is unknown. Both of these drainages have steeper slopes that appear to be void of thick glacial deposits. The lower reaches of Roaring Fork Creek have actually become incised due to the overdeepening of Minto Creek by the McConnell ice lobe.

Sedimentology

Introduction

Thirty sections were examined in detail in the Highet Creek and Minto Creek area between 1995 and 1998. Sections were located at active mining cuts, natural and road exposures and stream cutbanks. Figures 39 and 40 show the location of the sections; these are summarized in Appendix 1c.

Dominant facies and interpreted environments of deposition

Highet and Minto creeks are completely outside of the McConnell ice limit but were ice-covered during the Reid glaciation, which deposited high level terraces above Minto Creek and in the lower reaches of Highet Creek as glaciofluvial complexes. These complexes include sediments of Facies 1 (massive boulder-cobble diamict – Dmm), Facies 3 (weakly stratified/imbricated boulder gravel – Gms), and Facies 11 (laminated and rippled sand, silt and mud - Flr). Holocene valley fill gravels occur mainly in the valley centres of Highet and Minto creeks, and dominant sediments include Facies 5 (stratified/cross-stratified gravel - Ghpt), Facies 6 (massive to stratified pebbly fine sand – Sh), Facies 7 (planar tabular cross-bedded pebbly fine sand – Sp) and Facies 9 (ripple cross-bedded sand – Sr). Low-level late McConnell outwash terraces along Minto Creek contain well-stratified gravel of Facies 5 (Ghpt).

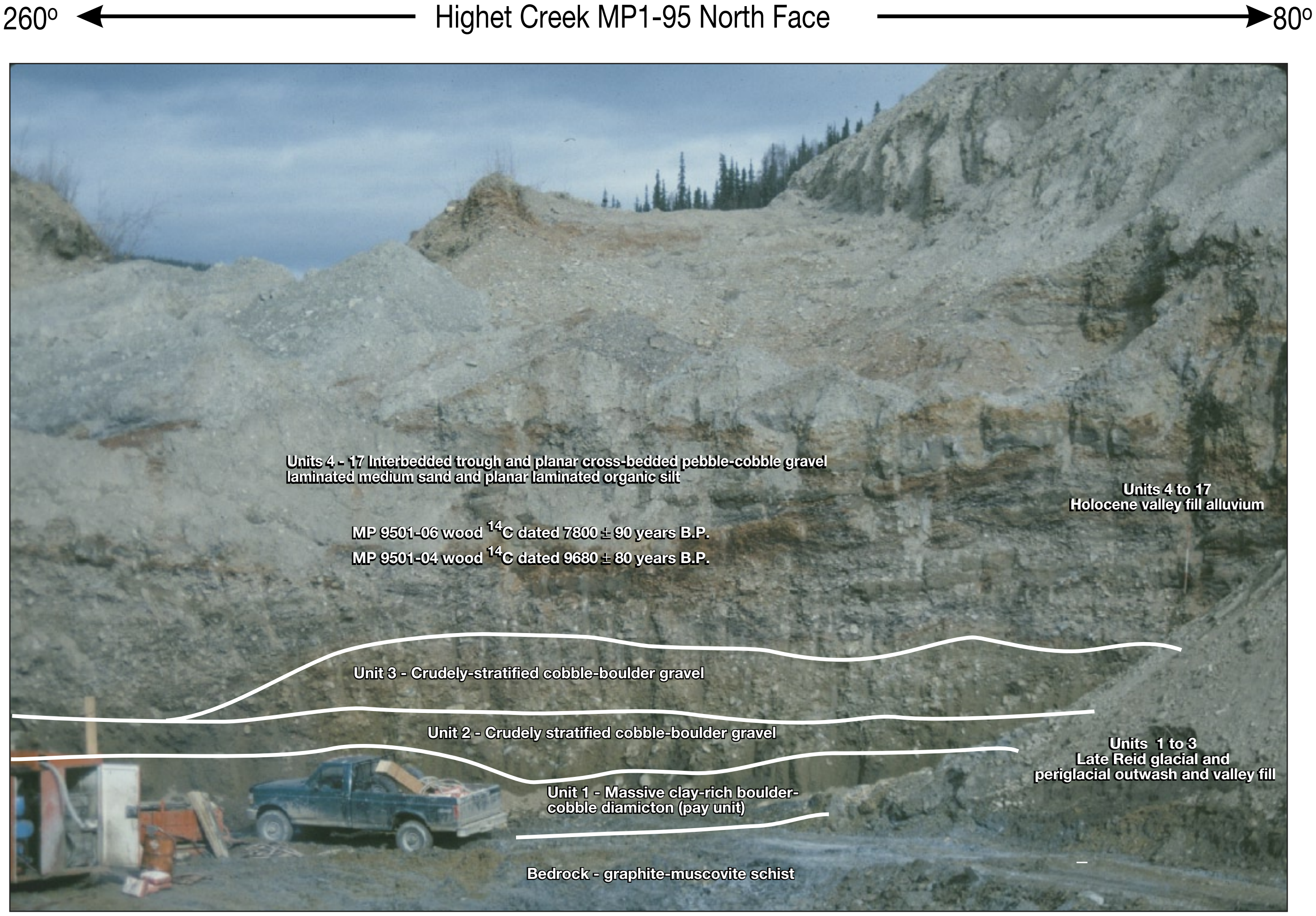


Figure 41. *Panel diagram showing typical stratigraphy on Highet Creek. Reid glacial till, outwash and periglacial sediments are unconformably overlain by Holocene creek gravel.*

Stratigraphy

Representative stratigraphic sections

Figure 41 is a panel diagram demonstrating typical stratigraphy in the Highet Creek/Minto Creek area (measured section MP1-95). Additional sections are located in Appendix 4.

Lithostratigraphic assemblages

Eight lithostratigraphic assemblages are found in the Highet Creek/Minto Creek area; a representation of these is shown in Figures 42 and 43, which are schematic cross-valley profiles.

They are as follows:

- Assemblage 1 – Pre-Reid interglacial sediments;
- Assemblage 2 – Early to Middle Reid glacial, periglacial and glaciolacustrine sediments;
- Assemblage 3 – Late Reid glacial and periglacial sediments;
- Assemblage 4 – Post-Reid (Koy-Yukon) interglacial alluvium;
- Assemblage 5 – Early and Middle McConnell periglacial sediments;
- Assemblage 6 – McConnell glacial, glaciofluvial and glaciolacustrine sediments;
- Assemblage 7 – Late McConnell periglacial sediments; and
- Assemblage 8 – Holocene alluvial sediments.

Stratigraphic relationships

Lithostratigraphic Assemblage 1 – Pre-Reid interglacial sediments

This assemblage occurs in the lower reaches of Highet Creek as crudely stratified cobble gravel where it is unconformably overlain by Early to Middle Reid glacial and glaciolacustrine sediments of Assemblage 2 (measured sections HT2-95, HT3-95).

Lithostratigraphic Assemblage 2 – Early and Middle Reid glaciofluvial, glacial and periglacial sediments

This assemblage was found in several exposures that were studied on Minto and Highet creeks, which included measured sections HT2-95, HT3-95, MIC9701, MIC9702, MIC9703, MIC9707 and MIC9711. Glaciofluvial outwash and glaciolacustrine silt capped by glacial till form high-level terraces along Minto Creek and the lower reaches of Highet Creek.

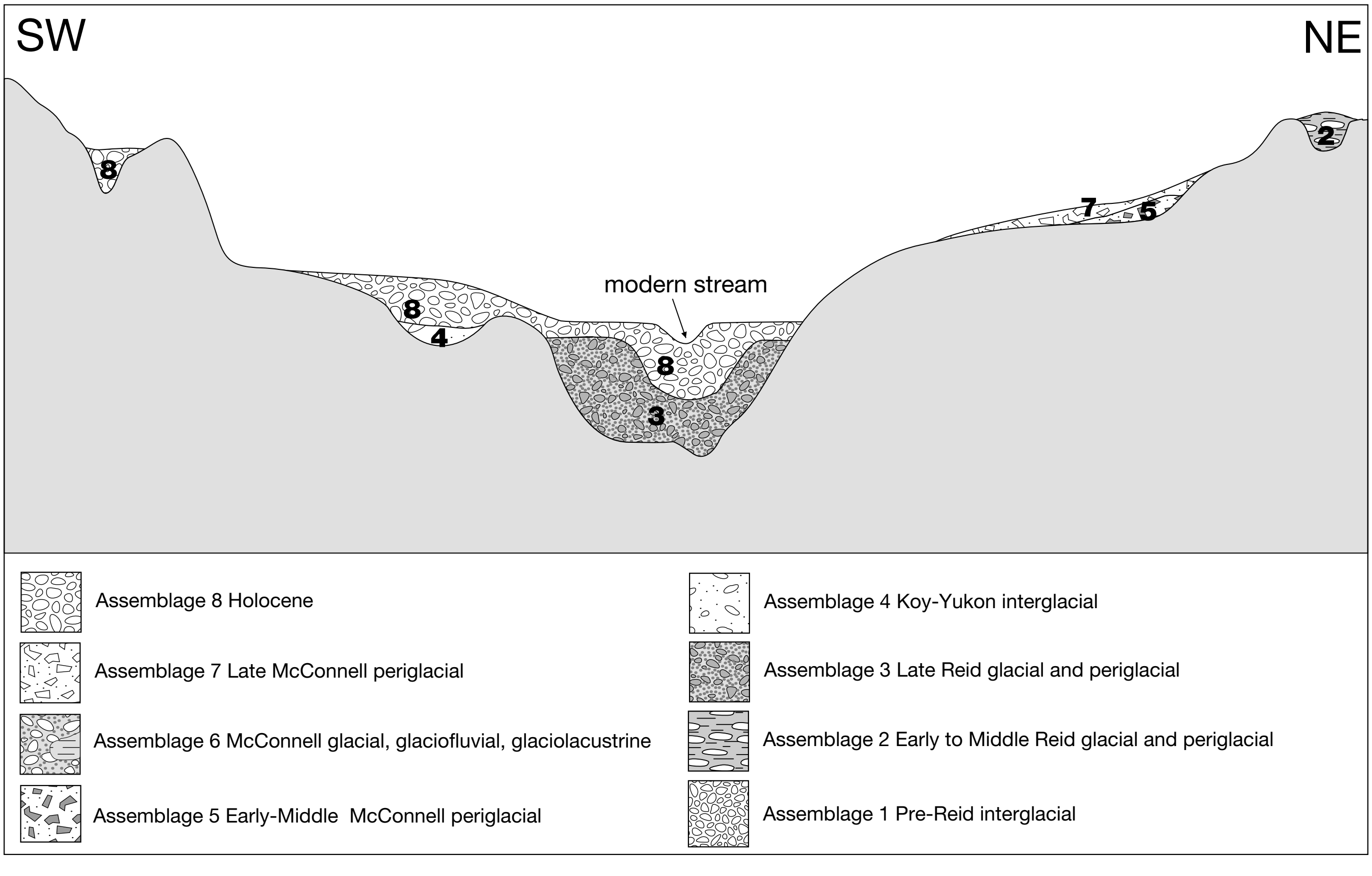


Figure 42. *Schematic cross-valley profile of Highet Creek, illustrating relationships between lithostratigraphic assemblages.*

Lithostratigraphic Assemblage 3 – Late Reid glaciofluvial, glacial and periglacial sediments

Diamict of Assemblage 3 lines the valley floor in both Highet and Minto creeks, and appears to form a mid-level terrace on the valley side of Minto Creek. This assemblage is incised into sediments of Assemblage 2 in the main valley of Minto Creek, as it commonly occurs in a low stratigraphic position near bedrock. These terraces likely formed during the late or retreat phase of the Reid glaciation.

Lithostratigraphic Assemblage 4 – Post-Reid (Koy-Yukon) interglacial alluvium

This assemblage was found on the right limit of Highet Creek where it formed an alluvial terrace (measured section KK1-95), which is overlain by colluvium of Assemblage 8. On Minto Creek, this assemblage is represented by a Diversion Creek paleosol that developed on sediments of Assemblage 3 and buried by periglacial sediments of Assemblage 5 (measured section MIC9710 – Fig. 40).

Lithostratigraphic Assemblage 5 – Early and Middle McConnell periglacial sediments

These periglacial sediments formed during the McConnell glaciation but lie outside the ice limits and glaciofluvial meltwater flow. On Highet Creek, periglacial sedimentation was noted in measured section HT1-95. In Minto Creek, periglacial debris flows and alluvial fans have resedimented Reid glacial sediments of Assemblage 2 and preserved a Diversion Creek paleosol (measured section MIC9710).

Lithostratigraphic Assemblage 6 – McConnell glacial sediments

This assemblage is found in the valley of Minto Creek as low-level gravel terraces, which incise into Reid glacial sediments and locally lie directly in contact with bedrock.

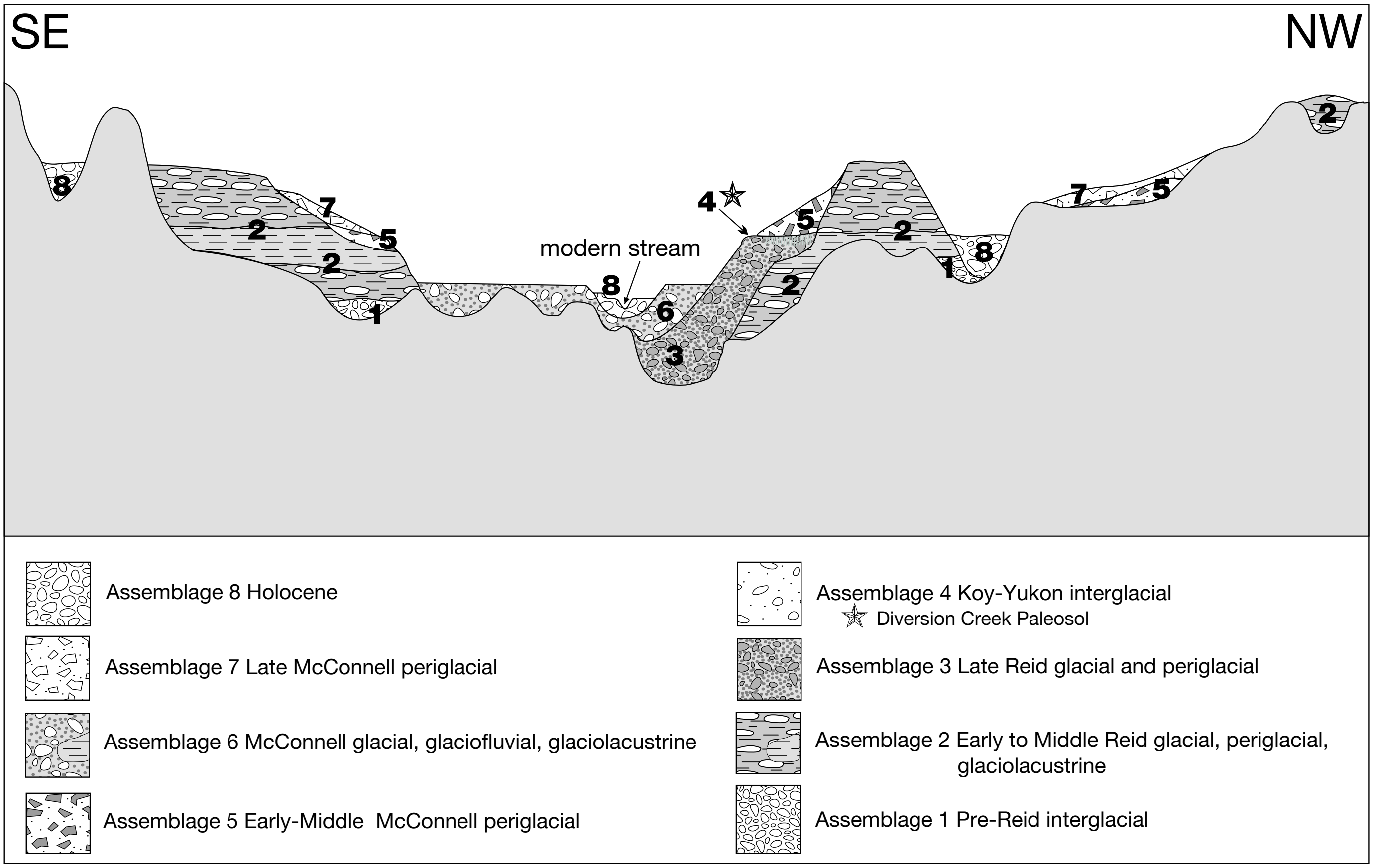


***Figure 43**. Schematic cross-valley profile of Minto Creek, illustrating relationships between lithostratigraphic assemblages.*

Table 8. *Radiocarbon dates for Holocene sediments, Highet/Minto creeks.*

Unit number	Sample number	Location	^{14}C Date (type)	Comments
MP1-95-4	Beta-86848	Highet Creek	9680 ± 80 (conventional)	Unit 4a wood
MP1-95-4	Beta-86849	Highet Creek	7800 ± 90 (conventional)	Unit 4b wood
FE1-95-2	Beta-86850	Highet Creek	6190 ± 90 (conventional)	Unit 2 wood

Lithostratigraphic Assemblage 7 – Late McConnell periglacial sediments

This assemblage was deposited continuously throughout the McConnell glaciation and lies conformably in contact with periglacial sediments of Assemblage 5.

Lithostratigraphic Assemblage 8 – Holocene alluvial, colluvial and eolian sediments

In Minto Creek, Holocene stream gravels lie adjacent to the modern stream. In Highet Creek, Holocene stream gravels (Table 8) of this assemblage incise into sediments of Assemblage 3, and form gulch gravels in higher reaches. Modern gulch gravels have also incised into sediments of Assemblage 1 and 2 in the lower reaches of Highet Creek.

Paleogeographic history

During the Reid and pre-Reid glaciations the Cordilleran ice sheet inundated the Minto area. The Reid limit reaches approximately 4200 ft (1280 m) on Scheelite Dome, just north of Minto Creek. The passage of ice through the area was from the Mayo River valley, up Minto Creek, and down the Moose and Bear Creek drainages. Ice entering Minto Creek was probably part of the valley glacier flowing south from Haldane Creek valley. Its flow pattern up the Minto drainage was likely assisted by the compressive forces of three lobes coming together in the Mayo River valley at the mouth of Minto Creek. They consisted of the Mayo River lobe, Janet Lake lobe, and the Haldane lobe. Because the Mayo River lobe and the Janet Lake lobe were advancing from east to west, and the Haldane lobe was flowing south, it was likely the Haldane lobe that was pushed west into the Minto Creek drainage. The glacial history of the Reid advance into the Minto valley is recorded in a section exposed at the mouth of Highet Creek (HT2-95, HT3-95). A proglacial lake developed in Highet Creek prior to the ice thickening and advancing over the glaciolacustrine sediments. The proglacial lake appears to have migrated up the Highet Creek drainage as the ice continued to thicken. This would have provided a mechanism to protect the pre-existing placers from glacial erosion.

