Indian and Northern Affairs Canada / Affaires indiennes et du Nord Canada

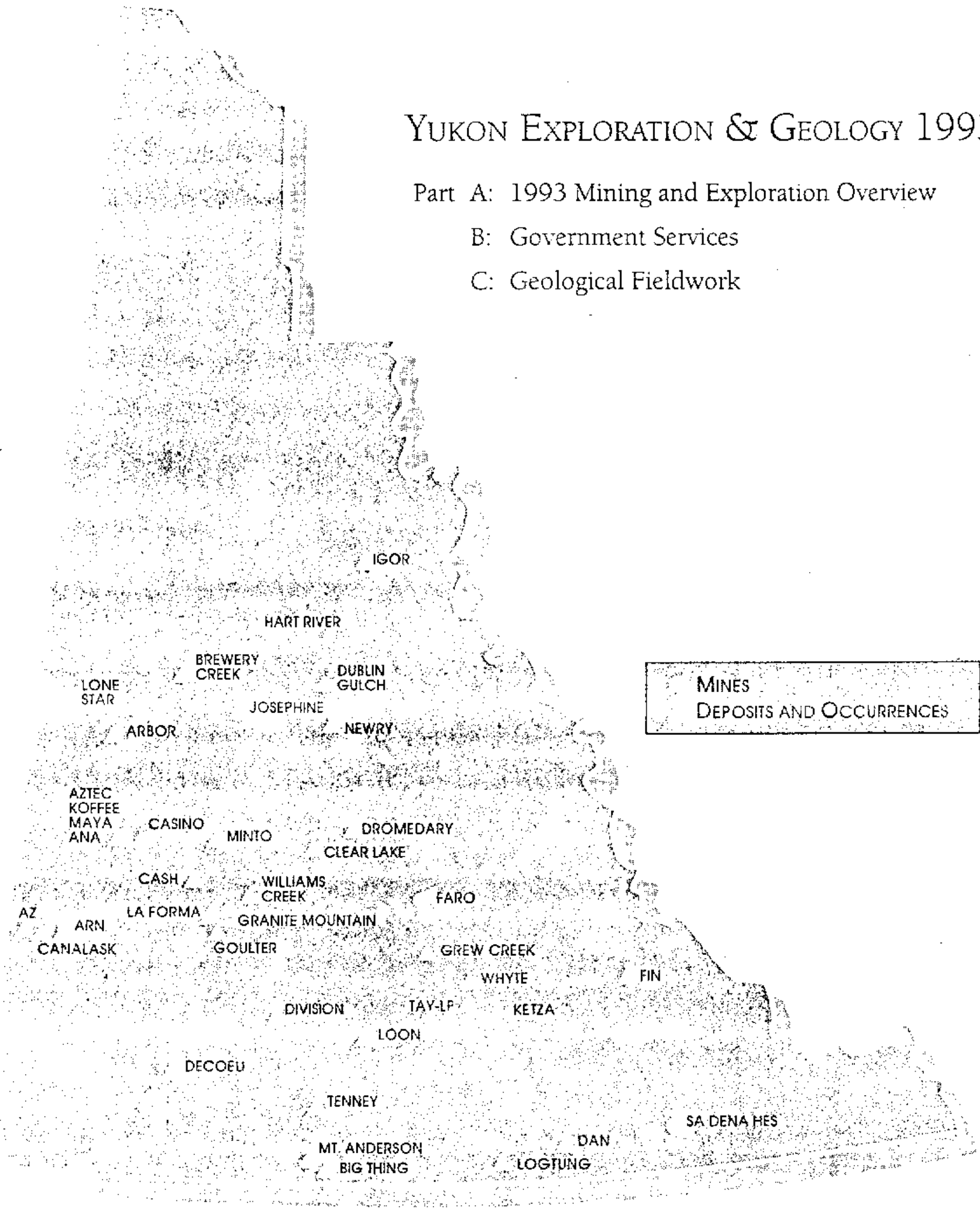
EXPLORATION AND GEOLOGICAL SERVICES DIVISION, YUKON REGION

YUKON EXPLORATION & GEOLOGY 1993

Part A: 1993 Mining and Exploration Overview

B: Government Services

C: Geological Fieldwork



Canada

Canada/Yukon Economic Development Agreement
To strengthen and diversify the Yukon economy

Yukon
Economic Development

Yukon Exploration and Geology 1993

Part A:
1993 Mining and Exploration Overview

Part B:
Government Services

Part C:
Geological Fieldwork

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PREFACE

Yukon Exploration and Geology 1993 consists of three parts: Part A is a comprehensive overview of mining and exploration activity in the Yukon; Part B summarizes the activities of Government agencies in which provide technical and financial assistance to the Yukon mining and exploration industries; and Part C documents new geological information gathered by Canada/Yukon Geoscience Office geologists.

Much of the information in this volume comes from prospectors, exploration geologists and mining companies who are willing to share information for the collective benefit of Yukon's minerals industry. This assistance is gratefully acknowledges and sincerely appreciated.

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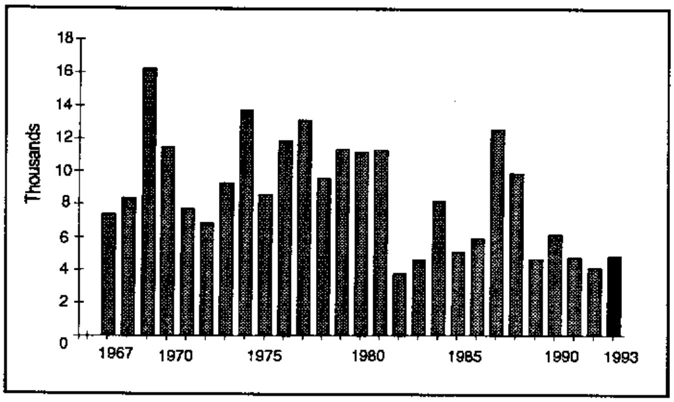
Part A

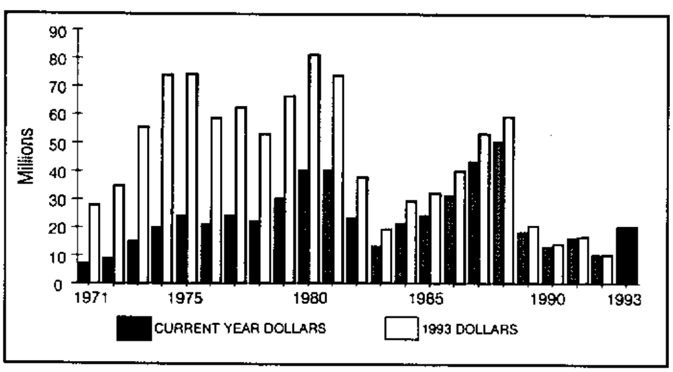
1993 Yukon Mining and Exploration Overview

Introduction

Mining in Yukon suffered a serious blow in 1993 with the closure of Curragh Resources' Sa Dena Hes and Faro-Vangorda mines. For the first time in several decades there are no operating hard rock mines in the Yukon. However, there is some hope for the future. Placer production remained steady at over 100 000 oz. Three projects currently at the feasibility stage could see production in the near future. Exploration spending doubled to $20 million, largely due to Pacific Sentinel Gold Corp.'s 50 000 m drill program on the Casino copper-gold-molybdenum porphyry deposit. The Casino project was Canada's largest single exploration program in 1993, with spending on Casino and several related properties in the Dawson Range accounting for almost $13 million. Most other exploration was carried out on over 35 existing properties. Grassroots exploration remained at a low level. About 5 000 new claims were staked, up slightly from 1992, and claims in good standing dropped slightly to about 40 000.



Quartz Claims Staked 1967–Oct. 1993.



Exploration Expenditures 1971–1993.

Placer Mining

The number of operating placer mines remained about the same as last year as miners abandoned the traditional areas in the Klondike and moved west into the Madson creek area. Total production to the end of November was 104 660 crude ounces, a 5% increase over the same period last year. The increase can be attributed to the sudden increase in bullion prices (U.S. $405 per ounce) experienced early in the year. Placer claims in good standing showed a slight increase over last year.

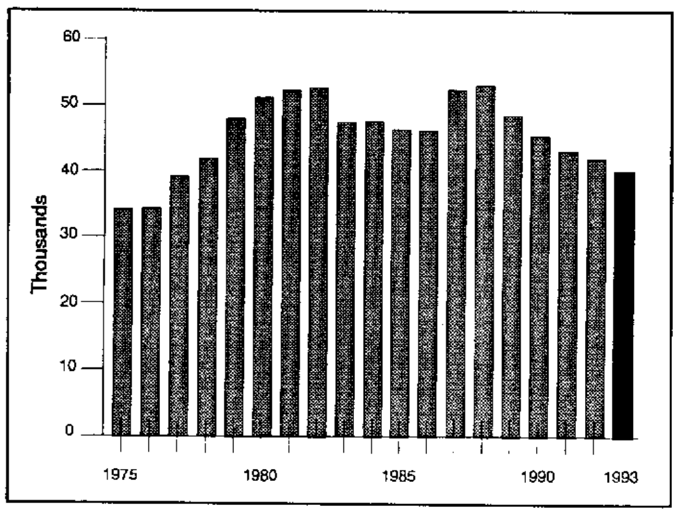
Lode Mining

Curragh continued open pit production from its 7.1 million tonne VANGORDA deposit until April at which time all operations at the mine ceased. Stripping on the 16.9 million tonne GRUM deposit was also curtailed in April. Curragh's SA DENA HES mine in the Watson Lake area ceased operations in April of 1993.

The KING ARCTIC JADE (Minfile #105H 016) property continued to produce nephrite jade, on a seasonal basis, for southern and overseas markets. The property is located in the Frances Lake area, north of Watson Lake.