Ice in Highet Creek eventually flowed into the Morrison Creek drainage where it merged with McQuesten valley ice. During deglaciation of Minto Creek, ice stagnated in the valley leaving thick blankets of sediment in the valley bottom and on the lower slopes. Meltwater channels are clearly evident on the benches between Highet Creek and Minto Lake. As the ice melted back towards the Mayo River valley, outwash eroded a channel through the thick fill in the valley bottom. This is most evident between Highet Creek and Minto Lake.

During the McConnell glaciation, ice terminated at the present day mouth of Minto Creek. Outwash flowed up the drainage and through the Minto Lake area to Moose Creek, further deepening the canyon cut through the Reid sediments and bedrock. The modern drainage has since downcut through the McConnell outwash surface leaving three distinct terraces in the bottom of the canyon.

Placer geomorphology

Highet Creek has historically been the main gold-producing creek in the Minto Creek drainage and continued to have active placer mining in 1999. One of the reasons for the richness of Highet Creek placer deposits is that interglacial alluvial deposits (Lithostratigraphic Assemblage 4), which had formed prior to the Reid glaciation, were protected from the advancing Reid ice sheet by a blanket of proglacial lake sediments. During the height of the Reid glaciation, the ice sheet advanced up Highet Creek but was unable to scour the buried interglacial sediments. With the retreat of the Reid glaciation and the initiation of downcutting in Minto Creek valley. a period of incision also began in Highet Creek. Throughout Highet Creek the sediment cover was eroded and the paleo-placers became reworked into the interglacial streambed. During the McConnell glaciation the base level of Highet Creek was affected again when erosive meltwater cut through Minto Creek valley. This caused a slight drop in base level at the mouth of Highet Creek and the stream began to downcut into the interglacial fill. When this occurred in the upper part of Highet Creek, where the interglacial fill was shallow, there was a complete reworking of the gravel and placers into the modern Holocene deposits. The only remnant of the interglacial streambed was a right limit bench (Fig. 44). In the lower part of the drainage, post-McConnell stream incision cut into the interglacial sediments but did not reach bedrock. Therefore, the interglacial placers on bedrock remained intact near the bottom end of the drainage. Early mining activity was concentrated in gulch and bench deposits on the upper reaches of the drainage, however, in modern times placer mining has exposed the buried interglacial deposits in the lower reaches of Highet Creek.

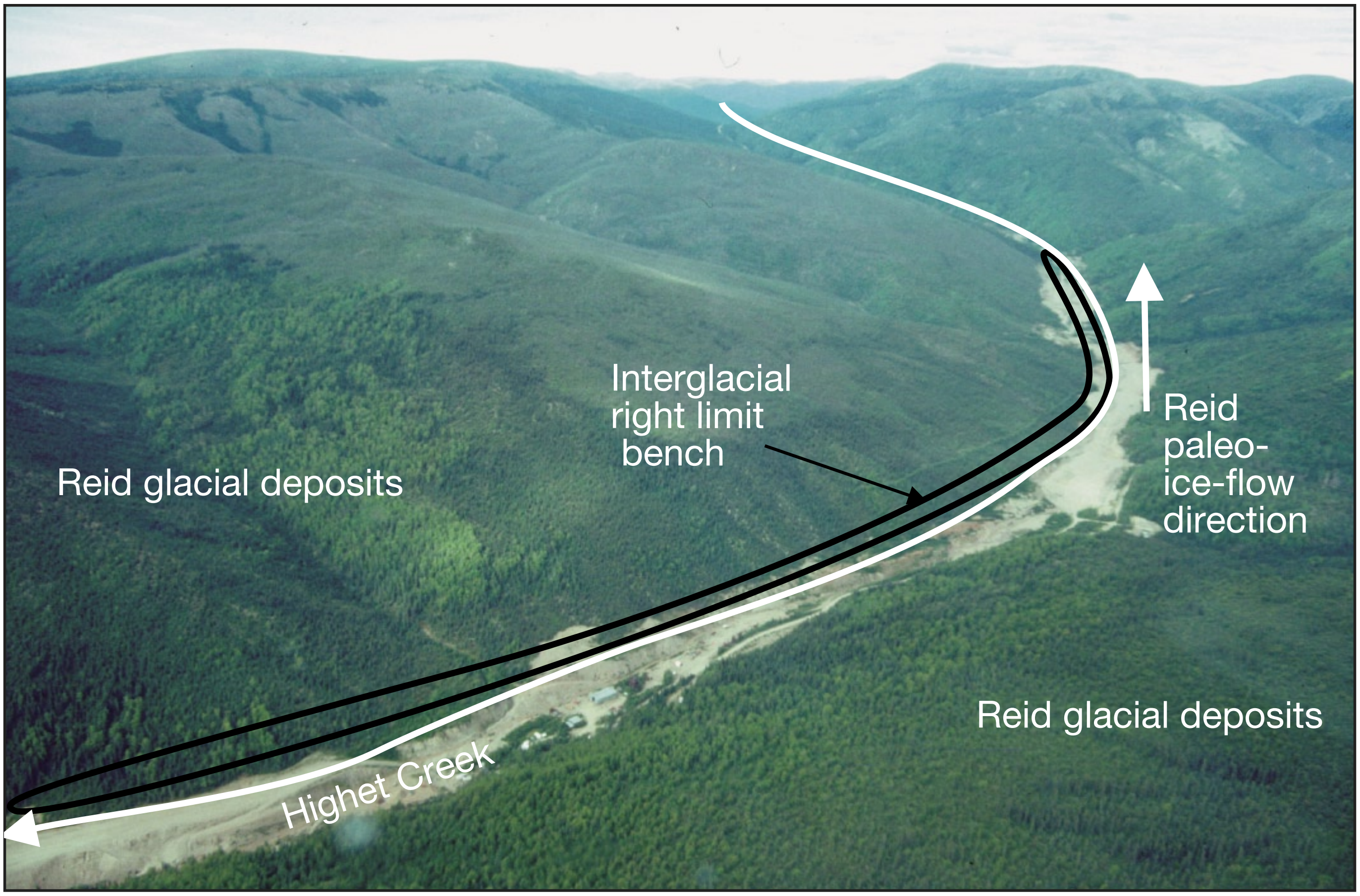


Figure 44. *Highet Creek looking upstream. Reid glacial ice flowed up the valley, blocking the drainage and preserving some interglacial placer deposits beneath glacial lake sediments. A pre-McConnell age interglacial right-limit bench was also preserved, which was the focus of historical placer mining.*

HAGGART CREEK/DUBLIN GULCH

Introduction

Coarse gold was first found on Haggart Creek in 1895, and significant mining activity began on Dublin Gulch in 1899. A number of operators mined there including Fred Taylor who acquired the ground in 1937. In 1971 the property was sold to Dublin Gulch Mining Ltd. (R. Holway and D. Duensing), who leased it to Canada Tungsten in 1978. An unknown quantity of tungsten (scheelite) and gold was recovered in subsequent years by Canada Tungsten. The property was returned to Dublin Gulch Mining in 1987. Mining since that time has concentrated mainly on the left and right limits of Haggart Creek, until 1998 when operations ceased. The total recorded placer gold production from 1895 to 1998 for Haggart Creek and Dublin Gulch is 77,751 crude ounces (2 418 300 g).

Location and access

Haggart Creek is one of the principal tributaries of the South McQuesten River and lies within the NTS map sheets 106D/4, 105M/13 and 115P/16 (Figs. 2 and 45). Haggart Creek drainage basin is located approximately 85 km north of Mayo; access to the area is by the Silver Trail highway and the South McQuesten road. Haggart Creek is over 33 km long and flows generally south-southwest into the South McQuesten River. Dublin Gulch is a left-limit tributary to Haggart Creek and lies within NTS map sheet 106D/4. Right-limit tributaries to Haggart Creek include Gill Gulch and Fisher Gulch, which also lie within NTS map sheet 106D/4.

Local geology

Within the Haggart Creek map area, moderately to highly strained sedimentary rocks are exposed in two northward-overlapping thrust sheets, known as the Robert

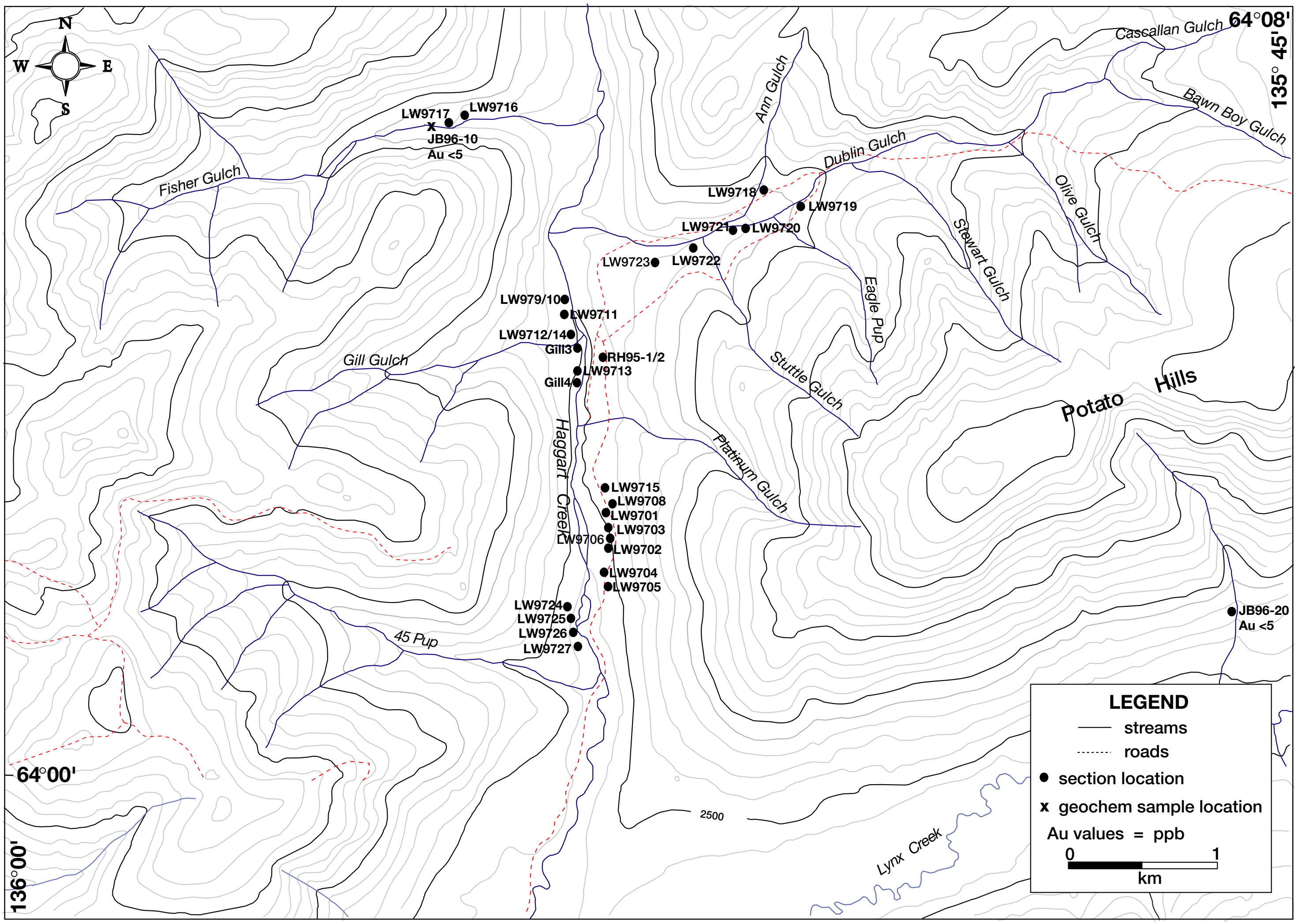


***Figure 45.** Location of measured sections on Haggart Creek and Dublin Gulch.*

Service and the Tombstone thrust sheets (Fig. 4, Roots, 1997).

The Robert Service is the more southerly of the two thrust sheets. The oldest rocks exposed within the Robert Service Thrust Sheet are Late Proterozoic to Early Cambrian Hyland Group metasedimentary rocks (Roots, 1997). The Hyland Group is divided into two formations, the Yusezyu and the Narchilla. The older Yusezyu formation comprises predominantly phyllite, metasiltstone, medium- to coarse-grained metasandstone, metaconglomerate, and sandy marble, whereas the Narchilla formation includes quartzofeldspathic sandstone, maroon and green argillite, and grey, weathered marble (Green, 1971; Murphy and Héon, 1994). Overlying the Hyland Group rocks is a Cambrian to Middle Devonian succession, which includes the Gull Lake (green and dark brown siltstone), Rabbitkettle (thin, discontinuous white limestone), Duo Lakes (dark siltstone, argillite and chert) and Steel (green cherty argillite) formations. Together, the Hyland Group rocks and overlying formations form a component of the regional Selwyn Basin and are unconformably overlain by Upper Devonian Earn Group argillite, chert and chert-pebble conglomerate (Roots, 1997; Murphy and Héon, 1994).

The Tombstone Thrust Sheet lies to the northeast of the Robert Service Thrust Sheet. This sheet is comprised of highly strained Earn Group carbonaceous phyllite and metaconglomerate, overlain by Mississippian Keno Hill Quartzite (Roots, 1997; Green, 1971).

The Potato Hills stock outcrops above Haggart Creek, and consists of a medium-grained phaneritic granodiorite body dated at 92.8 ± 0.5 Ma (Smit et al., 1995). The stock has a width of up to 2 km and a length of 5.5 km and is elongated in the direction 70° (Smit et al., 1995). Developed around the stock, is a contact aureole of andalusite and biotite hornfels (Smit et al., 1995; Hitchins and Orssich, 1995). The Dublin Gulch deposit consists of gold-bearing sheeted veins and stockwork within the Potato Hills stock. Here an inferred and potential resource of 50.3 Mt at 0.93 g/t Au has been calculated (Brown et al., 2002). The Ray Gulch tungsten skarn deposit occurs on the eastern margin of the stock and contains drill-indicated and inferred reserves of 5.4 Mt at 0.82% WO_3 (Brown et al., 2002).

Other intrusive bodies occur west of Haggart Creek, however these bodies are much smaller in area and are only weakly mineralized. These bodies are predominantly dykes and sills of granodiorite to quartz monzonite composition; no quartz-gold veins were observed in any of the intrusions (Hitchins and Orssich, 1995). A more detailed account of the placer geology is given by Weston (1999).

Physiography

Haggart Creek lies in an area that is part of the Stewart Plateau, northeast of the Tintina Trench. It is proximal to the southern foothills of the Ogilvie Mountains. Elevations range from 2500 ft a.s.l. (760 m) in valley bottoms to approximately 5000 ft a.s.l. (1500 m) on local uplands. Haggart Dome, Lynx Dome, and Potato Hills are all broad rolling hills, which are above treeline (Figs. 2 and 45).

The major drainages in the area include Haggart Creek and Lynx Creek. Haggart Creek flows generally south-southwest into the South McQuesten River, while Lynx Creek flows southwest into Haggart Creek. Gill Gulch and Fisher Gulch are right limit tributaries to Haggart Creek while Dublin Gulch is an important left-limit tributary.

The lower reaches and the upper reaches of Haggart Creek are physiographically distinct. Lower Haggart Creek is morphologically an extension of the Lynx Creek valley and these creeks both occupy a very large, broad, u-shaped glacial valley. Upper Haggart Creek, having been less extensively glaciated, has a much narrower u-shaped glacial valley. Tributaries such as Dublin Gulch, Gill Gulch and Fisher Gulch are all transverse to the main regional ice flow and consequently these tributary valleys remain narrow and v-shaped with steep valley sides.

Surficial geology

The study area is characterized by colluvium-covered uplands, with minor exposed bedrock on plateau summits, ridges, and locally in gulches. A colluviated Reid till veneer was mapped between 2800 and 3600 ft (850-1100 m) on the left limit of Haggart Creek near the mouth of Lynx Creek (Bond, 1997b). Remnant Reid terraces are present at the confluence of Haggart and Lynx creeks and can be traced into upper Haggart Creek along the left limit. This terrace is exposed as a till blanket in a mining cut near the mouth of Dublin Gulch (measured section LW9722). The Reid terrace can be traced down the right limit of lower Haggart Creek to the mouth of Secret Creek. McConnell periglacial fans originate from all major tributaries in Haggart Creek. In Lynx Creek, periglacial fans coalesce to form an apron of sediment on the flanks of the valley. Colluvial aprons are present between the tributary fans in Haggart and Lynx creek valleys. Modern alluvium lines the floodplains of major streams.

Sedimentology

Introduction

Thirty-one sections were examined in detail in the Haggart Creek area between 1995 and 1997. Sections were located at active mining cuts, natural and road exposures and stream cutbanks. Figure 45 shows the location of the sections; these are summarized in Appendix 1d.

Dominant facies and interpreted environments of deposition

Haggart Creek and Dublin Gulch lie within the limit of the Reid glaciation but are outside of the limit of the McConnell glaciation. Landforms in the area include a remnant glaciofluvial terrace, alluvial fans and colluvial slope deposits. Several of the alluvial fans are dominated by sediments of Facies 11 (laminated and rippled sand, silt and mud - Flr) and Facies 1 (massive boulder-cobble diamict – Dmm). On bedrock along Haggart Creek, Facies 1 and Facies 2 (weakly stratified boulder-cobble diamict) are gold-bearing and are interpreted to be periglacial debris flows.

Stratigraphy

Representative stratigraphic sections

Figure 46 is a panel diagram demonstrating typical stratigraphy in the Haggart Creek area. Additional sections are located in Appendix 4.