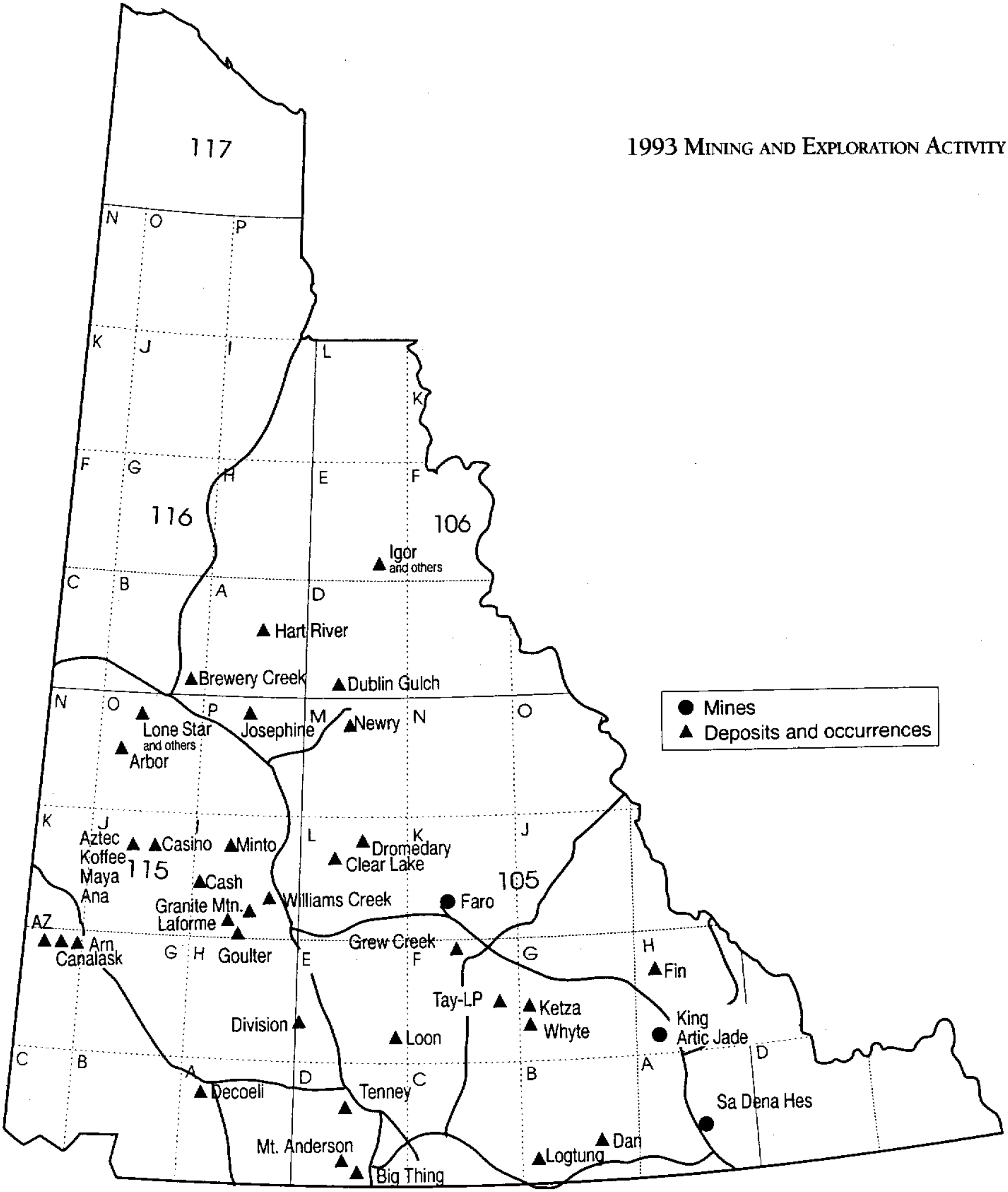
Advanced Development

Western Copper Holdings and Thermal Exploration continued their development of the WILLIAMS CREEK oxide copper-gold deposit (Minfile #115I 008). Thirteen zones, eight of which have been drilled, have been found on the property. The Main or No. 1 zone is the largest, with open pit mineable reserves of 11.34 million tonnes



Claims in Good Standing 1975 to October 1993.

1993 Mining and Exploration Activity



grading 1.15% Cu and 0.52 g/t Au. It strikes NNW dips steeply east, and is approximately 30 m thick and 395 m long .

The deposit is a screen of strongly foliated feldspar-biotite-hornblende-quartz gneiss containing bornite, chalcopyrite and minor molybdenite, as disseminations and fine veinlets. The host is weakly foliated granodiorite of the Granite Mountain Batholith (Jurassic). The deposit is oxidized to a depth of 240 m. It appears on geophysical maps as a magnetic low. The proposed open pit mining operation would use a heap leach/solvent extraction process followed by electrowinning to produce 90 kg copper ingots.

Work in 1993 included numerous engineering and geotechnical studies to assist with environmental permitting, pit wall stability, archaeological site identification, and determination of soil stability and permafrost distribution, along with metallurgical and pre-feasibility studies. A 250 tonne bulk sample was collected from the main zone and trucked to the community of Carmacks, located 40 kilometres to the southeast, for a test leach operation conducted at the village garbage dump. The bulk sample proved to be higher in grade than initial trench samples had shown indicating that the actual grade of the near surface material may be richer in copper than first thought. A feasibility study is expected by year end.

Minto Explorations Ltd., a private company, has acquired the right to develop the MINTO copper gold deposit (Minfile #s 1151 021 & 022) located 75 kilometres northwest of Carmacks. The deposit has a geological reserve of 8 million tonnes grading 1.75% Cu with significant gold and silver values. A mineable reserve of 5.5 million tonnes grading 2.21% Cu, 10.0 g/t silver and 0.65 g/t gold has been delineated. The company proposes to put the deposit into production with a mining rate of 1 550 tonnes per day. Work in 1993 consisted of an airborne radiometric survey, and diamond drilling (984 metres) for infilling and metallurgical studies.

The Minto Deposit resembles the Williams Creek Deposit and consists of widely spaced, sub-parallel, sub-horizontal, discontinuous gneissic zones in Jurassic granodiorite. The gneisses are variably mineralized with chalcopyrite, bornite and magnetite, minor pyrite, and traces of molybdenite. The gneissic zones are similar in composition to the granodiorite but contain more biotite and quartz. The gneissic zones define a synform, the axis of which trends northwest through the east side of the Minto claims. The east limb dips steeply (45–60°) west, whereas the west limb dips more gently (15–30°) east. Two areas of mineralization have been explored by drilling, both on the western limb. The main zone is at least 335 m long and 247 m wide and has a vertical thickness of 6 to 61 m. Drilling in 1993 better defined a lower, sub-parallel mineralized zone. Ore zonation in the deposit depends largely on host rock lithology with bornite-chalcopyrite-magnetite zones occurring with quartzofeldspathic gneiss and siliceous ores (chalcopyrite-pyrite) with biotite rich gneiss.

Loki Gold Corporation negotiated a 100% purchase of the BREWERY CREEK (Minfile #116B 160) gold deposit from Hemlo Gold Mines. The purchase agreement required Loki to transfer two million shares of Loki to Hemlo Gold and pay Hemlo $2 million within 90 days. The property is located 57 kilometres east of Dawson City, a distance suitable for a drive-in drive-out operation, eliminating the necessity of onsite housing. Loki Gold Corporation has moved its head office to Dawson City and has become a Yukon corporation.

Trenching and drilling to Jan/92 outlined a large, low grade oxide gold deposit with reserves of 15 471 570 tonnes grading 1.89 g/t Au, using a cutoff grade of 0.5 g/t and a specific gravity of 2.6. This reserve includes 10 810 376 tonnes of heap leachable oxide material grading 1.99 g/t Au. The deposit contains 28 910 703 grams Au, of which 21 564 056 grams are contained in oxide. The reserves are distributed in eleven zones over a strike length of more than 12 km. Individual zones are about 100 m wide and 20 m thick. Most of the reserves lie within 60 m of surface on a south-facing dip slope, and are amenable to open pit mining with a stripping ratio of 1.18:1. A 30-day column leach test on oxide material gave an average recovery of 90.6%.

The property is located in unglaciated terrain on the west edge of Selwyn Basin, adjacent to the Tintina Fault. The deposit is hosted by Cretaceous quartz monzonite and underlying greywacke of the Devono-Mississippian Earn Group. Mineralization is structurally controlled by several imbricated low-angle basal detachments and by sets of vertical listric faults which run northwest, northeast and east-west. The main basal detachment separates a quartz monzonite dike swarm from underlying greywacke, shale, graphitic argillite, bedded barite, pyroclastic rocks and chert pebble conglomerate of the Devono-Mississippian Earn Group. The fault has been traced over a strike length of 10 km between the Pacific and Bohemian zones. Earn Group shale beneath the fault is sheared and shows no evidence of hornfelsing. Lenses and slivers of sheared, altered argillite and sheared, bleached intrusive rock are common along the fault zone.

Mineralization consists of submicroscopic gold particles, 0.5 microns in size, associated with pyrite and fine-grained arsenopyrite. The gold appears to be associated with a fine quartz stockwork in areas of strong phyllic alteration. The stockworks occur in high angle north and east trending extensional faults expressed as zones of close-spaced fracture cleavage cutting the dikes, and in wedge shaped zones of silicified, brecciated graphitic footwall rocks along the trace of the basal detachment fault. Low-temperature quartz-stibnite veins appear to postdate the gold deposition. High grade pockets of oxide material occur locally.