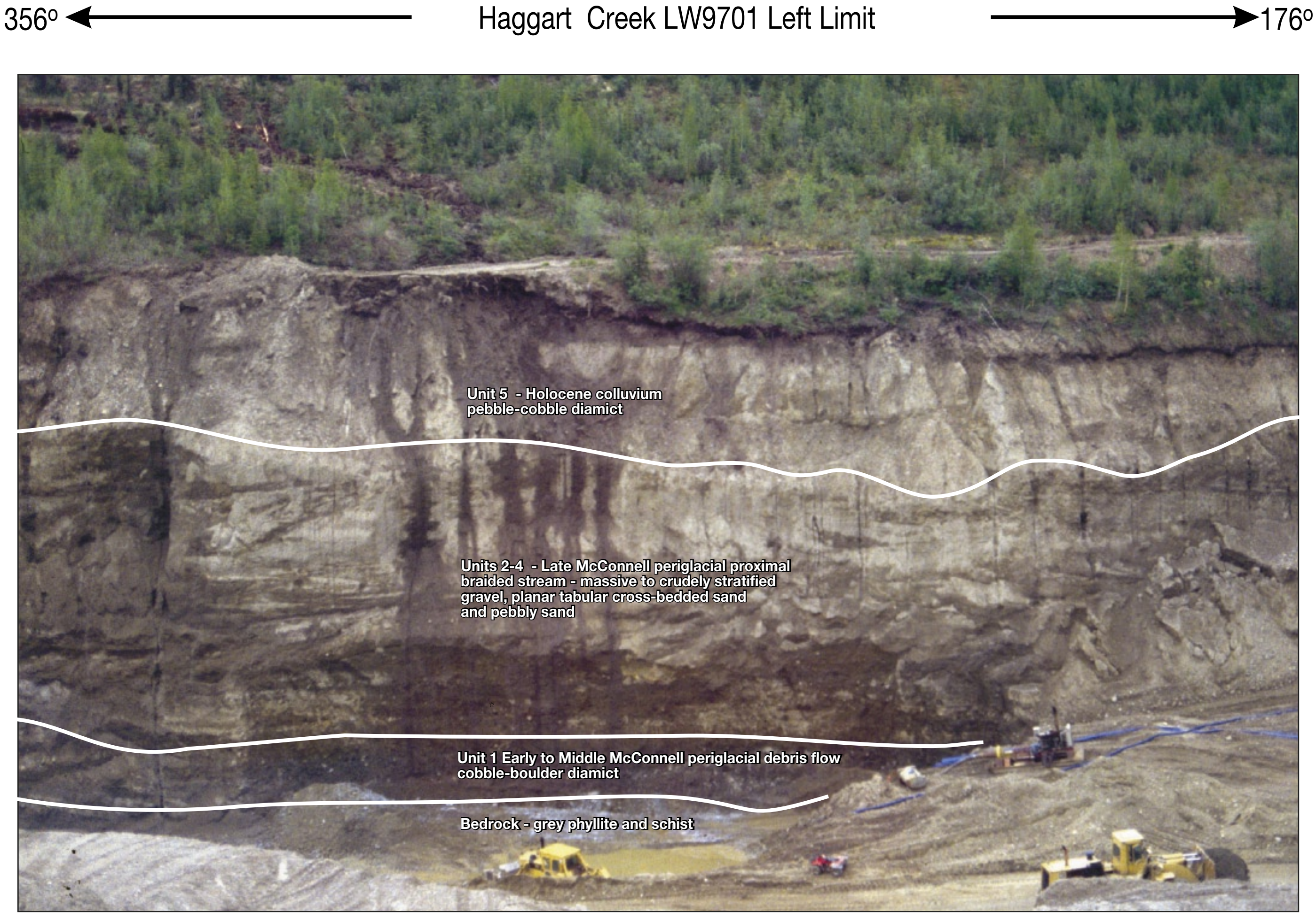


Figure 46. *Measured section LW9701 illustrates typical stratigraphy on the left limit of Haggart Creek. Gravelly diamict of an early to middle McConnell periglacial debris flow is overlain by late McConnell periglacial proximal braided stream gravel and sand; and Holocene colluvium.*

Lithostratigraphic assemblages

Six lithostratigraphic assemblages are found in the Haggart Creek area; a representation of these is shown in Figure 47, which is a schematic cross-valley profile.

They are as follows:

- Assemblage 1 – Pre-Reid interglacial sediments
- Assemblage 2 – Early and Middle Reid glaciofluvial, glacial and periglacial sediments;
- Assemblage 3 – Late Reid glacial and periglacial sediments;
- Assemblage 5 – Early and Middle McConnell periglacial sediments;
- Assemblage 7 – Late McConnell periglacial sediments; and
- Assemblage 8 – Holocene alluvial sediments.

Stratigraphic relationships

Lithostratigraphic Assemblage 1 – Pre-Reid interglacial sediments

Assemblage 1 consists of pre-Reid interglacial fluvial, gulch and alluvial fan sediments that have been variably reworked and/or buried. In Dublin Gulch, a debris flow was found beneath Reid till on measured section LW9722. Reworked organic material from this unit was ^{14}C dated at >37 740 B.P. (Beta 111603, Table 9). This assemblage also occurred in Haggart Creek valley in measured section RH95-2.

Lithostratigraphic Assemblage 2 – Early and Middle Reid glaciofluvial, glacial and periglacial sediments

This assemblage was found on Dublin Gulch on measured section LW9722, where Reid till capped a pre-Reid debris flow. On Haggart Creek in measured section

Table 9. *Radiocarbon dates for pre-Reid sediments, Haggart Creek/Dublin Gulch area.*

Unit number	Sample number	Location	^{14}C Date (type)	Comments
LW97-22-U1	Beta-111603	Dublin Gulch	>37 740 (conventional)	organics @top of debris flow in contact w/till

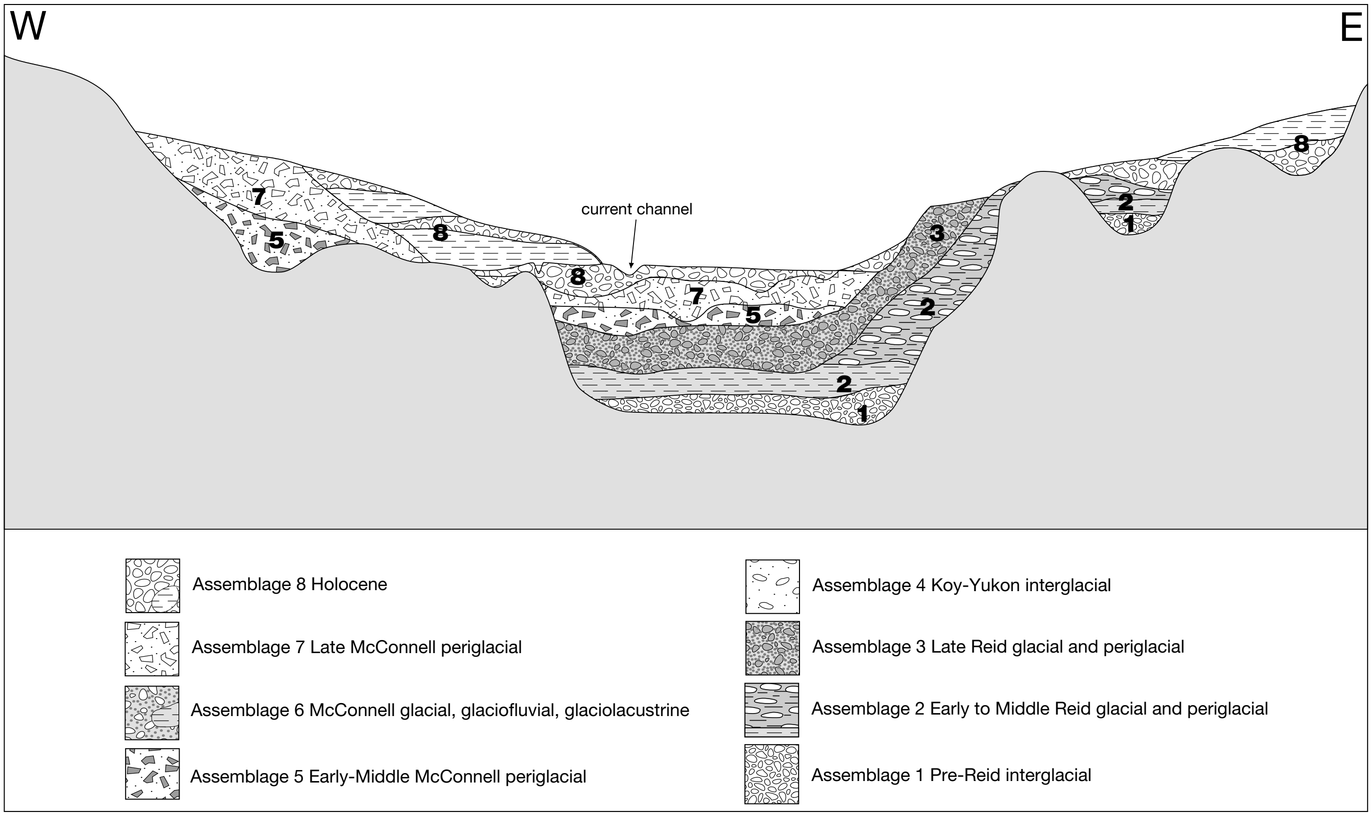


Figure 47. *Schematic cross-valley profile of Haggart Creek and tributaries. Not to scale.*

Table 10. *Radiocarbon dates for Holocene sediments, Haggart Creek/Dublin Gulch area.*

Unit number	Sample number	Location	^{14}C Date (type)	Comments
LW97-05-07/1	Beta-109146	Haggart Creek	8170 ± 80 (conventional)	organics 50 cm from base
LW97-05-07/2	Beta-109147	Haggart Creek	7600 ± 80 (conventional)	organics 50 cm from top
LW97-08-05	Beta-109152	Haggart Creek	7970 ± 60 (conventional)	wood
LW97-26-U1	Beta-111605	Haggart Creek	6040 ± 70 (conventional)	80 cm from top of unit 1
LW97-18-U6	Beta-111602	Dublin Gulch	7430 ± 70 (conventional)	organic silt
LW97-09-02	Beta-109150	Gill Gulch	12310 ± 120 (conventional)	wood
LW97-13-U1	Beta-111604	Gill Gulch	8130 ± 80 (conventional)	organics at base of debris flow
LW9608-0	Beta-102618	Gill Gulch	8230 ± 60 (conventional)	Gill Gulch organics bag

RH95-2, Reid glaciolacustrine silts were observed overlain by diamict interpreted to be till.

Lithostratigraphic Assemblage 3 – Late Reid glaciofluvial, glacial and periglacial sediments

Reid till occurs as remnant terraces on both sides of Haggart Creek (Bond 1997b). It is likely that some of these terraces formed during the retreat (late) phase of the Reid glaciation, depositing glacial, glaciofluvial and periglacial sediments in the valley centre, which were later dissected and reworked by subsequent processes.

Lithostratigraphic Assemblage 5 – Early and Middle McConnell periglacial sediments

Assemblage 5 commonly contains reworked elements of Assemblage 4 (Koy-Yukon interglacial sediments) including organic material; and this is likely the case in Haggart Creek although such an occurrence was not observed in section during this study. Assemblage 5 occurs as periglacial fans on the valley side and as valley fill deposits along the main Haggart Creek valley.

Lithostratigraphic Assemblage 7 – Late McConnell periglacial sediments

McConnell age periglacial alluvial fan sediments were noted along Haggart Creek; these fans were probably deposited continuously throughout the McConnell glaciation, depositing sediments of Assemblage 7 on top of Assemblage 5.

Lithostratigraphic Assemblage 8 – Holocene alluvial, colluvial and eolian sediments

On the right limit of Haggart Creek below Dublin Gulch, Holocene alluvial gravels are found against the bedrock rim. At Gill Gulch, a low terrace of alluvial gravels (paleo-Haggart Creek) is covered by colluvium derived from reworked loess and organics. A sample of wood from this material was ^{14}C dated at 12 310 ± 320a B.P. (Beta 109150, Table 10), which represents the earliest post-McConnell date in central Yukon.

Paleogeographic history

The Reid glaciation was the last glacial episode that left significant surficial deposits in Haggart Creek. Lynx Creek valley acted as a conduit for ice spilling over from the South McQuesten River valley at its headwaters and at the headwaters above Skate Creek. Ice in Lynx Creek reached elevations of approximately 3700 ft (1100 m) and upon intersecting upper Haggart Creek valley spilled northwards against the local drainage. The glacier likely had little scouring energy in the valley because upper Haggart Creek was perpendicular to regional ice-flow. In addition, since the glacier was advancing uphill against the drainage, a glacial lake likely formed at the toe of the glacier, which provided a bed of lake sediment for the glacier to advance upon. This would have protected pre-existing placers from glacial scouring or reworking by meltwater. Reid ice glaciated the length of upper Haggart Creek valley and breached the pass into the East McQuesten River drainage (Fig. 48). In the vicinity of the pass, Haggart Creek ice would have merged with ice impinging up Christie Creek from the east McQuesten River valley. In contrast, Lynx Creek and lower Haggart Creek were aligned with the regional ice-flow patterns of the Reid glaciation. As a result, glacial flow was more rapid and erosion of the valley sides would have been significant. Reid ice also advanced up Swede Creek and breached the divide with Red Creek.

Placer geomorphology

The placer geology of upper Haggart Creek and Dublin Gulch reflects the process of late Pleistocene interglacial and glacial episodes. Following the Reid glaciation, upper Haggart Creek contained a significant amount of glacial fill, which covered pre-Reid interglacial placers (Fig. 49). The beginning of the post-Reid interglacial period (Koy-Yukon interglacial) marked a period of downcutting into the Reid sediments. The downcutting was extensive enough that it intersected the pre-Reid interglacial deposits and continued into bedrock.

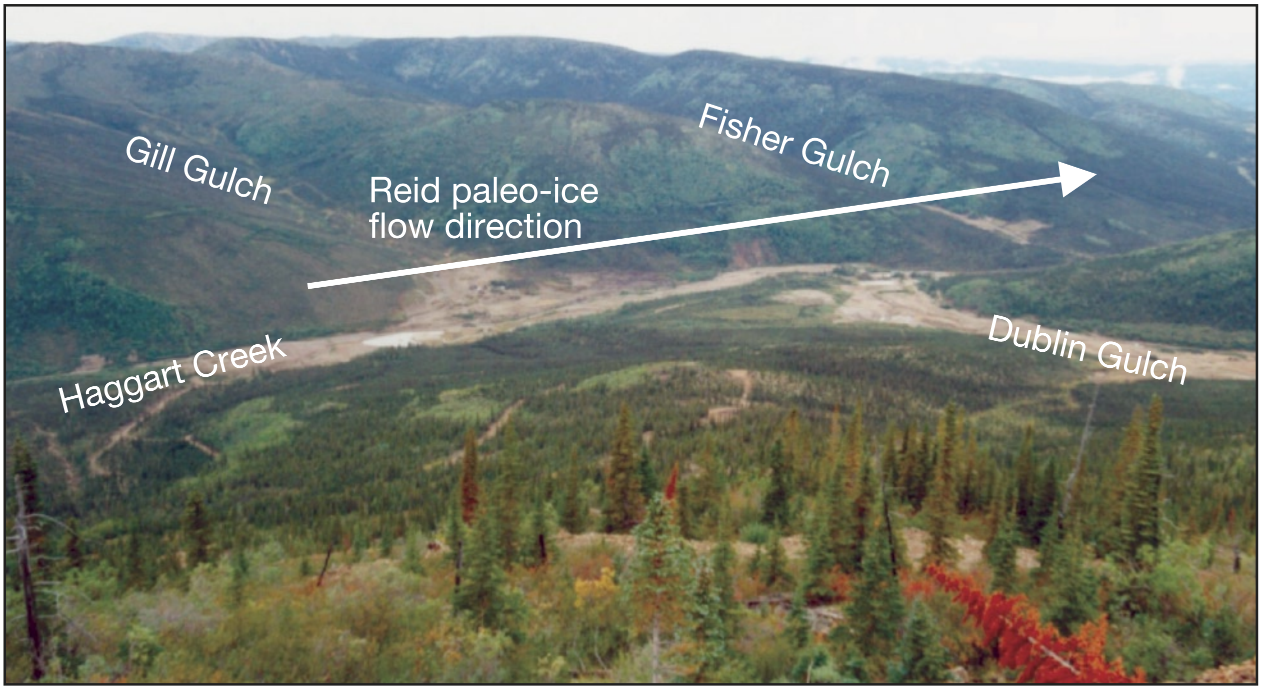


Figure 48. *View west towards Gill Gulch and Dublin Gulch at Haggart Creek. Reid ice moved though the valley from left to right, but was confined by the valley walls.*

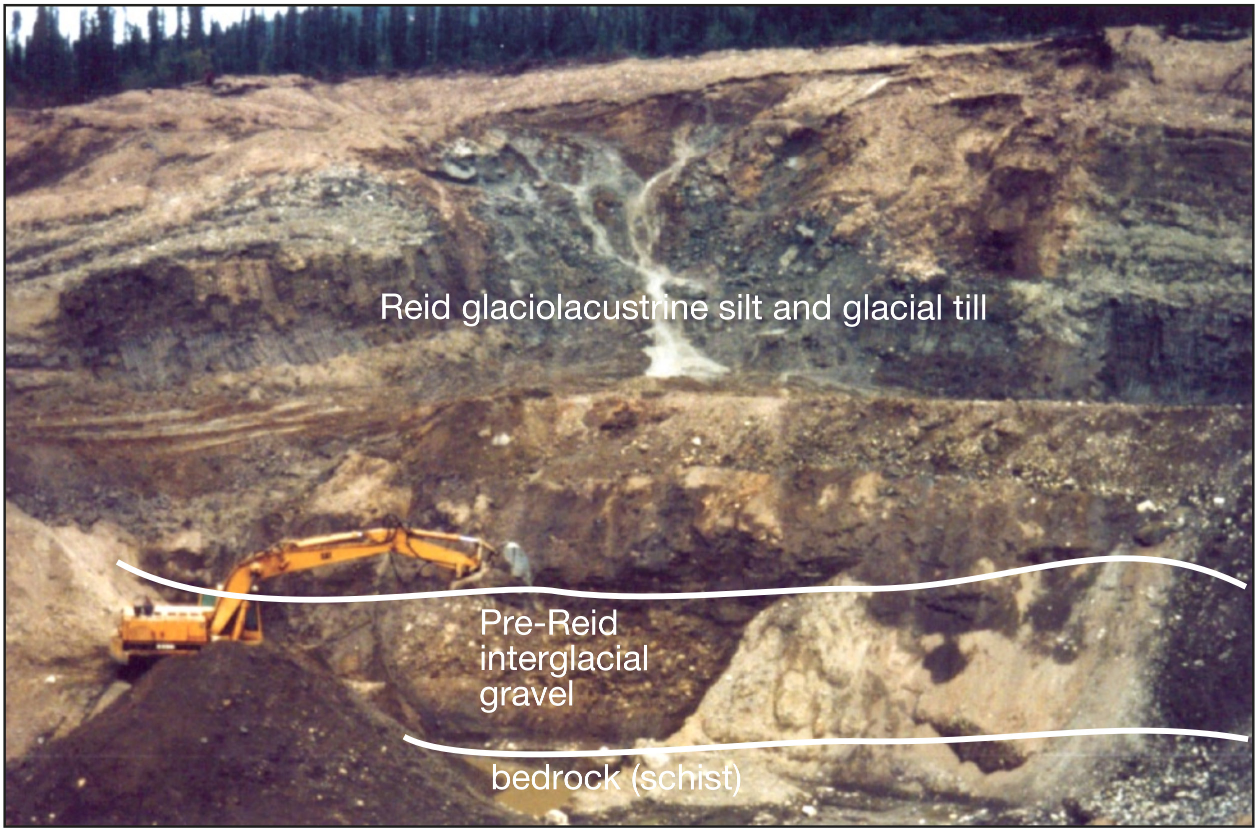


Figure 49. *Placer mining in 1995 on the left limit of Haggart Creek exposed gold-bearing pre-Reid interglacial gravels beneath Reid glaciolacustrine silt and glacial till, in measured section RH95-2.*

Thus, pre-existing placers became part of the active stream channel during the last interglacial period. During the McConnell glaciation, a period of cold, harsh weathering conditions began, which initiated a period of periglacial fan sedimentation. Periglacial fans developed on the tributaries to upper Haggart Creek and subsequently buried the placer-gold bearing interglacial floodplain. By the end of the McConnell glaciation, periglacial fans covered a considerable amount of the floodplain in the valley. During the late McConnell and early Holocene, placer deposits formed on low terraces along Haggart Creek. Periglacial fan sedimentation on tributaries continued, which both controlled the course of Haggart Creek and buried previously-formed placer deposits. Early miners found the Holocene placers relatively accessible, but as mining progressed and these deposits were depleted, exploration focused on the placers buried along the margins of the valley. In recent years, most placers being mined on Haggart Creek have been early Holocene Haggart Creek deposits that were buried and preserved under Middle Holocene periglacial fans.

SOUTH MCQUESTEN/SEATTLE CREEK

Introduction

Seattle Creek and its tributary Morrison Creek have seen intermittent mining activity since the Discovery claim was staked in 1915. Gold production from both creeks combined is officially recorded as 224 crude ounces (6970 g), based on the limited data provided by Indian and Northern Affairs Canada Mining Recorder royalty records. Dan Klippert and family have mined on Seattle Creek since 1994 (Fig. 50).

Goodman and Rodin creeks have seen little mining activity since the Discovery claim was staked on Rodin Creek in 1908.

Location and access

The South McQuesten drainage basin is on NTS map sheet 115P/16 and includes the right limit tributaries of Goodman, Rodin and Haggart creeks, and the left limit tributaries Johnson, Castnor and Seattle creeks (Figs. 39

Figure 50. *Aerial view of Dan Klippert's mining operation on Seattle Creek in 1997. Gold-bearing gravel was found here beneath a McConnell-age periglacial fan.*

and 51). Access consists of a two-wheel drive summer road which branches from the Silver Trail Highway, 15 km north of the village of Mayo (Fig. 2). A network of four-wheel drive trails connects Johnson, Highet and Seattle creeks with some of their tributaries. Seattle Creek is connected to the South McQuesten road via a four-wheel drive road that branches off near Ross Creek.

Local geology

The Robert Service Thrust Fault crosses the map area at Seattle Creek, where it divides Upper Proterozoic to Lower Cambrian Hyland Group from Mississippian Keno Hill Quartzite and Devono-Mississippian Earn Group (Murphy, 1997). Cretaceous hornblende granodiorite intrudes Hyland Group phyllite on the uplands between Highet Creek and Seattle Creek (Murphy, 1997). The faulted McQuesten Antiform trends northeast through the map area mainly following the valley of the South McQuesten River.

Several mineral deposits are located in the area including the Jaybee and Seattle lead-zinc silver veins (Yukon MINFILE, 1997, 115P 001, 115P 002), the Hawthorne and Bennett gold-stibnite veins (Yukon MINFILE, 1997, 115P 003, 115P 033) and the Scheelite Dome stock, which hosts a gold-tungsten skarn deposit (Yukon MINFILE, 1997, 115P 004).

Physiography

The South McQuesten map area consists of a large incised plateau bounded by broad, u-shaped, glaciated valleys, including the South McQuesten River, which flows from northeast to southwest through the centre of the map area, and the North McQuesten River which joins the South McQuesten River from the north. The Secret/Red creek drainage is an intermediate scale east-trending valley that runs across the north half of the map area (Fig. 2). Uplands north of the South McQuesten River average 3900 ft (1200 m) a.s.l., while uplands south of the South McQuesten River reach 5240 ft (1600 m) a.s.l. The Scheelite Uplands are drained by the deeply-incised valleys of Johnson, Seattle and Castnor creeks to the north and Highet and Bennett creeks to the south.

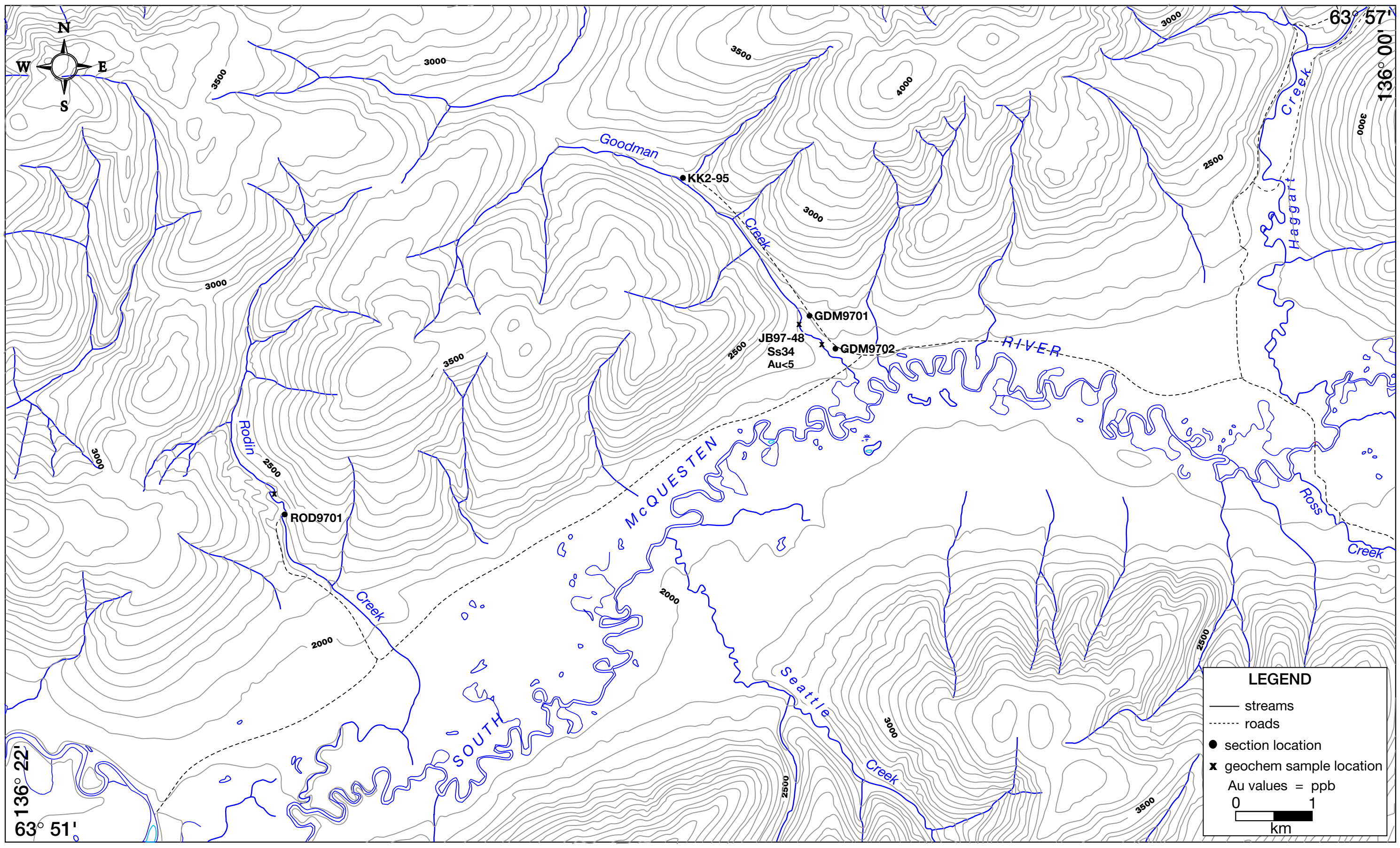


Figure 51. *Location of measured sections on Goodman and Rodin creeks.*

Surficial geology

McConnell and Reid Cordilleran glacial deposits and South McQuesten River alluvial deposits dominate the surficial geology of the South McQuesten River area. McConnell till flanks the lower slopes of Mt. Haldane and the south-facing slope of an unnamed ridge separating Haggart Creek from the South McQuesten River valley. This ridge is informally termed Snowshoe ridge. The limit of McConnell till rises from the valley bottom to 3300 ft (1000 m) onto Snowshoe Ridge east of Shanghai Creek (Bond 1998b). The South McQuesten River valley bottom consists of McConnell glaciofluvial plains and terraces with alluvial deposits in the modern floodplain.

Outside the McConnell limit, the plateau slopes and summits are draped with a veneer of colluviated Reid till. A Reid till blanket is present near the confluence of Haggart Creek valley with the South McQuesten River valley. Aeolian deposits were mapped on the Rodin Creek alluvial fan in South McQuesten River valley. The sand is derived from thick Reid glacio-deltaic deposits in Rodin Creek that have been redeposited into the alluvial fan during the last interglacial and modern interglacial. The dunes may have developed from katabatic winds originating from the McConnell ice sheet.

Sedimentology

Introduction

Ten sections were examined in detail in the South McQuesten drainage between 1995 and 1997. Sections were located at active mining cuts and stream cutbanks. Figures 39 and 51 show the location of the sections; these are summarized in Appendix 1e.

Dominant facies and interpreted environments of deposition

Seattle, Rodin and Goodman creeks are outside of the McConnell glacial limits but within the limits of the Reid glaciation. Dominant landforms in this area are periglacial alluvial fans, which formed during the McConnell glaciation. These alluvial fans include sediments of Facies 1 (massive boulder-cobble diamict – Dmm), Facies 3 (weakly stratified/imbricated boulder gravel – Gms), Facies 5 (stratified/cross-stratified gravel - Ghpt), Facies 6 (massive to stratified pebbly fine sand – Sh), Facies 7 (planar tabular cross-bedded pebbly fine sand – Sp), and Facies 9 (ripple cross-bedded sand – Sr). A McConnell-age braided outwash plain along the south McQuesten River is dominated by Facies 3 (weakly stratified/imbricated boulder gravel – Gms).

Stratigraphy

Representative stratigraphic sections

Figure 52 is a panel diagram demonstrating typical stratigraphy in the South McQuesten/Seattle Creek area. Additional sections are located in Appendix 4.

Lithostratigraphic assemblages

Six lithostratigraphic assemblages are found in the South McQuesten/Seattle Creek area; a representation of these is shown in Figure 53, which is a schematic cross-valley profile.

They are as follows:

- Assemblage 1 – Pre-Reid interglacial sediments
- Assemblage 2 – Early and Middle Reid glaciofluvial, glacial and periglacial sediments;
- Assemblage 3 – Late Reid glacial and periglacial sediments;
- Assemblage 5 – Early and Middle McConnell periglacial sediments;
- Assemblage 7 – Late McConnell periglacial sediments; and
- Assemblage 8 – Holocene alluvial sediments.

Stratigraphic relationships

Lithostratigraphic Assemblage 1 – Pre-Reid interglacial sediments

Assemblage 1 consists of pre-Reid interglacial fluvial, gulch and alluvial fan sediments that have been variably reworked and/or buried. On Seattle Creek, a rusty alluvial gravel, likely of pre-Reid age, underlies the Reid glaciofluvial gravel. This unit has scattered placer gold values within it although it was not found to be economic at that locality.

Lithostratigraphic Assemblage 2 – Early and Middle Reid glaciofluvial, glacial and periglacial sediments

This assemblage occurs as isolated deposits of glaciofluvial gravel including eskers and kame terraces on ridges above 2500 ft (760 m). Remnants of this assemblage also likely occur on the bedrock floor of many of the tributaries to the South McQuesten River.

Lithostratigraphic Assemblage 3 – Late Reid glaciofluvial, glacial and periglacial sediments

Remnant terraces of Reid till occur on several tributary drainages of the South McQuesten, including Seattle Creek. In addition, a boulder-rich glaciofluvial gravel lies beneath McConnell periglacial fan sediments of Assemblage 5 on Seattle Creek and Goodman Creek. Placer gold within this assemblage is likely a result of this glaciofluvial outwash reworking pre-Reid interglacial alluvial gravel of Assemblage 1 from upstream.

Lithostratigraphic Assemblage 5 – Early and Middle McConnell periglacial sediments

Assemblage 5 occurs as periglacial fans on the sides of Seattle, Goodman and Rodin creeks. As Assemblage 5 is the initial stage of fan development, it commonly contains reworked elements of Assemblage 4 (Koy-Yukon interglacial sediments). This may account

Figure 52. *Panel diagram illustrating typical stratigraphy on Seattle Creek, with McConnell periglacial fan sediments overlying Reid glaciofluvial gravel and pre-Reid alluvial gravel. Placer gold is found mainly in the early McConnell periglacial gravelly diamict, although some gold occurs in the Reid glaciofluvial gravel and the pre-Reid alluvial gravel.*

for the occurrence of placer gold within it, especially on Seattle Creek.

Lithostratigraphic Assemblage 7 – Late McConnell periglacial sediments

Outside of the McConnell glacial limit, McConnell age periglacial alluvial fan sediments were deposited continuously throughout the South McQuesten drainage, depositing sediments of Assemblage 7 on top of Assemblage 5. In Rodin Creek, periglacial processes reworked Reid-age glaciofluvial sediments from a Reid delta into a McConnell periglacial fan. Ice-cast sand wedges are common throughout this assemblage (Fig. 54).

Lithostratigraphic Assemblage 8 – Holocene alluvial, colluvial and eolian sediments

Holocene alluvial gravel occurs in all of the South McQuesten tributaries in addition to the main valleys. In Rodin Creek, these gravel deposits contain placer gold where they overlie periglacial sand deposits, which act as a "false bedrock."

Paleogeographic history

The South McQuesten River valley acted as a conduit for Cordilleran ice flowing south from the Ogilvie and Wernecke Mountains during both the Reid and McConnell glaciations. Most of the ice glaciating the South McQuesten River valley originated from the drainages of the Beaver and Rackla rivers and flowed into the South McQuesten River valley via McQuesten Lakes valley and the Keno-Ladue River valley.

During the Reid glaciation, ice overtopped many of the plateaus bordering the South McQuesten River. Scheelite Dome and Mount Haldane were the largest nunataks in the vicinity of the South McQuesten River. Reid ice reached 4500 ft (1400 m) on Mount Haldane and 4300 ft (1300 m) on Scheelite Dome. Most tributary valleys to the South McQuesten River were infilled with Reid ice, which merged with the North McQuesten ice lobe

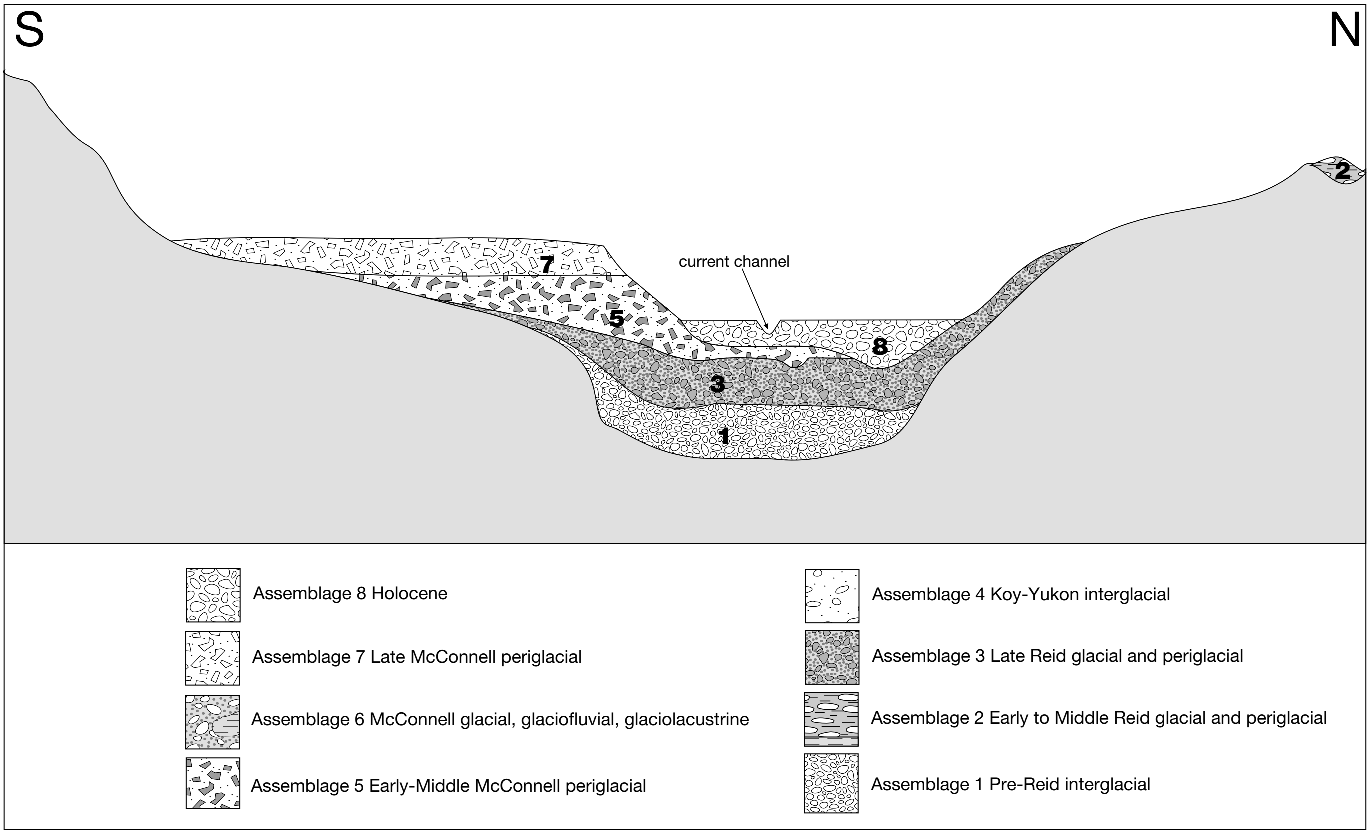


Figure 53. *Schematic cross-valley profile of Seattle Creek showing relations between lithostratigraphic assemblages. Not to scale.*

and advanced to its terminus at the Tintina Trench (Bond, 1997b).