Loki Gold continued exploring the property in 1993 with definition drilling on the Canadian and Foster zones for pit design and step-out drilling on the reserve blocks. The program also identified new zones near the Foster and Pacific zones. Some limited drilling was also completed on the Classic, Bohemian and Schooner zones located to the southeast. Reverse circulation drilling in 1993 consisted of 7 956 metres in 151 holes.

Base Metal Exploration

Pacific Sentinel Gold Corporation carried out an extensive diamond drilling program on the CASINO property (Minfile #115J 028). Casino is one of the largest bulk tonnage copper-gold-molybdenum porphyry deposits in North America. It is located at the northwest end of the Dawson Range, 60 km west of the end of the Mt. Freegold road. The property was drilled extensively in the late 1960's and early 1970's by Casino Silver Mines, which found uneconomic copper grades but did not assay for gold. The deposit is hosted by the Casino Complex, a subvolcanic suite of breccias, dykes and porphyritic phases dated at about 70 Ma, which intrude granodiorite of the Mid-Cretaceous Klotassin Batholith. The mineralized unit is a conical breccia body measuring about 600 by 350 m on surface, which plunges steeply to the south. The mineralization is zoned, and consists of a leached cap overlying a supergene enriched alteration zone and an underlying hypogene zone.

The 1993 drill program got underway in March with four diamond drills. By September there were six drills producing more than 300 metres of core per day. By the end of the season in middle November a total of 50 000 metres of core in 126 holes had been completed. Engineering studies on gravels for construction of foundations and infrastructure, environmental baseline studies on local fauna, and socioeconomic impact studies were expanded in 1993 and are expected to be accelerated in the coming year.

Pacific Sentinel reports reserves of 558 million tonnes containing 1.43 billion kilograms of copper, 184.79 million grams of gold and 140 million kilograms of molybdenum from the leached cap, supergene, and hypogene zones. Included in this calculation is an expanded high grade open pit mineable core of 90 million tonnes grading 0.4% Cu, 0.05% Mo and 0.48 g/t Au. The deposit remains open to the north and west. Drilling is expected to continue in the spring of 1994.

Eastfield Resources, in partnership with Breckenridge Resources, Achievers Training Group, Rockwealth International, and Canadian Comstock Explorations, worked on five recently acquired properties adjacent to the western boundary of the Casino deposit. The program included geochemical sampling and geophysical surveys. Geochemical sampling on the Ana property (Minfile #115J 101) was extended eastward to the common boundary with Pacific Sentinel's Casino property. IP and magnetic surveys were also completed on the grid. Coincident geophysical and geochemical anomalies outlined an extensive open-ended target 1.8 kilometres long by 1.0 kilometre wide. The company reported strong quartz-sericite alteration in breccias similar to those found at Casino. The target was tested with 804 metres of HQ diamond drilling in six holes.

The Granite Mountain copper property (Minfile #115I 057), located 45 kilometres northwest of Carmacks, was examined by Pintail Resources. Exploration included geological mapping, geochemical sampling, proton magnetometre and VLF surveys, followed by bulldozer trenching. A crudely arcuate, east-trending copper geochemical anomaly 1500 m long and 60 to 240 m wide is associated with a mineralized breccia zone along the south side of a Cretaceous(?) stock. The stock, which varies from biotite granite to quartz monzonite diorite in composition, intrudes hornblende granite of the Jurassic Granite Mountain Batholith and is cut by a sill-like body of quartz porphyry and granitic dykes up to 30 m wide. Chalcopyrite and pyrite occur as disseminations and in fracture veinlets around the margin of the stock, while molybdenite is in quartz veinlets. Incomplete surface leaching locally extends to depths of 73 m. The 1993 program was directed toward evaluating the gold potential of the porphyry and locating epithermal mineralization found in float samples.

Mitsui Kinzoku Resources of Canada Ltd and Total Energold Corp. continued exploring the CLEAR LAKE (Minfile #105L 045) shale hosted lead-zinc deposit located 80 km northwest of the town of Faro. The deposit is hosted by carbonaceous argillite of the Devono-Mississippian Earn Group, and is bound to the east by the Tintina Fault and to the west by Mid-Devonian Askin Group shallow water clastic and carbonate rocks. Claims were first staked in the area in 1965 following the discovery of the Vangorda deposit to the southeast. The deposit consists of a sigmoid-shaped massive sulphide body 1000 m long by 120 m wide, which contains approximately 30 million tonnes of massive sulphides, including 5.53 million tonnes grading 11.34% Zn, 1.99% Pb and 40.8 g/t Ag. Recent work has shown that the deposit is folded, faulted and overturned. Evidence of exhalative activity includes silicified hanging wall and footwall rocks, pyritized worm tubes, and a separate tuff and barite unit in the stratigraphic footwall. The 1993 exploration program tested coincident gravity and magnetic anomalies peripheral to the known mineralized area. The six holes intersected predominantly chlorite graphite quartz phyllite with up to 30% pyrrhotite. A total of 1 456 metres of drilling was completed.

The Canalask nickel-copper deposit, located 320 kilometres northwest of Whitehorse, was explored with trenching and sampling by Expatriate Resources. Pyrrhotite and lesser amounts of pentlandite, sphalerite, pyrite, marcasite and chalcopyrite, occur as fine-grained patchy disseminations and less commonly as small massive lenses in Permo-Pennsylvanian volcanic rocks of the Station Creek Formation. These rocks are dense and siliceous and probably of tuffaceous origin. The main sulphide zone lies 122 m from the footwall contact of a peridotite sill. The main zone has a length of 107 m and a width of 15 m and is cut off at the west end by a fault. Two other zones are also present but of lower grade. Reserves were given by Canalask in 1956 as 491 700 tonnes grading 1.68% Ni and 0.04% Cu, and by Discovery ML in 1967 as 454 545 tonnes at 1.5% Ni.

First Yukon Silver Resources optioned the GOSSAN/DAN property (Minfile # 105B 026, 027) in the Swift River area to Cominco Exploration. The property covers several showings of massive sphalerite hosted by Late Paleozoic calc-silicate rocks and felsic tuff along an east-west trend. Cominco conducted geophysical surveys, prospecting and trenching followed by an eight hole diamond drill program totalling 1 581 metres.

Cominco also explored its FIN property (Minfile #105H 047) with geophysics and mapping. The occurrence consists of sphalerite and galena in carbonaceous, calcareous and pyritic laminated mudstone of the Devono-Mississippian Earn Group. A 1000 by 200 m coincident lead and zinc soil anomaly with spotty silver values occurs near the showing, and drilling in 1980 intersected minor laminated sphalerite, galena and pyrite, pyrite-barite nodules and several barite lenses up to 15 cm thick. Drilling to the south in 1984 intersected layers of pyrite and sphalerite mineralization up to 70 cm thick, which assayed 11.6% Zn and 0.4% Pb. A geophysical survey in 1991 produced several EM anomalies, one of which is identical to the anomaly over the main zone. In 1992, the extent of the mineralization was tested by six reconnaissance holes averaging 100 m in depth.

Noranda Exploration Co. Ltd drilled 4 holes for a total of 232 metres of diamond drilling on the AZ property (Minfile #115F 050). The property is located on the southwest flank of Hump Mountain north of the White River. The AZ showing consists of poorly exposed copper-gold-bearing skarn in a gently dipping layer of limestone and calcareous volcanic rocks interbedded with Triassic Nikolai Greenstone (rift basalt) in contact with a Cretaceous quartz monzonite to granodiorite stock.

Pamicon Developments Limited, Equity Engineering Limited and Westmin Resources Ltd carried out an exploration program in the Wernecke and Ogilvie Mountains. The companies were targeting breccia bodies within the Middle Proterozoic Wernecke Supergroup and Fifteenmile group. The bodies, collectively termed Wernecke Breccias, consist of variably metasomatized clasts of siltstone and dolostone of host lithologies and, in some cases, clasts of syn- to posttectonic, gabbroic to dioritic rocks. Mineralization, consisting of Cu, U, Co, Ag and Au, occurs within metasomatized clasts and in sedimentary wallrocks. Exploration is following the Olympic Dam deposit model from Australia. The 1993 program included extensive staking, prospecting, rock geochemistry and geological mapping/ prospecting, with magnetic and IP surveys on some properties. The Joint Venture group has been joined by Newmont, and an extensive program is planned for 1994.

International Prism Explorations Ltd. and Western Keltic Mines, among others, also explored for economic deposits within the Wernecke and Ogilvie mountains.

In 1992 Inco Limited optioned the Hart River deposit (Minfile #116A 009) located approximately 150 kilometres by air northeast of Dawson City. The volcanogenic massive sulphide deposit occurs within the Middle Proterozoic Gillespie Lake Group where orange dolomite exhibits a facies change to argillite. In 1993, exploration included an extensive HLEM geophysical survey followed by diamond drilling of anomalies.

Gold exploration

In the Mayo Mining District, Ivanhoe Goldfields evaluated several properties in the Dublin Gulch and Haggart Creek areas (Minfile #'s 106D 021-029) for their Fort Knox type bulk tonnage gold potential. The properties were worked extensively in 1992 by Amax. Gold bearing quartz-arsenopyrite veins occur along the contacts of Cretaceous granite and granodiorite stocks intruding Proterozoic to Lower Cambrian sedimentary rocks. In 1993, Ivanhoe completed 10 reverse circulation holes totalling 2078 metres, 250 metres of excavation trenching, 2.5 kilometres of Genie EM survey and a contour soil sampling program. The drilling was done on the Eagle zone. Other work included geological mapping and baseline environmental work.

Aurchem Exploration Ltd continued exploration on its DISCOVERY CREEK (Minfile # 1151 093) option, 50 km west of Carmacks. Gold and silver-bearing veins occur along two major north-trending structures named the WILLOW CREEK and ELIZA CREEK zones. The veins cut Paleozoic(?) metasedimentary rocks and Cretaceous granodiorite and diorite. The property is thought to host both porphyry and vein mineralization. Work in 1993 consisted of an expanded geophysical survey.

Arbor Resources Inc. and other companies in the Arbor Group continued to explore their substantial holdings in the Klondike District near Dawson. Exploration included geological mapping and trenching. Reconnaissance work was carried out on recently staked ground in the Black Hills south of the Klondike.

Kennecott Canada Inc. increased their exploration program in the Klondike. The company, working in conjunction with the Arbor Group of companies, was involved in property acquisition, percussion drilling, trenching, mapping and geophysical surveying on several properties in the area. The season began with a 3 100 metre percussion drill program (41 holes) on the Lone Star occurrence (Minfile # 115O 072). The Boulder Lode vein on the Lone Star property produced 6940 tonnes of 5 g/t material in the early 1900's. The vein is one of a series of discordant quartz and quartz-pyrite veins located in the hanging wall of the low angle, southeast trending Lone Star thrust fault. The fault cuts middle Permian quartz augen schist (Klondike Schist). A syngenetic origin for mineralization has been suggested on the basis of lead isotopic data. Kennecott also conducted several grassroots level exploration programs and property examinations elsewhere in the Yukon.

On Mt. Anderson, in the Wheaton River area south of Whitehorse, Adda Minerals continued exploration for gold-bearing veins and skarns on the ROB claims (Minfile # 105D 029).

Feather Gold Resources and Amcorp Industries diamond drilled on their property adjacent to the Arctic Big Thing mine (Minfile #105D 056) on Montana Mountain east of Carcross. Veins on the ridge zone are thought to be the western extension of the Big Thing Vein. The showing occurs in Cretaceous granodiorite which intrudes Paleozoic(?) Volcanic rocks and Jurassic Laberge Group sedimentary rocks. Along the contact between the volcanic and sedimentary rocks, the volcanic rocks are flow banded and extensively brecciated. Ten holes totalling 762 metres intersected moderate to low grade precious metal and base metal mineralization over a strike length of 160 metres.

Yukon Revenue Mines returned to the Yukon exploration scene with the optioning of the Aurex property (Minfile # 105M 060 Newry). The property covers an area explored originally for the southeast extension of the Silver King structure mined by United Keno Hill

Mines. The area is underlain by Proterozoic to lower Cambrian Hyland Group metasedimentary and metavolcanic rocks. Skarns identified in old trenches suggest the presence of a buried pluton. A percussion drill program of 128 holes totalling 2 169 metres outlined extensive gold-arsenic anomalies and zones of elevated gold, arsenic, tungsten, bismuth, copper, lead and zinc from skarn layers within quartz-sericite schist.

Mountain Province Mining Incorporated conducted a diamond drill program on their Ketza River property (Minfile # 105F 122 WHYTE) adjacent to Canamax's Ketza gold mine. Two zones of sulphide bearing mantos in lower Cambrian carbonate, some 1 500 feet apart, were tested. Most holes intersected disseminated and massive sulphides, including pyrrhotite, pyrite and arsenopyrite. The mineralization proved to be highly anomalous in arsenic and copper, and locally in lead, zinc, silver, antimony and bismuth.