The McConnell glaciation terminated north of Mount Haldane in the South McQuesten River valley and, like elsewhere in central Yukon, was less extensive than the Reid glaciation. Broad McConnell glaciofluvial terraces are preserved along the margins of the South McQuesten River valley from McQuesten Lake to the North McQuesten River confluence. McConnell katabatic winds eroded and deposited a veneer of loess across much of the valley bottom landforms.

Placer geomorphology

Few placer occurrences have been documented in the South McQuesten River area, aside from those in Haggart Creek drainage. Placers have been reported in Seattle, Rodin, and Goodman creeks. Johnson Creek also has placer gold and flows into the McQuesten River just downstream from the confluence of the North and South McQuesten Rivers. Recent activity in Seattle Creek has focused in the upper parts of the drainage basin near the confluence of a tributary stream with Seattle Creek. This tributary is informally named Klippert Gulch. Gold placers have been mined beneath a McConnell periglacial fan from Klippert Gulch. Two distinct deposits have reported production near the base of the fan. The lower deposit is a coarse Reid glaciofluvial outwash that has a flow direction down Seattle Creek. The second deposit lies above the outwash and is considered to be a debris flow deposit originating from Klippert Gulch. Underlying these gold-bearing units is rusty alluvial gravel of pre-Reid age. The origin of placer gold in the outwash deposit is likely a result of outwash reworking upstream pre-Reid alluvial gravel. Placer gold in Klippert gulch likely consists of interglacial gold that was reworked by periglacial processes during the McConnell glaciation.

The gold-bearing unit on Goodman creek consists of coarse boulder-cobble gravel that is probably Reid glaciofluvial outwash. In a placer setting nearly identical to that of Seattle Creek, this placer deposit is buried by a McConnell age periglacial fan.

On Rodin Creek, gold-bearing gravel is exposed above bedrock within a thick stratified sand succession, which is interpreted as a variably reworked Reid glaciofluvial delta. This auriferous cobble-boulder gravel probably reconcentrated placer gold within channels that eroded weathered bedrock or paleoplacer sources upstream. Reworked deltaic sands and silts acted as resistant false bedrock, which allowed placer gold to concentrate along the gravel/sand contact.

Figure 54. *Ice-cast sand wedges are well developed in McConnell-age periglacial sediments on Seattle Creek.*

REGIONAL INVESTIGATIONS – EXPANDING THE BORDERS

GUSTAVUS RANGE

The Gustavus Range is located immediately south and east of Keno City. Placer deposits, mentioned earlier in this report, have been mined from Thunder, Lightning and Upper Duncan creeks. All these drainages originate in the Gustavus Range. Numerous other drainages originate in this highland and bear placer potential based on the pre-existing producers and widespread similar geology. These streams include Keystone, Granite, Glacier, McNeill, McMillan, Allen and McKim creeks.

The Gustavus Range consists of Late Proterozoic to Early Cambrian Hyland Group phyllite, psammite and rare calcsilicate rock in the southwest and Devono-Mississippian Earn Group, Mississippian Keno Hill Quartzite and Triassic sills in the northeast (Murphy and Roots, 1996). Gold mineralization in the Gustavus Range occurs within vein-faults that were filled by hydrothermal fluids in the Keno Hill Quartzite and Triassic metadiorite sills. The origin of the fluids is thought to be connected with either the Roop Lakes pluton to the east, or from a more local unidentified intrusive source that underlies the range proper (Murphy, 1997; D. Ouellette, pers. comm., 2002). The timing of fluid emplacement for the argentiferous fluids and the auriferous fluids is uncertain and it is possible they represent separate hydrothermal events that occupied similar structural gaps in the host rocks (D. Ouellette, pers. comm., 2002). The gold potential of the Hyland Group appears less prospective relative to the younger Triassic and Mississippian rocks in the Gustavus Range. However, there is nearby placer gold production from streams draining Hyland Group rocks along Mayo Lake.

The glacial history is one of the controlling factors for placer development in the Gustavus Range. The alpine glacial history is variable in the range, and depends on the orientation and elevation of cirques. Drainages with north-, northeast- and east-facing cirque headwalls have had more ice accumulation in the past than drainages with west- and south-facing headwalls. This history plays a large role in the drainage geomorphology and placer development. The main producing creeks from the Gustavus Range are Thunder Gulch, including Lightning Creek below Thunder Gulch, and upper Duncan Creek, which are both west-facing drainages that had limited to no ice accumulation during the McConnell glaciation. Thunder Gulch, in particular, was not glaciated during the McConnell and has a relatively incised drainage morphology that is conducive to placer concentration. Upper Duncan Creek had small alpine glaciers develop at its headwaters during the McConnell glaciation. While the hydrology of the stream would have fluctuated during the glaciation, there is a long unglaciated reach in this drainage for heavy minerals to concentrate.

Keystone Creek

The only other drainage in the Gustavus Range that has had limited alpine ice accumulation is Keystone Creek. No placer production is reported from the stream, however the bedrock geology in the drainage is similar to Upper Duncan Creek. McConnell meltwater spilled down the drainage from the divide with Granite Creek, where McConnell ice terminated. Also, ice in Mayo Lake valley flowed into Keystone Creek, advancing a short distance up the drainage (see Bond, 1998d, in pocket). The effect of the Mayo Lake ice was probably non-erosive, but would have deposited glacial sediment in the drainage. This would have included glacial lake silt and clay. The effect of the meltwater spilling over the Granite Creek divide may have remobilized placers higher in the drainage and redeposited them at a higher stratigraphic level downstream. The extent of this reworking is unknown. A kame terrace was sampled at the mouth of Keystone Creek on the right limit. Sediment in the kame is likely of Keystone origin but may have a large outwash component from the Granite Creek spillway. Heavy mineral analyses from the kame returned 16 gold grains, abundant magnetite and a topaz crystal. Overall the heavy mineral assemblage was anomalous (see Heavy Mineral Studies). Keystone Creek has also undergone base level changes following the drop in the Mayo lake shoreline during deglaciation. This erosional event is considered beneficial in reducing the depth to bedrock in the drainage. Incised fan-delta remnants are visible near the apex of the modern fan-delta and provide evidence of the former lake level (Fig. 31). The stream sediment geochemistry of Keystone Creek and its tributaries contained only background levels of gold (<5 ppb) with the exception of the lower right-limit tributary, which contained 10 ppb gold.

McNeill Gulch, McMillan Gulch, Granite Creek and Glacier Creek

McNeill Gulch, McMillan Gulch, Granite Creek and Glacier Creek all have a similar drainage morphology and prospective geology. During the last glaciation alpine ice accumulated in each of the four drainages and advanced 3-5 km. Well-developed end moraines are documented at the mouth of each cirque (Fig. 9; Bond, 1998d, in pocket). The intensive ice-flow within these drainages would have scoured the former streambeds and reworked alluvium into the end moraines. Pockets of paleo-alluvium may still exist in the glaciated valleys where lithologic or structural contacts provide topographic traps. Paleo-channels may also be buried under the end moraines. The thick moraine accumulations will hinder the economics of these placer settings. Previous placer exploration on McNeill Gulch has focused where the stream cuts through and concentrates the low-grade placer-bearing end moraine sediment. This placer setting probably provides the most viable opportunity in these drainages, with the exception of McMillan Gulch, where the stream has not eroded a significant portion of the end moraine. The gold geochemistry measured in stream sediments at McNeill Gulch was 65 ppb. This is considered an anomalous value from the Mayo area dataset.

Lower Granite Creek

Lower Granite Creek differs from the upper alpine glaciated portion. The lower reach of Granite Creek flows east into the Roop Lakes and was glaciated by McConnell Cordilleran ice flowing up-valley. The stream is incised into the glacial fill and in places into bedrock where it traverses the Roop Lakes stock. The glacial fill is likely significantly thick near the terminus of the McConnell ice. There may be more potential further down the valley where the stream becomes incised into bedrock. Cut-in-bedrock benches were noted along the lower section of the stream, which would provide a good means of prospecting the stream. The stream geochemical value for gold in Granite Creek near the alpine end moraine was 20 ppb. The north-flowing tributary opposite upper Granite Creek contained 25 ppb gold in stream sediments. This geochemistry, while not anomalous, suggests the prospective geology continues into this part of the Gustavus Range.

Allen Creek

Allen Creek drains north out of the Gustavus Range into the Keno-Ladue River. The geology of Allen Creek is similar to surrounding drainages and is considered prospective for gold placers. The glacial history is also similar, however the ice did not advance down the full length of the drainage during the last glaciation. As a result, pre-existing placers would have been reworked in the upper part of the drainage and probably deposited into the lower reaches. This is a similar glacial history as Upper Duncan Creek but with more extensive alpine ice accumulations. Economic placer deposits in Allen Creek may be restricted to pocket accumulations, such as at the confluence with Faith Creek. Cordilleran ice glaciated the lower part of the drainage, however ice flow was transverse to the drainage and deposition was likely dominant. Gold values in the stream sediments were below detection limits in this drainage.

McKim Creek

McKim Creek flows northeast off the Gustavus Range into the Keno-Ladue River. McKim Creek has a similar geologic setting as Allen Creek but is more proximal to the Roop Lakes stock. According to Green (1971) a portion of the Roop Lakes stock enters into the drainage. This may provide an intrusive-hosted gold source for McKim Creek. Approximately 80 % granitic cobbles and boulders were noted in McKim Creek at the stream sediment sampling station. Alpine ice accumulated in the upper part of the drainage, however most of the drainage was glaciated by the McConnell Cordilleran valley glacier flowing west-northwest in the Keno-Ladue River valley. Distinct lateral moraines are visible in the basin and actually impounded ice marginal drainage into small glacial lakes. The middle reaches of McKim Creek are not well incised. The lower 6 km of the drainage would be considered more prospective where it becomes entrenched into glacial fill and bedrock. The stream sediment geochemistry of McKim Creek returned a value of <5 ppb Au.

WEST MAYO AREA

The west Mayo area includes water courses such as Sprague Creek, North McQuesten River and upper Little South Klondike River and tributaries north of the McQuesten River. Although placer gold has been mined from several streams within the area including Gem Creek, Arizona Creek and Hobo Creek, there are currently no active placer mines. The following bedrock geological summary is adapted from Murphy (1997). The area is underlain by deformed low-grade Upper Proterozoic to mid-Paleozoic metasedimentary rocks and two suites of Cretaceous felsic intrusions. The intrusive suites include the horneblende-bearing Tombstone Suite

(91-93 Ma) and the muscovite-bearing McQuesten Suite (64 and 66 Ma). Mineralization occurs in veins, breccias and as disseminated mineralization associated directly with the intrusion, and peripherally in the surrounding metasedimentary rocks. The Tombstone Suite is considered more prospective for gold mineralization, whereas the McQuesten Suite has silver, tin and base metal potential. Breccias associated with north-northwest-trending structural lineaments are also anomalous in gold.

The area lies beyond the limit of the Cordilleran McConnell glaciation, straddles the Reid limit, and was more regionally glaciated during pre-Reid glaciations. Evidence of Reid ice entering the map sheet is confined to lower Sprague Creek valley and the McQuesten River valley where till and outwash terraces are preserved along the valley sides (Bond, 1998a,b and e, in pocket). Evidence of pre-Reid glaciations was noted from drainage anomalies in Sprague Creek valley and interfluve meltwater channels incised between drainage courses. Locally, alpine ice accumulations were abundant during Reid and pre-Reid glaciations on West Ridge, East Ridge and Red Mountain. During the McConnell glaciation a small alpine glacier developed on the north slope of Mt. Bostock at the south-end of East Ridge and four alpine glaciers developed on West Ridge (Bond, 1998a, 1999, in pocket).

The effect of glaciations on the map area is most notable in the drainage physiography. Tributaries to the McQuesten River are far more incised than tributaries of the Klondike River due to the more recent glacial history of the McQuesten River valley. McQuesten River valley was a conduit for glaciers, which resulted in increased erosion of the valley. Although the Klondike River valley was a conduit for valley glaciers, it is more distal to those Little South Klondike River tributaries and therefore had less capability to influence base-level changes in the area. A comparison of the cross-valley profiles of two similar drainages, on either side of the regional divide, shows the contrast in the physiography within the west Mayo area (Fig. 55).

The morphologic differences of the drainage basins within the area have likely impacted the potential placer settings. The drop in base-level for the McQuesten River tributaries is evident by the v-shaped morphology outlined in the cross-valley profiles. This morphology also indicates a large volume of erosion has taken place, which is a favourable history for the development of placer deposits. The large drop in base level would have reworked possible pre-existing placers into new settings, such as pocket concentrations. A similar situation was documented from stratigraphic records on Highet Creek following the Reid glaciation. Potential placer deposits will likely lie on bedrock, and possibly at higher stratigraphic horizons on false bedrock surfaces that contain placers from partial incision events. Depth to bedrock in the tributaries to the McQuesten River will vary within the individual drainage basins as well as between drainage basins. Typically, depth to bedrock will increase along the lower reaches of a drainage basin. Possible minor variations due to Holocene base-level changes may occur near the mouth of a stream or at cascades within a water course that result from resistant bedrock lithologies.

Base-level reductions have been less dramatic for the Klondike River tributaries. In addition, no continental glaciers have impacted the landscape for at least 300 000 years. It is suspected that potential placer deposits will occur within relatively shallow ground in this terrain. This may not be true for streams such as Josephine Creek, which drain West Ridge and have been glaciated in their upper reaches during the McConnell and Reid glaciation. Because base-level changes have been less dramatic with a correspondingly smaller amount of bedrock erosion, viable placer deposits may require higher initial bedrock gold concentrations as compared to McQuesten River tributaries.

McQuestion River tributaries

The McQuesten River has numerous south-draining tributaries from the divide with the Little South Klondike River. These include Forty Mile, May, Boulder and Sunshine creeks. The regional stream geochemistry data (RGS) indicates values above the 90th percentile in Forty Mile Creek, May Creek and Boulder Creek. A stream sediment geochemical project from this study sampled Forty Mile Creek and verified anomalous gold in that drainage. A sample taken from the upper left fork tributary returned a value of 520 ppb Au. This is the highest value from the entire Mayo survey area. A value of 15 ppb Au was obtained in a sample from the upper right fork tributary. Bedrock in the Forty Mile drainage consists of Yusezyu Formation phyllites, psammite and marble (Murphy and Héon, 1996). The gold may have originated in association with black cassiterite that occurs within the Tombstone Strain Zone (Murphy, 1997). Stream sediment geochemical anomalies in May and Boulder creeks are likely related to the Bos stock Tombstone intrusion lying between the two drainages. The placer potential of these creeks is favourable, however economic values may be restricted to pockets such as near tributary junctions. The mineability of Boulder Creek will be restricted by the presence of abundant granite boulders in the stream-bed from the Boulder Creek stock.

Little South Klondike River tributaries

Tributaries with placer exploration history in the Little Klondike River drainage basin include Josephine, Big, Hobo, Arizona, Sprague and Gem creeks. Placer

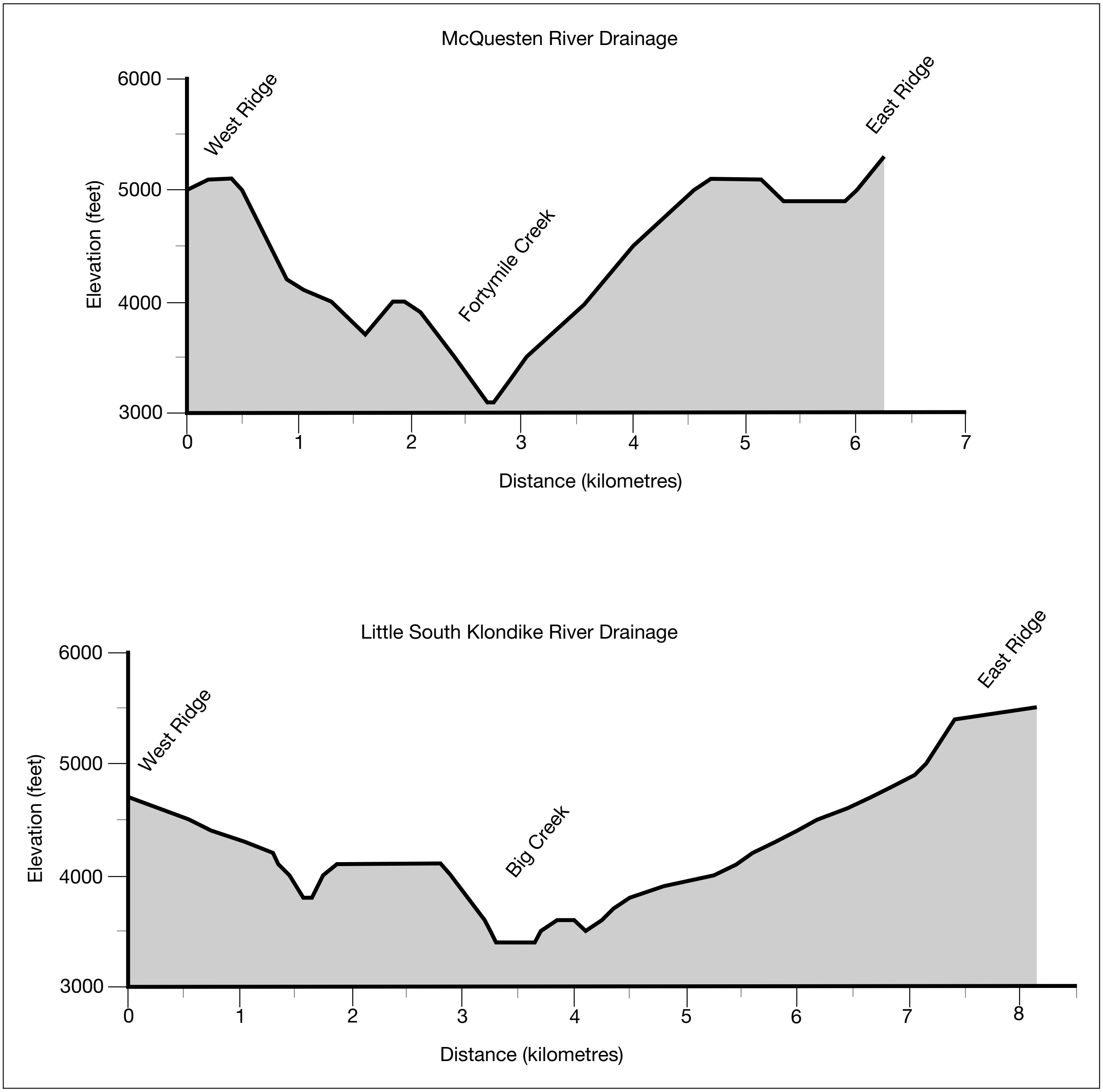


Figure 55. *Cross-valley profiles of Forty Mile Creek and Big Creek drainages. Note the difference in valley erosion between the two drainages. Location of East Ridge can be seen in the west-central area of Figure 2, while West Ridge is just off the map to the west.*

production has occurred in Hobo, Arizona and Gem creeks. Josephine and Big creek drain the east side of West Ridge, which is also shared by Left Clear Creek on the west side. Previous testing on Josephine Creek has been unsuccessful. Depths to bedrock along the lower reaches are from 2.1 to 2.7 metres and probably increase near the head of the drainage (Kreft, 1993), which is consistent with the glacial history. Local alpine glaciers developed at the headwaters during the McConnell and Reid glaciations, but their extent was limited to the upper-half of the creek (Bond, 1997b). Many small Tombstone Suite intrusions outcrop within the headwaters of these two drainages and provide favourable source rocks for gold. RGS data for Josephine and Big creeks show gold values >95th in both creeks and arsenic values also exceeded the 95th percentile. A stream sediment sample on Josephine Creek from the Mayo placer project returned a gold value of 355 ppb, the second highest gold value from the Mayo area sampling. Arsenic concentrations equaled 532 ppm, this is the fourth highest overall arsenic value. Prospects appear to have been tested in the lower reaches. The upper half of the creeks may be more promising where Reid glaciers overrode and possibly buried pre-existing placers.

Hobo and Gem creeks both have headwaters that originate within the Red Mountain stock, and in breccia zones northeast of the summit. Mining has occurred on both creeks but more extensively on Gem Creek where small-scale placer mining occurred over a 12-year period (Kreft, 1993). Hobo Creek has been prospected but the only mining has taken place near the mouth of Arizona Creek (Kreft, 1993). The alluvial deposits in that area consisted of 1 m of muck overlying 2 to 2.5 m of gravel (Kreft, 1993). The placer potential of Hobo Creek is favourable considering the bedrock setting at its headwaters. Economic grades may occur higher up in the drainage. The stream sediment geochemistry for Hobo Creek is anomalous in both gold and arsenic. Other creeks that have source areas on Red Mountain include tributaries to Ballard and Sprague creeks; these too have placer potential.

Arizona Creek lies 7 km west of Red Mountain and has a history of placer production. The ground is relatively shallow (approximately 4 m to bedrock) and is underlain by rocks of the Cambrian Gull Lake Formation (Kreft, 1993, Murphy and Héon, 1996). The drainage does not contain any reported intrusives or intrusion-altered metasedimentary rocks. Placer gold in Arizona Creek may have originated from veins related to the Red Mountain stock. The distinct north-northwest lineation of bedrock is likely bedding rather than structural control according to Murphy and Héon (1996). Structural control would have suggested a breccia-related gold source. Stream sediment geochemistry did not indicate any anomalous gold, arsenic or antimony values.

EMPIRE CREEK

Empire Creek is an isolated placer occurrence located 20 km southeast of Mayo in the Francis Creek drainage. Empire Creek flows south through a narrow incised valley off a broad plateau, informally termed Talbot Plateau, and into a large valley occupied by Francis Creek. Francis Creek drains southeast into Nogold Creek, which is an east-northeast flowing tributary of the Stewart River (Fig. 2 and Bond, 1999, in pocket). Placer mining has focused on the alluvial plain in the lower reaches of the valley. Coarse placer gold has been recovered, and recorded production has totalled 997 crude ounces (31 000 g) from a small operation that has been active since 1985 (Fig. 56). No other placers have been documented south of the Stewart River in the Mayo District other than Russell Creek 130 km to the southeast in the McMillan River drainage.

Empire Creek lies within the limit of the McConnell glaciation. Ice advancing west up Nogold Creek valley bifurcated into Francis Creek valley to the northwest (Fig. 3). The ice lobe terminated 10 km northwest of Empire Creek and only 4 km from the Stewart River valley ice lobe. Ice in Francis Creek valley was approximately 900 ft (270 m) thick at the mouth of Empire Creek valley and glaciated the lower reaches of the tributary valley. Limited ice scouring occurred in Empire Creek valley because of its orientation transverse to local ice flow.

Figure 56. *Coarse placer gold is typical of Empire Creek. This 10-ounce (330 g) nugget was recovered by placer miner Don Sabo.*

During the retreat of McConnell ice from Francis Creek valley, outwash flowed northwest into the Stewart River valley. The surficial landform features indicate a change from a braided outwash river to a large incised meandering river in Francis Creek valley, as the McConnell ice front became more distant. Post-glacial downcutting in Francis Creek valley also lowered the base-level for tributary streams. This initiated erosion in Empire Creek valley and created the canyon on the lower reaches of the drainage basin (Fig. 57). The Empire Creek alluvial fan that developed during post-glacial downcutting likely consists of reworked McConnell glacial sediments and may include gold placers near the apex of the fan.

The stream sediment gold geochemistry of Empire Creek was below the detection limit of 5 ppb. Obviously, this does not reflect the gold placer deposit in the drainage. Perhaps the –80 mesh fraction used to determine the geochemical value is too fine. The placer gold in Empire Creek is coarse and may reflect a coarse lode source, such as vein gold that may not be detectable by this sampling method. Such sources may also prove difficult to detect because of the nugget effect, where the gold is coarse yet infrequent in the alluvium. Elsewhere in the Mayo district, this stream sediment sampling/geochemical method proved accurate in detecting the known gold placer deposit where it originates directly from a granitic or hornfels source. This is attributed to the fine disseminated gold particles that are typically produced from these sources.

Undiscovered placer deposits may exist in other streams that drain Talbot Plateau. Future exploration should focus on stream reaches that have had limited glacial erosion and a drop in base-level, similar to Empire Creek.

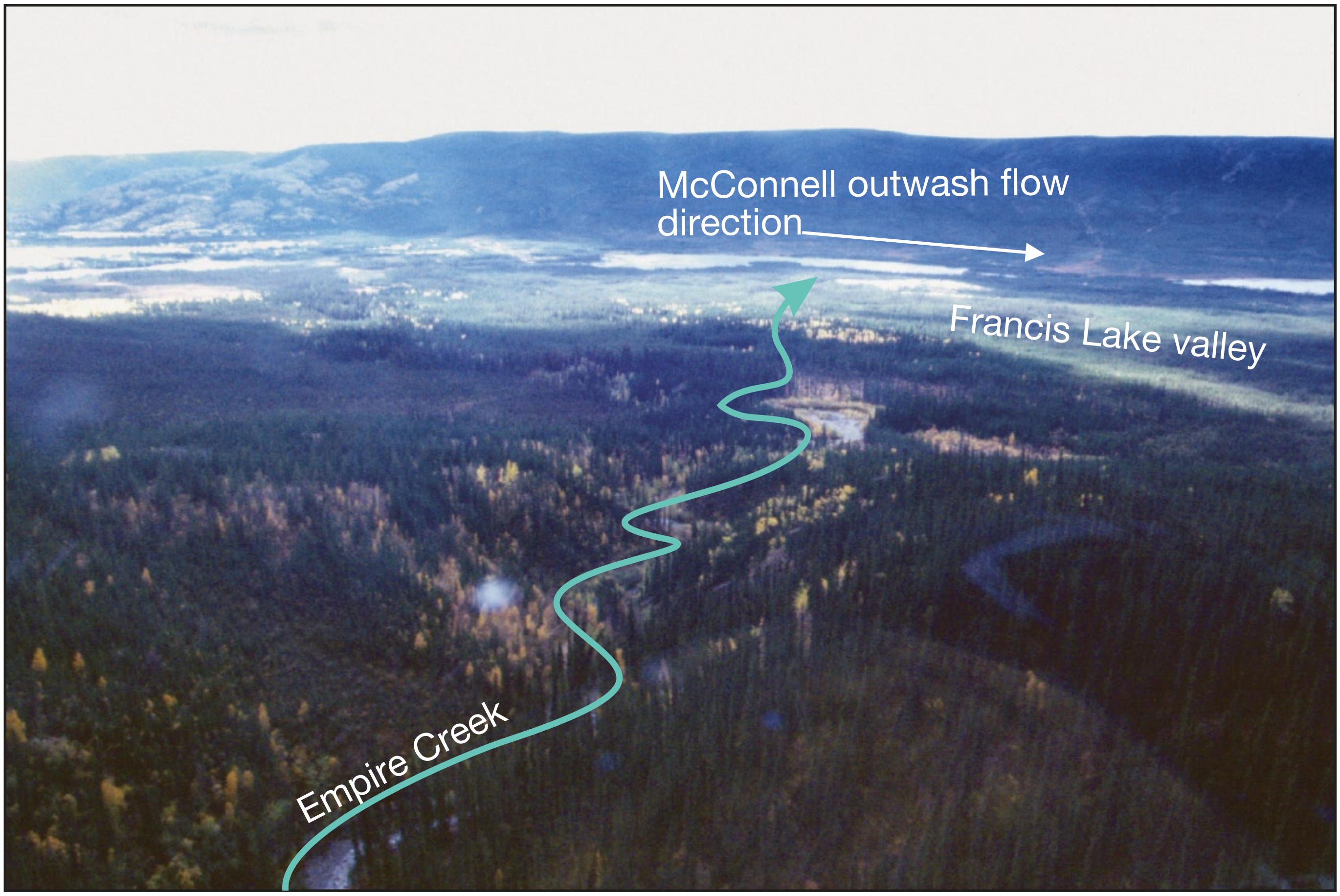


Figure 57. *View of Empire Creek and Francis Lake valley looking west. The canyon on Empire Creek was created during the retreat of the McConnell ice sheet.*

HEAVY MINERAL STUDIES

INTRODUCTION

The goal of the heavy mineral study was to examine the heavy mineral fraction of samples from a variety of placer deposits and settings (gravel, till, soil samples, colluvium, terraces, etc.) and use this information to define possible relationships between the heavy mineral content, bedrock lithologies and mineral showings. In addition, study of the heavy mineral fraction provides information that can used to study provenance and transport mechanisms in fluvial deposits.

A conclusive heavy mineral study, of the type produced by Gleeson (1970) for the Klondike area, was beyond the scope of this study. Simple mineral extraction and mineral identification techniques were used. The cost-effective methodology developed for this study can be adopted by prospectors and exploration geologists interested in using heavy mineral analysis as an exploration tool. With the exception of 16 mineral grains which were sent for microprobe analysis, all mineral identifications in this study should be considered tentative, until confirmed by more sophisticated equipment.

From 1995 to 1997, 148 samples were collected for heavy mineral analysis. Walton Geological Services of Whitehorse, Yukon was commissioned to extract and study the heavy mineral fraction of the samples presented. Detailed results are given in Appendix 2.

METHODOLOGY

Sample processing and extraction of heavy minerals

The following procedure was followed:

1. The -18 mesh, -35 mesh and -60 mesh size fractions were combined and put into a black plastic gold pan and concentrated down to between 3 to 20 grams of heavy mineral concentrate.
2. The percentages of the magnetic and non-magnetic fractions were noted.
3. Each pan concentrate was checked for gold content before removal from the gold pan.
4. The pan concentrate was allowed to dry on a coffee filter perched on top of a paper plate.
5. The non-magnetic fraction of each dried pan concentrate was poured through a separating funnel containing methylene iodide. This procedure was carried out under a fume hood.
6. Minerals or rock fragments with a specific gravity greater than 3.32 sink to the bottom of the separating funnel. Minerals or rock fragments with a specific gravity less than 3.32 float on the surface of the methylene iodide.
7. The <3.32 fraction is removed with a spoon and discarded. The heavy mineral fraction (>3.32) is rinsed with ethyl alcohol and flushed out to dry on filter paper.
8. When dry, the filter paper is used as a trough to get the >3.32 fraction into a labeled glass vial.

Note 1. Methylene Iodide should be used under a fume hood and with strong plastic gloves, as it can be highly toxic to lethal.

Note 2. The above method does not a produce a completely “clean” heavy mineral concentrate, but was perfectly adequate for the purpose of this study. Gleeson (1970) recommends using a set of sluice boxes to produce a concentrate then using bromoform, a hand magnet and a Frantz isodynamic separator to remove the heavy minerals.

Note 3. It should be noted that the >3.32 mineral fraction also includes rock fragments. In some cases, rock fragments, as opposed to individual mineral grains made up almost 100% of the sample.

Examination of heavy mineral fraction

All microscope work was carried out at the Yukon Geology Program office in Whitehorse, Yukon. Basic mineral identification equipment was used, including:

- binocular microscope,
- longwave and shortwave ultraviolet light,
- pen-light and hand-held microscope with micrometer (for measuring the size of individual grains),
- a variety of magnets,
- fine-tipped tweezers,
- dilute HCl,
- dichroscope for determining pleochroism,
- a stainless steel pushpin and hardness points (for scratch tests) and,
- a wine cork with a needle stuck in it (the most used piece of equipment – for moving around mineral grains)

The heavy minerals were examined using the following procedure:

1. The >3.32 fraction was placed on black construction paper and examined under the binocular microscope.
2. The room lights were then turned off and the sample was examined under longwave and shortwave ultraviolet light. Due to the extremely small size of the mineral grains, the sample was aligned in the binocular microscope, and any fluorescence was observed under magnification by holding the ultraviolet light source as close as possible to the sample.
3. The room lights were turned back on and the sample was then placed on white paper.
4. The magnetite fraction was removed and the remaining mineral grains were examined.
5. If warranted, the <3.32 fraction was also examined.

Mineral identification was difficult due to the very small size of most mineral grains, which was, on average, less than 1.0 mm. Mineral identification was done using basic techniques (ultraviolet light, magnification, magnetism, and crystal form).

DISCUSSION

General

In general, the heavy minerals observed in samples collected in 1995 to 1997 show some variety in the degree of homogeneity of samples and in the angularity of the mineral grains. Many samples contain mostly euhedral heavy minerals or angular heavy mineral fragments indicating a nearby bedrock source. Rock fragments were abundant. The most abundant heavy minerals were magnetite, garnet and ilmenite in varying proportions. Samples from Highet Creek contain the most ilmenite.

In some cases, more gold was expected in samples than was actually observed or recovered. This result may be a function of gold loss during the sieving or splitting process. In addition, some of the gold particles may have been less than 120 mesh and were therefore not panned into a concentrate.

Gold

Of the 148 samples of heavy mineral concentrates, 45 contained some gold. Table 11 shows the heavy mineral content of all samples that contain gold grains. Most gold grains observed are rounded nuggets with little or no crystal form, however crystalline gold was noted in four samples. Sample FT8-95-1 contains two gold grains; one is a 0.2 mm flattened leaf, relatively crystalline with jagged, irregular edges, and the other is elongated leaf gold perched on a limonite-coated oxidized mineral grain (pyrite?). Both grains are bright yellow, very fresh looking and may indicate a gold-bearing vein deposit nearby. Sample LDG9702-01 contains one crystalline gold piece (0.4 mm) in addition to one rounded grain (0.3 mm). RUD-97-01-02 contains one mass of yellow gold (1.0 mm) with leafy to subcrystalline form and a smaller crystalline gold piece (0.3 mm). Sample LW-97-21 (Unit 1) contains six pieces of fresh, crystalline gold up to 0.6 mm in diameter. The crystalline gold is singular or perched on quartz matrix fragments. Subcrystalline gold was noted in samples MIC9704-02, WL-96-02, and LW-97-12.

Other heavy minerals

Magnetite, garnet and ilmenite are the most abundant heavy minerals other than gold. Schistose rock fragments were also very common. Significant other minerals include pyrite/goethite, staurolite, sphene, rutile, epidote, zircon, scheelite and hypersthene. Arsenopyrite was noted in three samples, while galena and boulangerite were each found in one sample.

Magnetite content in the samples varied dramatically, ranging from 0% to up to 70%. Samples from Haggart Creek and Gill Gulch contained little magnetite while some of the samples collected from pay gravels of individual workings contained up to 70% magnetite.

Pyrite was common along with geothite/limonite/hematite pseudomorphs after pyrite. Although pyrite occurs in trace (<1%) amounts in many of the samples, it comprises 80-90% of sample FT3-95-1/1 (Duncan Creek). Lustrous, unoxidized pyrite occurs in quantities greater than 25% in samples from McIntyre Creek (MIC9709-07) and Haggart Creek (LW97-01 (a), LW97-01 (b), LW9704, LW-97-22, and LW-97-27). Some pyrite grains showed extensive oxidation; the microprobe study confirmed that pyrite in many samples had been replaced by a hematite/goethite combination. These pseudomorphs after pyrite form cubes, pyritohedrons or anhedral blebs.

Garnet content was variable ranging from 0% to 45%. Sample FT2-95-9 (Duncan Creek) contained near gem-quality pink garnets.

Samples from Seattle Creek (SEA979701-03, SEA9703-02, SEA9705-02), and Rudolf Gulch (RUD9701-01, RUD9701-02 and RUD9701-03) were ilmenite-rich (up to 98%).