Coal Exploration

Cash Resources explored the Division Coal (Minfile# 115H 013) deposit located about 90 kilometres northwest of Whitehorse. The deposit is about 18 kilometres west of the Klondike highway along which runs a major power transmission line. Over 30 coal seams occur within a 400 m sandstone and shale interval which forms part of the Jurassic Laberge Group. The main Cairnes seam occurs near the base of the sequence, on the northeast limb of a northwest-trending syncline. Where exposed in a surface trench it is 15.6 m thick and contains two partings, 92 and 54 cm thick. Drilling in 1972 showed that a 2 m thick coal seam occurs in the footwall, 7.5 m stratigraphically below the Cairnes seam. At least 27 other seams, ranging in thickness from 0.2 to 2.5 m, lie stratigraphically above it. The hanging wall seams appear to be less continuous than the Cairnes and footwall seams, but aggregate thickness of all the seams wider than 0.5 m is 24.8 m. Proximate analyses and petrologic and geochemical studies show that the Cairnes seam has an ASTM rank of High Volatile Bituminous B and a calorific value of about 7500 kcal/kg (13 500 Btu/lb). Weighted ash content for the seam, exclusive of major partings, is 21.8%. Sulphur content is 0.3% and trace element contents are very low (0.6 ppm Se; 0.5 ppm Sb; 3.0 ppm As). The 1993 program included detailed mapping around the main showing, hand trenching, and 16 diamond drill holes totalling 1826 metres. Drill indicated, surface and underground, mineable reserves now total 11 200 000 tonnes.

1993 Exploration Projects

COMPANY	PROJECT	MINING DISTRICT	MINFILE NUMBER	WORK TYPE	COMMODITY
Adda Minerals	ANDERSON	Whitehorse	105D 029	GP, T	Au, Ag, Pb
Arbor Resources	DAWSON	Dawson	115N & O	T, GP, GC	Au
Aurchem Explorations	GOULTER	Whitehorse	115I 093	GP	Au, Ag
Cash Resources	DIVISION COAL	Whitehorse	115H 013	DD	Coal
Cash Resources	DAWSON	Whitehorse	105D	DD	Cu, Au
Cominco Resources	FIN	Watson Lake	105H 047	DD	Zn, Pb, Ag
Cominco Resources	DAN	Watson Lake	105B 027	G, GC, DD, GP	Zn
Dromedary Minerals Inc.	DROMEDARY	Whitehorse	105L 051	GC, GP	Zn, Pb
Eastfield Resources Achievers Training Group	MAYA, NICE	Whitehorse	115J 035	GC, G, GP	Cu
Eastfield Resources Breckenridge Res.	ANA	Whitehorse	115I 101	DD, G, GP, GC	Cu
Eastfield Res. Canadian Comstock	AZTEC	Whitehorse	115I 035	GC, G, GP	Cu
Eastfield Res. Rockwealth Res.	KOFFEE	Whitehorse	115J 036	GC, G, GP	Cu
Expatriate Res.	CANALASK	Whitehorse	115F 045	GC, G, T	Ni, Cu
Feather Gold Amcorp Industries	ROOTS	Whitehorse	105D 056	DD	Au, Ag
Graham Davidson	DECOELI	Whitehorse	115A 040	GP	Au, Cu, Ni
Hemlo Gold Mines	KETZA	Watson Lake	105D 019	compililation	Au

COMPANY	PROJECT	MINING DISTRICT	MINFILE NUMBER	WORK TYPE	COMMODITY
Inco	HART RIVER	Mayo	116A 009	G, GP, GC, DD	Cu, Pb, Au
Ivanhoe Gold Res.	DUBLIN GULCH	Mayo	106D 021-029	PD, T, G, GC	Au
Ivanhoe Gold Res.	JOSEPHINE	Mayo	115P 011	G, GC	Au
Kennecott Canada	LONE STAR	Dawson	115O 072	RC, T	Au
Kennecott Canada	VARIOUS	Dawson	various	GC, G, GP	Au
Kennecott Canada	VARIOUS	various	various	R, G, PE	Cu, Zn, Pb
Loki Gold	BREWERY CREEK	Dawson	116B 160	G, GC, DD, PD, T	Au
Mendocino Res.	ARN/TAYLOR	Whitehorse	115F 048	T	Au
Minto Explorations	DEF-MINTO	Whitehorse	115I 021, 022	DD, GP	Cu, Au, Ag
Mitsui Kinzoku Res.	CLEAR LAKE	Whitehorse	105L 045	DD	Pb, Zn
Mountain Province	WHYTE	Watson Lake	105F 122	DD	Au, Ag
NDU Resources	LOGTUNG	Watson Lake	105B 039	DD, GC, G	Au, Ag
Noranda	AZ	Whitehorse	115F 051	DD	Cu, Au
Pacific Comox Res	TAY-LP	Watson Lake	105F 121	G, GC	Au
Pacific Mariner Exp Wealth Resources	CLARA	Dawson	115O 057	GP, T	Au
Pacific Sentinel Gold Corp.	CASINO	Whitehorse	115I 028	DD	Cu, (Au, Mc)
Pamicon Development Equity Engineering International Prism Westmin Resources	VARIOUS	Mayo	106C, D, E, F	G, GC, GP	Cu, Au, U
Patriate Resources	CASH/NITRO	Whitehorse	115I 037	GP	Cu, Mo, Au
Pintail Resources	GRANITE MTN	Whitehorse	115I 057	GP, GC	Cu, Au
Redell Mining	LAFORMA	Whitehorse	115I 054	GC	Au
Silver Sabre Res.	TENNEY	Whitehorse	105D 121	T, GC,	Pb, Ag, Cu
Western Keltic	NEW	Mayo	115P	G, GC	Cu, U, Co
Western Copper Thermal Exploration	WILLIAMS CREEK	Whitehorse	115I 008	T, PD	Cu, Au
YGC Resources	GREW CREEK	Whitehorse	105K 009	DD, GC, GP	Au, Ag
Yukon Revenue	NEWRY	Mayo	105M 060	G, GC, PD,	Au

T Trenching; DD Diamond Drilling; PD Percussion Drilling; G Geology; GC Geochemistry; GP Geophysics; AG Airborne Geophysics; R Reconnaissance; PE Property Evaluation