Table 11. Heavy mineral content of samples containing gold grains (L=low, M=medium, H=heavy, tr=trace, gr=grains, gvl=gravel).

Duncan Creek	**Yield**	**Gold**	**Magnetite**	**Ilmenite**	**Garnet**	**Scheelite**	**Pyrite**	**Hematite**
FT2-95-1/2 Unit1 (top)	L	4 gr	2-5	tr	2-5		tr	
FT3-95-1/1 Pay Unit1	L	2 gr	2-3	20-40	5-15		tr	
FT3-95-1/2 Unit1 area2	L	1 gr	<1	5-20	5-15		tr	
FT3-95-1/3 Unit1 area3	L-M	3 gr	<1	10-30			tr	tr
FT8-95-1 Lower Unit1	L	2 gr	1-2	10-20				
Taylors Pay1997	M	4 gr	10-15	30-50	3-5		2-5	
LW9601 (UD9601) Unit3	M-L	1 gr	2-5	70-90	5-10		1-3	
UD971-01(b)	L	2 gr	2-5	10-20				
Mayo Lake	**Yield**	**Gold**	**Magnetite**	**Ilmenite**	**Garnet**	**Scheelite**	**Pyrite**	**Hematite**
LDG9701-01	M-H	1 gr	5-10	50-70				
LDG9702-01	H	2 gr	10-15	40-60	5-10	<tr	<tr	
DVD9701-01	M-H	1 gr	45-55	40-50	2-3		tr	
DVD9702-01	M-H	3 gr	20-30	40-60	1-2	<<tr		
DVD9703	H	3 gr	40-60	25-35	1-2	<<tr		
Davidson Creek clay	M-H	2 gr	25-35	25-35	1-3	<<tr	5-10	
JB-96-50 Heavy #4	M	16 gr	75-90	10-15	1			2-3
JB-96-59 Heavy #5	M-L	1 gr	5-10	50-70	1-2		5-10	
Highet Creek	**Yield**	**Gold**	**Magnetite**	**Ilmenite**	**Garnet**	**Scheelite**	**Pyrite**	**Hematite**
MP1-95-2 Unit2 Pay gvl	L-M	39 gr	3-		1	tr		
WL9601 Unit1	M	1%	35-55	35-50	1	tr		
WL9601 Unit1	M	5 gr	50-60	40-50	1-3	tr		tr
WL9601 Unit2	M	1 gr	25-35	65-75		tr		
WL9601 Unit2	H	5 gr	55-65	40-45	1	tr		
WL9601 Unit4	M	1 gr	tr	90-95	1-3	tr		
HT3-95-1 Near old cabin	L-M	5 gr	10-15	50-80				
KK1-95-1 Unit1	M	20 gr	1-2	90-95		1		
WL96-02	L	1 gr	15-25	60-80	2-5		2-5	
RUD9701-01	M	3 gr	tr-1	95-98	tr	1-3		
RUD9701-02	M	2 gr	tr-1	95-98	tr	tr-1		
MIC9704-02	M	2 gr	5-10	40-60	15-25		1-2	
MIC9705-01	L	1 gr	5-10	40-60	5-10	tr		
MIC9706-01	H-M	3 gr	15-25	30-40	10-20	tr		
MIC9708-01	L-M	4 gr	5-10	25-50	20-35	tr	tr-1	
BEAR9702-01	L-M	1 gr	20-30	15-25	1-3	<<tr	tr	
Duncan Creek	**Yield**	**Gold**	**Magnetite**	**Ilmenite**	**Garnet**	**Scheelite**	**Pyrite**	**Hematite**
DK1-94-1A Pay	L	4 gr	5-10	5-15			tr	
DK1-94-1A Pay	L	4 gr	5-10	5-15	2-3		tr	
SEA9701-02	L-M	1 gr	2-5	50-70	2-5	<tr	tr	
SEA9703-02	M	3 gr	20-30	70-85	1-2	<tr		
SEA9705-02	M	1 gr	5-10	75-90	1-2	<tr		
ROD-97-01-04	H	2 gr	5-15	40-50	3-5			
Haggart Creek	**Yield**	**Gold**	**Magnetite**	**Ilmenite**	**Garnet**	**Scheelite**	**Pyrite**	**Hematite**
LW-97-01(a) Unit 1	H	>10 gr	tr				40-60	
LW-97-21 Unit 1	L	7 gr	tr	5-10	2-5	55-60	2-5	
LW9608 Section 2	M-H	7 gr	3	15-20	5-10	45-55	tr	20-30
LW-97-12 Unit 1	L-M	1 gr	1-2	2-5	2-5	tr		
LW96-09 Unit 1	M	1 gr	2-5	20-30		5-10		
JB-96-20 Heavy #2	M	1 gr	1-2		15-30	25-40		
JB-96-21 Heavy #3	M-L	1 gr			10-20	40-55		

Trace amounts of scheelite were present in many samples, especially from the Haggart Creek drainage. Two samples from Dublin Gulch included up to 65% scheelite (LW-97-20, LW-97-21). Samples from Gill Gulch also contained abundant scheelite (up to 10%). Sample LW-97-15 contained 2-3% scheelite and samples RUD9701-01, RUD97-01-02 and RUD97-01-03 contained 1-3% scheelite.

In addition to scheelite, many of the samples from Haggart Creek and Dublin Gulch (LW-97-22 Unit 2) contain euhedral cassiterite, along with arsenopyrite and boulangerite. Two samples from Gill Gulch were unusual: sample LW-97-09 Unit 1 contained manganese andradite-spessartine garnets, and sample LW-97-12 Unit 1 contained one grain of bright yellow subcrystalline gold (0.4 mm), 2-5% rutile, 1% anatase, a trace of crystalline cassiterite and one corundum crystal. The corundum crystal has six-sided columnar form, subadamantine lustre, and a light grey color.

Duncan Creek samples commonly contained staurolite. Hematite content was low except in a few samples from Haggart Creek and Duncan Creek.

A topaz crystal was noted in a heavy mineral concentrate from a glaciofluvial terrace near the outlet of Keystone Creek on Mayo Lake.

CONCLUSIONS

The presence of unweathered, crystalline gold in sample FT8-95-1 (Duncan Creek) indicates a possible undiscovered bedrock source of gold nearby. Bedrock mineralization in lower Duncan Creek is also indicated by euhedral, unoxidized arsenopyrite and pyrite crystals in sample FT2-95-1/1.

Samples LDG9702-01 (Ledge Creek), RUD97-01-02 (Rudolf Gulch) and LW-97-21 (Dublin Gulch) also contain crystalline unweathered gold, indicating nearby bedrock sources. While Rudolph Gulch drains the Scheelite dome occurrence (Yukon MINFILE, 1997, 115P 004) and Dublin Gulch drains the Potato Hills Stock (Yukon MINFILE, 1997, 106D 025), no bedrock gold source has been identified near Ledge Creek.

The most interesting samples, in terms of crystalline/subcrystalline gold, interesting sulphide or oxide mineral content or unusual minerals are:

LDG-97-03-01	Ledge Creek	crystalline gold
RUD-97-01-02	Rudolph Gulch	leafy, subcrystalline gold
LW-97-01 (a)	Haggart Creek	pyrite, arsenopyrite, gold
LW-97-01 (b)	Haggart Creek	pyrite, malachite, trace arsenopyrite
LW-97-04	Haggart Creek	pyrite, trace arsenopyrite, trace boulangerite
LW-97-12	Gill Gulch	subcrystalline gold, corundum
LW-97-16	Fisher Gulch	cassiterite
LW-97-17	Fisher Gulch	cassiterite
LW-97-21	Dublin Gulch	crystalline gold on quartz
LW-97-22	Dublin Gulch	pyrite, arsenopyrite, boulangerite
LW-97-27	Haggart Creek	pyrite, arsenopyrite, scheelite, cassiterite
JB96-50	Keystone Creek	topaz, gold

PLACER DEPOSIT SETTINGS AND EXPLORATION TARGETS

INTRODUCTION

Based on stratigraphic relationships and sedimentology, several placer deposit models may be described within the glacial limits of central Yukon, including the Mayo area. These can be grouped into modern, interglacial, glacial or periglacial placer settings. Figure 58 shows these settings in a schematic profile.

MODERN PLACERS

Modern placer deposits occur in floodplains, low alluvial terraces, alluvial fans, fan-deltas and gulches. These deposits are historically the most common type of placer to be mined throughout the Mayo area.

In the Duncan Creek drainage, modern placers occur in the floodplain, in gulch gravels in tributary valleys (including Thunder Gulch), and in side-valley alluvial fans. Within the floodplain of Duncan Creek, significant placers occur where the stream has incised to bedrock on the valley rim.

In the Mayo Lake area, modern placers occur in gulch deposits in tributary valleys and in related alluvial fan deltas, which drain into Mayo Lake.

In Highet Creek, modern placers mainly occur in tributary gulches and in the floodplain near the upper reaches of the drainage basin, where depth to bedrock is shallow.

In the Haggart Creek drainage, modern placers occur in the floodplain of Haggart Creek and in tributary valleys including Dublin Gulch and Fisher Gulch. Side-valley alluvial fans along Haggart and possibly Lynx creeks also contain placer deposits near their apex. In addition, these fans have buried part of the Late McConnell to Modern placer-deposit-bearing floodplain.

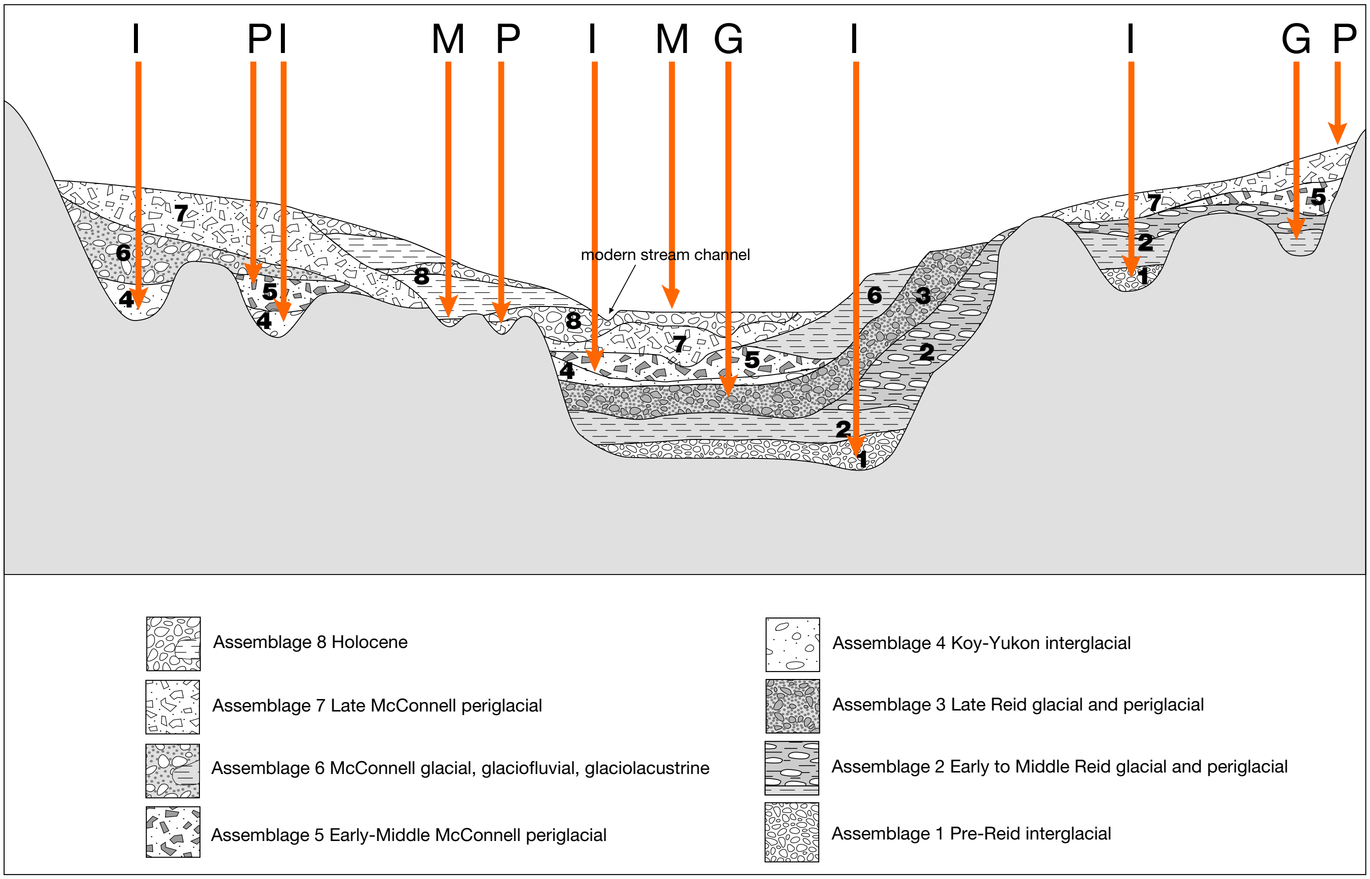


Figure 58. *Schematic cross-valley profile showing placer deposit settings and potential exploration targets in idealized stratigraphic settings. M - Modern, I - Interglacial, P - Periglacial, G - Glacial. Note that most targets are buried. Not to scale.*

In the South McQuesten drainage basin, including Seattle and Rodin creeks, modern placer deposits occur as gulch gravel in high gradient tributary valleys.

Potential new exploration targets include Modern stream placers in point and channel bars along Stewart River and gulch placers in high gradient tributaries throughout Mayo area.

INTERGLACIAL PLACERS

Interglacial placer deposits include alluvial plains, alluvial fans, and terraces and gulch deposits that may be subsequently buried and reworked by glacial drift and periglacial fan sediments. Within the glacial limit, interglacial placer deposits are best preserved near the terminus, especially in valleys oriented perpendicular or oblique to ice-flow, where the scouring of pre-existing sediment is minimal and depositional processes are dominant.

On Upper Duncan Creek above the canyon, alluvial fans containing pre-McConnell interglacial placer deposits are buried by periglacial sediments and colluvial deposits of McConnell age.

Buried interglacial placer deposits occur in the South McQuesten drainages of Seattle and Goodman creeks, outside of the McConnell ice limit where McConnell age periglacial fans have built out onto the interglacial floodplain.

On the lower reaches of Highet Creek, pre-Reid interglacial gravel is preserved beneath Reid glaciolacustrine sediments and till. Ice advancing in the valley of Minto Creek blocked Highet Creek and formed an ice marginal lake, which subsequently protected underlying sediments from the scouring effects of the advancing glacier. On Ledge Creek, a Mayo Lake tributary, interglacial gulch gravels are buried beneath McConnell glacial till and glaciofluvial outwash deposits. Unexplored placer targets of this type may occur on the drainages of Upper Duncan, Lightning, Minto, Highet, Haggart and Lynx creeks, Thunder gulch, and on tributaries of Mayo Lake.

GLACIAL PLACERS

Glacial placer settings include glacial till and glaciofluvial outwash gravel in major valleys. In central Yukon, the most significant gold-bearing placers of these types are Reid age or older. Glacial till commonly forms placer deposits in areas where local alpine glaciers have scoured and incorporated weathered bedrock and pre-existing placers. This settting occurred in the Gustavus Range, where alpine glaciers developed during both the Reid and McConnell glaciations. During the Reid glaciation, ice advanced down Upper Duncan Creek valley and reconcentrated placers into a till near the mouth. At McNeill gulch, placer gold is dispersed throughout a moraine that formed during the McConnell glaciation, when ice advanced down an alpine valley.

Glaciofluvial outwash placer deposits may form when meltwater flows from streams proximal to an active glacier. Favourable conditions for placer deposits exist when meltwater is erosive rather than depositional, such as when glaciers breach drainage divides and send an initial flux of meltwater into a drainage; and during the waning stages of glaciation, when base levels are unstable in heavily glaciated valleys. On Duncan creek, Reid outwash eroded interglacial sediments upstream and reconcentrated placers on bedrock in the lower reaches. This also occurred to some extent on Seattle Creek. Potential new exploration targets include glacial and glaciofluvial placers on Duncan, Goodman and Seattle creeks.

PERIGLACIAL PLACER DEPOSITS

In periglacial placer settings, alluvial fans may form just outside of the glacial limit due to increased physical weathering and slope erosion. In many cases, these fans buried and reworked paleoplacers, while in others, colluvial placer deposits formed because of the intense physical breakdown and slope erosion of bedrock gold sources. On Seattle Creek and Goodman Creek, tributaries to the South McQuesten River, periglacial sediments mark the initial period of fan development and have buried paleoplacers that may be Reid age glacial outwash. Some periglacial sediments on Seattle Creek also contain placer gold where it has been incorporated from pre-existing interglacial sources. Potentially unexplored targets include tributaries of Mayo Lake (such as Cliff and Cascade creeks) and South McQuesten River, including Seattle Creek and Haggart Creek.

CONCLUSIONS

Information developed in this study allows us to make the following conclusions:

1. The study area was subjected to at least three major episodes of glaciation, including the pre-Reid (multiple episodes), Reid and McConnell. No evidence of a mid-Wisconsinan glaciation was found during the study. Ice-flow directions during the Reid and McConnell glaciations were topographically controlled and oriented from east to west and northeast to southwest.

2. Base-level changes are the most important factor in the formation, preservation and exposure of placer deposits.

3. Significant placer deposits likely lie buried in valleys that were not excavated during base-level changes in post-glacial and modern times.

4. Placer deposits occur in modern, interglacial, glacial and periglacial settings.

5. The formation and preservation of these placer deposits can be directly attributed to both the presence of local bedrock sources of gold, and the location and orientation of the placer deposits relative to paleo-ice flow and the direction of glaciofluvial meltwater channels.

REFERENCES

Berger, G.W., 1994. Age of the Alaska/Yukon Sheep Creek tephra from thermoluminescence dating of bracketing loess at Fairbanks, “Bridges of the science between North America and the Russian far east.” 45th Arctic Science Conference, 25-27 August, 1994, Anchorage, Alaska, 29 August – 2 September, 1994, Vladivostok, Russia.

Barendregt, R.W. and Irving, E., 1998. Changes in the extent of North American ice-sheets during the Late Cenozoic. Canadian Journal of Earth Sciences, vol. 35 (5), p. 504-509.