1993 Drilling Statistics

PROJECT	DIAMOND Metres	DRILLING # Holes	PERCUSSION Metres	DRILLING # Holes
BREWERY CREEK Loki Gold	—	—	7 ,956	151
WILLIAMS CREEK WCopper/Thermal	3,781	11	2, 805	11
DUBLIN GULCH Ivanhoe Goldfields	—	—	2,079	10
CLEAR LAKE Mitsui Kinzoku	1,456	6	—	—
AZ Noranda	232	4	—	—
LONESTAR Kennecott Canada	—	—	3,100	41
DAN Cominco	1,581	8	—	—
CASINO Pacific Sentinel	50,316	127	—	—
LONE STAR Kennecott	1,212	20	—	—
MINTO Minto Explorations	984	8	—	—
HART RIVER Inco	1,200	6	—	—
NEWRY Yukon Revenue	—	—	2,169	128
BIG THING Feather Gold, Amcorp Industries	762	10	—	—
KETZA Mountain Province	1,533	23	—	—
LOON Cash Resources	116	2	—	—
DIVISION COAL Cash Resources	1,141	11	—	—
GREW CREEK YGC Resources	1,944	17	—	—
ANA Eastfield Resources	804	6	—	—
MOOSEHORN Hartley/Almberg	—	—	339	36
LOGTUNG NDU Resources	500	2	—	—
TOTALS	**62,569**	**230**	**15,643**	**366**

PART B

GOVERNMENT SERVICES

INTRODUCTION

In the Yukon Territory, government technical and financial assistance to the exploration and mining industry is administered through three programs. These are: Exploration and Geological Services Division, Northern Affairs Program, Indian and Northern Affairs Canada; Mineral Resources Program, Energy and Mines Branch, Department of Economic Development, Government of Yukon; and the Canada/Yukon Mineral Development Agreement. Each organization provides complementary services which together aim to provide a comprehensive geoscience data base and technical and financial support. Further assistance and information on mining and exploration in the Yukon can be obtained at the following addresses.

1. **Mineral Resources Directorate, Northern Affairs Program**
   200 Range Road,
   Whitehorse, Yukon Y1A 3V1
   a) **Exploration and Geological Services Division**
      (403) 667-3200 (S.R. Morison, Chief Geologist)
      (403) 667-3204 (Geoscience Information and Sales)
      (403) 668-2176 (FAX)
   b) **Mineral Development Division**
      (403) 667-3204 (A. Waroway, Regional Manager)
      (403) 667-6351) (FAX)
   c) **Mineral Rights Division**
      (403) 667-3260 (R. Ronagan, Regional Manager)
      (403) 667-8601 (FAX)

2. **Energy and Mines Branch**
   Department of Economic Development
   Government of Yukon
   P.O. Box 2703,
   Whitehorse, Yukon Y1A 2C6
   a) **Mineral Resources Program**
      Street Address: #305–211 Main Street,
      (403) 667-5884 (R. Hill Manager)
      (403) 667-8601(FAX)
   b) **Canada/Yukon Geoscience Office**
      Street Address: 2099 Second Avenue,
      (403) 667-8510 (J. Kowalchuk, MDA Coordinator)
      (403) 667-8516 (D. Murphy, Senior Project Geologist)
      (403) 667-7074(FAX)

EXPLORATION AND GEOLOGICAL SERVICES DIVISION (EGSD), GOVERNMENT OF CANADA

Exploration and Geological Services Division (EGSD) is part of the Mineral Resources Directorate, Northern Affairs Program, Indian and Northern Affairs Canada. The Mineral Resources Directorate is responsible for administration of mineral rights through the Yukon Quartz Mining and Placer Mining Acts. The primary role of EGSD is to accumulate and disseminate geological information, and provide related services that assist the exploration, development, and management of mineral resources in Yukon. Functions include detailed studies of mineral deposits and their geological setting, monitoring and reporting industry activities, and approval of technical reports for assessment credit. EGSD maintains a geological library, a core library, and a Geoscience Information and Map Sales Outlet.

Staff Activities

Staff presently includes S.R. Morison (Regional Manager/Chief Geologist), J.G. Abbott (Senior Geologist), T.J. Bremner (Geologist), D. Emond and N. Hulstein (Environmental Geologists), R. Deklerk, W.P LeBarge and D. Ouellette (Staff Geologists), M. Burke (Geotechnician and Core Librarian), and A. Wagner (Office Manager). E. Phillips (Manager, Map Sales) retired in 1993 and will be greatly missed by industry and government people who had the pleasure of working with her.

Stephen Morison (Chief Geologist), among other duties, is involved in the planning and implementation of the Geoscience Element of the Canada/Yukon Mineral Development Agreement as co-chair of the Geoscience Technical Committee. He continues to use his placer sedimentology expertise to advise client groups and support related geological studies. Grant Abbott (Senior Geologist) is chiefly responsible for 1:50 000 scale mapping projects and this year worked on Hart River 116 A/10 and 11 sheets. He is currently located at the MDA Geoscience office where he has taken on the role of scientific advisor. Trevor Bremner (Mineral Deposits Geologist) completed the YUKON MINFILE update and carried out fieldwork on the Brewery Creek deposit (MINFILE #116B 160) east of Dawson. Robert Deklerk (Staff Geologist) is responsible for approving placer and quartz assessment reports and visiting active mining properties in the Dawson and Mayo Mining Districts. Dennis Ouellette (Staff Geologist) is responsible for visiting mining properties and approving quartz assessment reports in the Whitehorse and Watson Lake Mining Districts. Bill LeBarge (Staff Geologist) returned from completing his MSc thesis, Sedimentology of Placer Gravels near Mt. Nansen, central Yukon Territory, and will be concentrating his efforts toward placer related projects in Yukon. Mike Burke (Geotechnician) continues to update the search and reporting capabilities of YUKON MINFILE and is coordinating renovations to the H.S. Bostock Core Library which will improve the core logging, sampling and viewing areas as well as the laboratory facilities.

Publications

EGSD publishes its own technical reports, and those produced by the Canada/Yukon Mineral Development Agreement. The two main products of EGSD are this volume, and YUKON MINFILE, a database containing information on mineral occurrences in the Yukon. Yukon Exploration and Geology is published annually in late January or early February. YUKON MINFILE is updated annually and released in late spring. From time to time EGSD also publishes bulletins on geological studies undertaken by staff and colleagues. A complete publication list is available upon request.

YUKON MINFILE is currently available in hard copy or on diskette as a set of word processor text files. Occurrence locations are recorded on 38 maps which cover all of Yukon, mostly at a scale of 1:250 000. A second version of YUKON MINFILE is also available and consists of a DBase file with UTM coordinates for each location and several major search fields. This version allows mineral occurrence locations to be plotted by CAD and GIS programs. A third version is modelled on B.C.'s Minfile system. This version continued to be improved and is scheduled for release on diskette in 1994. In the meantime, please contact Mike Burke (403-667-3202) for searches or for further information.

Geoscience Information and Map Sales

EGSD also manages the Yukon outlet of the Canada Map Office and sells topographic, geological (surficial and bedrock), aeromagnetic, aeronautical and land use maps. Geological and other relevant publications by EGSD, Canada/Yukon Mineral Development Agreement, Geological Survey of Canada, and Geological Association of Canada are also available.

Library

EGSD maintains a library of geological texts and journals and selected air photos covering Yukon south of 65°. The public is welcome to view these materials.

H.S. Bostock Core Library

The H.S. Bostock Core Library houses approximately 120 000 metres of diamond drill core from 179 Yukon properties. The facility is located across the street from the Northern Affairs building at 200 Range Road. The core is stored in its original boxes, with no sample reduction. Confidentiality is maintained on the same basis as mineral claim assessment reports; a letter of release from the company owning the property must accompany a request to view confidential core. Status of specific core can be checked and arrangements to view or submit new core can be made by contacting the core librarian at 667-3202. Diamond saws, a core splitter and microscopes are available for use in heated examination rooms.

Mineral Resources Program, Energy and Mines Branch, Government of Yukon

The Mineral Resources Program (MRP) is part of the Energy & Mines Branch whose primary objective is to encourage the development of Yukon's mineral and energy resources. MRP provides services in three main areas: Mining Programs, Mineral Policy, and the Canada/Yukon Mineral Development Agreement (MDA). MRP strives to increase public knowledge of the mining industry, and is available to advise companies and individuals on the relevant legislation and support programs for the industry.

R. Hill manages the Mineral Resources unit and the Canada/Yukon Geoscience Office, prepares briefings, and undertakes special projects at the request of the Minister or Deputy Minister. S. Abercrombie conducts mineral policy research projects relating to federal and territorial legislation and policies, and conducts economic and financial reviews of mining projects. K. Pelletier administers the Yukon Mining Incentives Program (YMIP) program and provides advice to individuals and companies on the relevant legislation and other government programs.

Yukon Mining Incentives Program

The Yukon Mining Incentives Program (YMIP) is designed to promote and enhance mineral prospecting, exploration and development activities in the Yukon. The program's function is to provide a portion of the risk capital required to locate and explore mineral deposits. Grassroots programs (Prospecting and Grubstake categories) are conducted on open ground (crown land) and Target Evaluation programs are conducted on undeveloped mineral claims. Technical assistance is offered to prospectors upon request.

Program funding for 1993/94 was $750,000. Two interest groups representing the mining industry were awarded grants to a total of $30 000 and an equal number of grants were allocated to each category, 28 in the Grassroots programs and 28 in the Target Evaluation Program. Approximately 60% of the total was allocated to placer gold exploration projects.

Canada/Yukon Mineral Development Agreement

The Mineral Development Agreement (MDA) is funded under the 1991–1996 Canada/Yukon Economic Development Agreement (EDA). The agreement includes three elements: 1) Geoscience; 2) Mining Technology; and 3) Information. The Energy and Mines Branch, Department of Economic Development, Government of Yukon administers the agreement. The Agreement is managed by a committee which includes representatives of Indian and Northern Affairs Canada, the Mining Sector of the Department of Natural Resources Canada, Government of Yukon, the Council for Yukon Indians, and the Yukon

Chamber of Mines. Independent project proposals are considered under all elements. Enquiries should be directed to the MDA coordinator c/o the Canada/Yukon Geoscience Office.

1) Geoscience Element

The long term objective of the Geoscience Element is to promote an active and successful hardrock and placer exploration industry by accelerating the development of a comprehensive, modern geoscience information base. The main components of the program are geological mapping at 1:50 000 scale in more economically significant areas of the Yukon, and regional geophysical and geochemical surveys.

Canada/Yukon Geoscience Office

The Canada/Yukon Geoscience office has been established in order to develop locally-based expertise in the regional geological setting of Yukon mineral deposits. The project manager is Rod Hill and the scientific authority is Steve Morison. Geoscience Office staff include D. Murphy (Senior Geologist), T. Fuller (Placer Geologist), C. Hart (Project Geologist), S. Johnston (Project Geologist), D. Thorkelson (Project Geologist), J. Kowalchuk (coordinator), W. VanRanden (Draftsperson), and D. Carruthers (Administrative Assistant). Seasonal geological assistance was provided by F. Andersen, J. Timmerman, D. Brent, N. Hachey, D. Heon, J. Hunt, and C. Wallace. C. Roots from the Geological Survey of Canada, and G. Abbott from Exploration and Geological Services Division, Northern Affairs Program are being supported by the Geoscience Program. Ongoing mapping programs are shown on the accompanying figure and in 1993, included the following map areas:

a) C. Hart and J. Hunt in the Whitehorse Trough near Whitehorse (105D/14).
b) S. Johnston and J. Timmerman in Yukon-Tanana Terrane near Aishihik Lake(115H/6,7)
c) D. Murphy and D. Heon in Western Selwyn Basin in the Clear Creek Area (115P/15).
d) D. Thorkelson and C. Wallace in the Wernecke Supergroup and Pinguicula Group in map area (106C/13).
e) E. Fuller and F. Andersen in unglaciated surficial deposits in the Dawson Range (115I/13; 115J/13,14,15,16; 115O/3,4,5,6,7,8,12; 115P/5,12).
f) C. Roots and D. Brent in Selwyn Basin in Lansing map area (105N), at 1:250 000 scale.
g) G. Abbott in the Hart River area along the boundary between Mackenzie Platform and Selwyn Basin (completed) (116A/10,11).

Regional Surveys

Regional geochemical and geophysical surveys are conducted by the Geological Survey of Canada. A combined radiometric, aeromagnetic and VLF Survey was flown in the Dawson Range (115J/9,10 and 115I/12E1/2) over the Casino porphyry copper molybdenum deposit and nearby areas with high mineral potential. A regional stream sediment survey in Dezadeash map area (115A), and a lake sediment orientation survey in Watson Lake map area (105Aw1/2) were completed. Results for all surveys will be released during the summer of 1994.

Other Geoscience Programs