Bond, J.D., 1996. Quaternary history of McQuesten map area, central Yukon. *In:* Yukon Quaternary Geology, Volume 1, W.P. LeBarge (ed.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 27-46.

Bond, J.D., 1997a. Late Cenozoic history of McQuesten map area, Yukon Territory, with applications to placer gold research. Unpublished M.Sc. thesis, Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, 160 p.

Bond, J.D., 1997b. The glacial history and placer gold potential of the North McQuesten (116A/1), Dublin Gulch (106D/4) and Keno Hill (105M/14) map areas, Mayo Mining District, central Yukon. *In:* Yukon Quaternary Geology, Volume 2, W.P. LeBarge and C.F. Roots (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 30-43.

Bond, J.D., 1998a. Surficial geology of Sprague Creek map area, central Yukon (115P/15). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1998-1, 1:50 000 scale map with marginal notes.

Bond, J.D., 1998b. Surficial geology of Seattle Creek map area, central Yukon (115P/16). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1998-2, 1:50 000 scale map with marginal notes.

Bond, J.D., 1998c. Surficial geology of Mt. Haldane map area, central Yukon (105M/13). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1998-3, 1:50 000 scale map with marginal notes.

Bond, J.D., 1998d. Surficial geology of Keno Hill map area, central Yukon (105M/14). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1998-4, 1:50 000 scale map with marginal notes.

Bond, J.D., 1998e. Surficial geology of North McQuesten River map area, central Yukon (116A/1). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1998-5, 1: 50 000 scale map with marginal notes.

Bond, J.D., 1998f. Surficial geology of Dublin Gulch map area, central Yukon (106D/4). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1998-6, 1:50 000 scale map with marginal notes.

Bond, J.D., 1999. Glacial limits and ice flow patterns, Mayo area, central Yukon. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1999-13, 1:250 000 scale map .

Bostock, H.S., 1948. Physiography of the Canadian Cordillera, with special reference to the area north of the fifty-fifth parallel. Geological Survey of Canada, Memoir 247, 106 p.

Bostock, H.S., 1966. Notes on glaciation in central Yukon Territory. Geological Survey of Canada. Paper 65-36, 18 p.

Bostock, H.S., 1969. Physiographic regions of Canada. Geological Survey of Canada, Map 1254A, 1:5 000 000 scale.

Boyle, R.W., 1979. The geochemistry of gold and its deposits. Geological Survey of Canada, Bulletin 280, 584 p.

Boyle, R.W. and Gleeson, C.F., 1972. Gold in the heavy mineral concentrates of stream sediments, Keno Hill area, Yukon Territory. Geological Survey of Canada, Paper 71-51, 8 p. (includes map 1:126 720 scale).

Brown, V.S., Baker, T. and Stephens, J.R., 2002. Ray Gulch tungsten skarn, Dublin Gulch, central Yukon: Gold-tungsten relationships in intrusion-related ore systems and implications for gold exploration. *In:* Yukon Exploration and Geology 2001, D.S. Emond, L.H. Weston and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 259-268.

Burn, C.R., 1987. Notes on features visible from the highway between Steward Crossing and Mayo. *In:* Guidebook to Quaternary Research in Yukon, S.R. Morison and C.A.S. Smith (eds.) XII INQUA Congress, Ottawa, Canada. National Research Council of Canada, Ottawa, p. 40.

Burn, C.R., 1990. Implications for paleoenvironmental reconstruction of Recent ice-wedge development at Mayo, Yukon Territory. Permafrost Periglacial Processes, vol. 1, p. 3-14.

Burn, C.R., 1994. Permafrost, tectonics, and past and future regional climate change, Yukon and adjacent Northwest Territories. Canadian Journal of Earth Sciences, vol. 31, p. 182-191.

Burn, C.R. and Friele, P.A., 1989. Geomorphology, vegetative succession, soil characteristics and permafrost in retrogressive thaw slumps near Mayo, Yukon Territory. Arctic, vol. 42, p. 31-40.

Carlyle, L., 1995a. Placer mining and exploration compilation (NTS 105 A/B/C/D). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File Report 1995-10(G), report with two maps.

Carlyle, L., 1995b. Placer mining and exploration compilation (NTS 106 D). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File Report 1995-11(G), report with one map.

Clayton, J.S., Ehrlich, W.A., Cann, D.B., Day. J.H. and Marshall, I.B., 1977. Soils of Canada, Volumes 1 and 2, Department of Agriculture, Ottawa, Canada, 239 p.

Doherty, R.A., Mougeot, C.M. and van Randen, J.A., 1994. Yukon GEOPROCESS File map of Mayo 105M. Geological processes and terrain hazards inventory. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1994, 1:250 000 scale.

Duk-Rodkin, A., 1996. Surficial geology, Dawson, Yukon Territory. Geological Survey of Canada, Open File 3288, 1:250 000 scale with marginal notes.

Duk-Rodkin, A, 1999. Glacial limits map of Yukon Territory. Geological Survey of Canada, Open File 3694, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1999-2, 1:1 000 000 scale.

Duk-Rodkin, A. and Hughes, O.L., 1991. Age relationships of Laurentide and montane glaciations, MacKenzie Mountains, Northwest Territories. Geographie physique et Quaternaire, vol. 45, p. 79-90.

Duk-Rodkin, A., Barendregt, R.W., Tarnocai, C. and Phillips, F.M., 1996. Late Tertiary to late Quaternary record in the MacKenzie Mountains, Northwest Territories, Canada: Stratigraphy, paleosols, paleomagnetism and chlorine-36. Canadian Journal of Earth Sciences, vol. 33, p. 875-895.

Folk, R.L., 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Co., Austin, Texas, 182 p.

Franzen, J.P., 1986. Metal-ratio zonation in the Keno Hill district, central Yukon. *In:* Yukon Geology, Volume 1, J.A. Morin and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, p. 98-108.

Fraser, T. A., 1995. On the Nature and Origin of Muck Deposits, Klondike District, Yukon Territory. Unpublished M.A. thesis, Department of Geography, Carleton University, Ottawa, 203 p.

Fraser, T. A. and Burn, C.R., 1997. On the nature and origin of “muck” deposits in the Klondike area, Yukon Territory. Canadian Journal of Earth Sciences, vol. 34, p. 1333-1344.

Friske, P.W.B. and Hornbrook, E.H.W., 1989. National geochemical reconnaissance stream sediment and water geochemical data, central Yukon (105 M). Geological Survey of Canada, Open File 1962 (105M), 26 p. with map indices.

Froese, D.G., 1997. Sedimentology and paleomagnetism of Plio-Pleistocene lower Klondike valley terraces, Yukon Territory. Unpublished M.Sc. thesis, Department of Geography, University of Calgary, 153 p.

Froese, D.G. and Hein, F.J., 1996. Sedimentology of a high-level terrace placer gold deposit, Klondike Valley, Yukon. *In:* Yukon Quaternary Geology, Volume 1, W.P. LeBarge (ed.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 13-26.

Giles, T.R., 1993. Quaternary sedimentology and stratigraphy of the Mayo Region, Yukon Territory. Unpublished MSc. thesis, Department of Geology, University of Alberta, 206 p.

Gleeson, C.F., 1970. Heavy mineral studies in the Klondike area, Yukon Territory. Geological Survey of Canada, Bulletin 173, 63 p.

Green, L.H., 1971. Geology of Mayo Lake, Scougale Creek and McQuesten Lake map areas, Yukon Territory (105M/15, 106D/2, 106D/3). Geological Survey of Canada, Memoir 357 (includes Map 1270A – Mayo Lake, 1:50 000 scale).

Green, L.H., 1972. Geology of Nash Creek, Larsen Creek, and Dawson map areas. Geological Survey of Canada, Memoir 364 (includes maps 1282A – Nash Creek and 1283A – Larsen Creek, 1:250 000 scale).

Harris, S.A., 1994. Chronostratigraphy of glaciations and permafrost episodes in the Cordillera of western North America. Progress in Physical Geography, vol. 18, p. 366-395.

Hawthorne, G., 1996. Investigation into the reprocessing of Elsa tailings for United Keno Hill Mines Limited, Elsa, Yukon. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1996-3(T), report with three maps.

Hein, F.J., Palmer, B.C. and Mindermann, P., 1996. Yukon placer MINFILE database: Prototype and version 1.1. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada and Yukon Territorial Government, Open File Report, 350 p. with computer diskette, index maps and stratigraphic sections.

Hitchins, A.C. and Orssich, C.N., 1995. The Eagle zone gold-tungsten sheeted vein porphyry deposit and related mineralization, Dublin Gulch, Yukon Territory. *In:* Porphyry deposits of the Northwestern Cordillera of North America, T.G. Schroeter (ed.), Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Special Volume 46, p. 803-810.

Hughes, O.L., 1982. Surficial geology and geomorphology, 105M/SW, 105M/SE, 105M/NW, 105M/NE. Four 1:100 000 scale maps with marginal notes. Geological Survey of Canada, Maps 1982-2, 1982-3, 1982-4 and 1982-5.

Hughes, O.L., 1987. Quaternary geology. *In:* Guidebook to Quaternary Research in Yukon, S.R. Morison and C.A.S. Smith (eds.), XII INQUA Congress, Ottawa, Canada. National Research Council of Canada, Ottawa, p. 12-16.

Hughes, O.L., Campbell, R.B., Muller, J.E. and Wheeler, J.O., 1969. Glacial Limits and Flow Patterns, Yukon Territory, South of 65 Degrees North Latitude. Geological Survey of Canada, Paper 68-34 (Report and Map 6-1968), 9 p.

Hughes, O.L., Rampton, V.N. and Rutter, N.W., 1972. Quaternary geology and geomorphology, southern and central Yukon (northern Canada). Guidebook, XXIV International Geological Congress, Montreal, PQ, 59 p.

Hunt, J.A., Murphy, D.C., Roots, C.F. and Poole, W.H., 1996. Geological map of Mount Haldane area, Yukon (105M/13). Indian and Northern Affairs Canada, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience map 1996-4, 1:50 000 scale.

Huscroft, C.A., Jackson, L.E., Jr., Barendregt, R.W. and Villeneuve, M., 2001. Constraints on ages of pre-McConnell glaciations based on new paleomagnetic investigations and Ar-Ar dating of basalt in west central Yukon, Canada. In: Occasional Papers in Earth Sciences No. 1, J. Hunston and J.E. Storer (eds.), Canadian Quaternary Association Meetings, 2001: Programs and Abstracts, Whitehorse, Yukon, p. 41.

Jackson, L.E. Jr. and Harington, R., 1991. Middle Wisconsinan mammals, stratigraphy, and sedimentology at the Ketza River site, Yukon Territory. Geographie physique et Quaternaire, vol. 45, p. 69-77.

Kindle, E.D., 1955. Geology, Keno Hill, Yukon Territory. Geological Survey of Canada, Map 1105A (1:63 360 scale), map with marginal notes.

Kotler, E., 1998. The cryostratigraphic and isotopic characteristics of "muck" deposits, Klondike area, Yukon Territory. Unpublished MSc. thesis, Carleton University, Ottawa, Ontario, Canada.

Kreft, B., 1993. Placer mining and exploration compilation (NTS 105 M and 115 P). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1993-10(G), report with two maps.

LeBarge, W.P., 1995. Sedimentology of placer gravels near Mt. Nansen, central Yukon Territory. Indian and Northern Affairs Canada, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 4, 155 p.

LeBarge, W.P., 1996a. Placer deposits of the Yukon: Overview and potential for new discoveries. *In:* Yukon Quaternary Geology, Volume 1, W.P. LeBarge (ed.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 1-12.

LeBarge, W.P., 1996b. Sedimentology and stratigraphy of Duncan Creek placer deposits, Mayo, central Yukon. *In:* Yukon Quaternary Geology, Volume 1, W.P. LeBarge (ed.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 63-72.

Lipovsky, P., Bond, J. and LeBarge, W., 2001. Mayo area placer activity map, portions of NTS sheets 105M, 106D, 115P and 116A, Yukon (1:250 000 scale). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 2001-35.

Lynch, J.V.G., 1986. Mineral zoning in the Keno Hill silver-lead-zinc mining district, Yukon. *In:* Yukon Geology, Volume 1, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 89-97.

Lynch, J.V.G., 1989. Large-scale hydrothermal zoning reflected in the tetrahedrite-freibergite solid solution, Keno Hill Ag-Pb-Zn district, Yukon. Canadian Mineralogist, vol. 27, p. 383-400.

Matthews, J.V., Jr., Schweger, C.E. and Hughes, O.L.,1990. Plant and insect fossils from the Mayo Indian Village section (central Yukon): New data on Middle Wisconsinan environments and glaciations. Geographie physique et Quaternaire, vol. 44, p. 15-26.

Mayo Historical Society, 1990. Gold and Galena: A history of the Mayo District, Mayo Historical Society, L.E.T. MacDonald and L.R. Bleiler (compilers), 502 p.

McLeod, C.R. and Morison, S.R., 1996. Placer gold, platinum. *In:* Geology of Canadian Mineral Deposit Types, O.R. Eckstrand, W.D. Sinclair and R.I. Thorpe (eds.), Geological Survey of Canada, Geology of Canada, no. 8, p. 23-32.

McNeely, R., 1991. Geological Survey of Canada radiocarbon dates XXIX. Geological Survey of Canada, Paper 89-7, 134 p.

Morin, J.A., 1989. Yukon Gold-Silver File. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, 227 p. with index of NTS map areas.

Morison, S.R., 1989. Placer deposits in Canada. *In:* Quaternary Geology of Canada and Greenland, R.J. Fulton (ed.), Geological Survey of Canada, Geology of Canada, no. 1, p. 687-697.

Morison, S.R. and Hein, F.J., 1987. Sedimentology of the White Channel Gravels, Yukon Territory: Fluvial deposits of a confined valley. *In:* Recent Developments in Fluvial Sedimentology – Contributions from the Third International Sedimentology Conference, F.G. Ethridge, R.M. Flores and M.D. Harvey (eds.), SEPM Special Publication No. 39, p. 205-216.

Mougeot, C.M., 1993. Soil survey of selected land parcels, Mayo area. Community and Transportation Services, Lands Branch, Yukon Government.

Mougeot, C.M. and Walton, L.A., 1996a. Yukon GEOPROCESS File map of Larsen Creek 116A. Geological processes and terrain hazards inventory. Exploration and Geological Services Division, Yukon Region, Indian and Affairs Canada, Open File 1996, 1:250 000 scale.

Mougeot, C.M. and Walton, L.A., 1996b. Yukon GEOPROCESS File map of McQuesten 115P. Geological processes and terrain hazards inventory. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1996, 1:250 000 scale.

Mougeot, C.M. and Walton, L.A., 1996c. Yukon GEOPROCESS map of Nash Creek 106D. Geological processes and terrain hazards inventory. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1996, 1:250 000 scale.

Murphy, D.C., 1997. Geology of the McQuesten River Region, northern McQuesten and Mayo map areas, Yukon Territory (115P/14, 15, 16; 105M/13/14). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 6, 122 p.

Murphy, D.C. and Héon, D., 1996. Geological map of Sprague Creek area, western Selwyn Basin, Yukon, (115P/15), 1:50 000 scale map with marginal notes.

Murphy, D.C. and Héon, D., 1994. Geological overview of Sprague Creek map area, western Selwyn Basin. *In:* Yukon Exploration and Geology 1993, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 29-46.

Murphy, D.C. and Roots, C., 1996. Geological map of Keno Hill area, Yukon (105M/14). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Geoscience Map 1996-5, 1:50 000 scale.

Oswald, E.T. and Senyk, J.P. 1977. Ecoregions of Yukon Territory. Fisheries and Environment Canada, 115 p.

Poole, W.H., 1965. Mount Haldane (105M/13) and Dublin Gulch (106D/4) map areas. *In:* Report of Activities, Field, 1964. Geological Survey of Canada, Paper 65-1, p. 32-34.

Roots, C.F., 1991. A new bedrock mapping project near Mayo, Yukon. *In:* Current Research, Part A, Geological Survey of Canada, Paper 91-1A, p. 255-260.

Roots, C.F., 1997. Geology of Mayo map area, Yukon (105M). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 7, 97 p., includes Geoscience Map 1997-1, 1:250 000 scale.

Roots, C. F. and Murphy, D.C., 1992a. New developments in the geology of Mayo map area, Yukon Territory. *In:* Current Research, Part A, Geological Survey of Canada, Paper 92-1A, p. 163-171.

Roots, C. F. and Murphy, D.C., 1992b. Geology of Mayo map area (105M). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1992-4, 1:250 000 scale.

Rutter, N.W., Foscolos, A.E. and Hughes, O.L., 1978. Climatic trends during the Quaternary in central Yukon based upon pedological and geomorphological evidence. *In:* Quaternary Soils, W.C. Mahaney (ed.); Geo Abstracts, Norwich, England, p. 309-359.

Smit, J. Sieb, M. and Swanson, C., 1995. Summary Information on the Dublin Gulch Project, Yukon Territory. *In:* Yukon Exploration and Geology, 1995, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 33-36.

Smith, C.A.S., Tarnocai, C. and Hughes, O.L., 1986. Pedological investigations of Pleistocene glacial drift surfaces in the central Yukon. Geographie physique et Quaternaire, vol. 40, p. 29-37.

Tarnocai, C. and Schweger, C.E., 1991. Late Tertiary and Early Pleistocene paleosols in northwestern Canada. Arctic, vol. 44, p. 1-11.

Tarnocai, C., Smith, C.A.S. and Hughes, O.L., 1985. Soil development on Quaternary deposits of various ages in the central Yukon Territory. *In:* Current Research, Part A, Geological Survey of Canada, Paper 85-1A, p. 229-238.

Weston, L., 1999. Sedimentology and Stratigraphy of Placer Gold Deposits of Haggart Creek, Central Yukon Territory. Unpublished MSc. thesis, University of Calgary, Calgary, Alberta, 201 p., with two 1:250 000-scale maps in pocket.

Watson, K.W., 1986. Silver-lead-zinc deposits of the Keno Hill – Galena Hill area, central Yukon. *In:* Yukon Geology, Volume 1, J.A. Morin and D.S. Emond (eds). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 83-88.

Wilson, C.E., Hutchinson, T.C. and Burn, C.R., 1996. Natural revegetation of placer mine tailings near Mayo, central Yukon. *In:* Yukon Quaternary Geology, Volume 1, W.P. LeBarge (ed.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 47-62.

Yukon MINFILE, 1997. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada.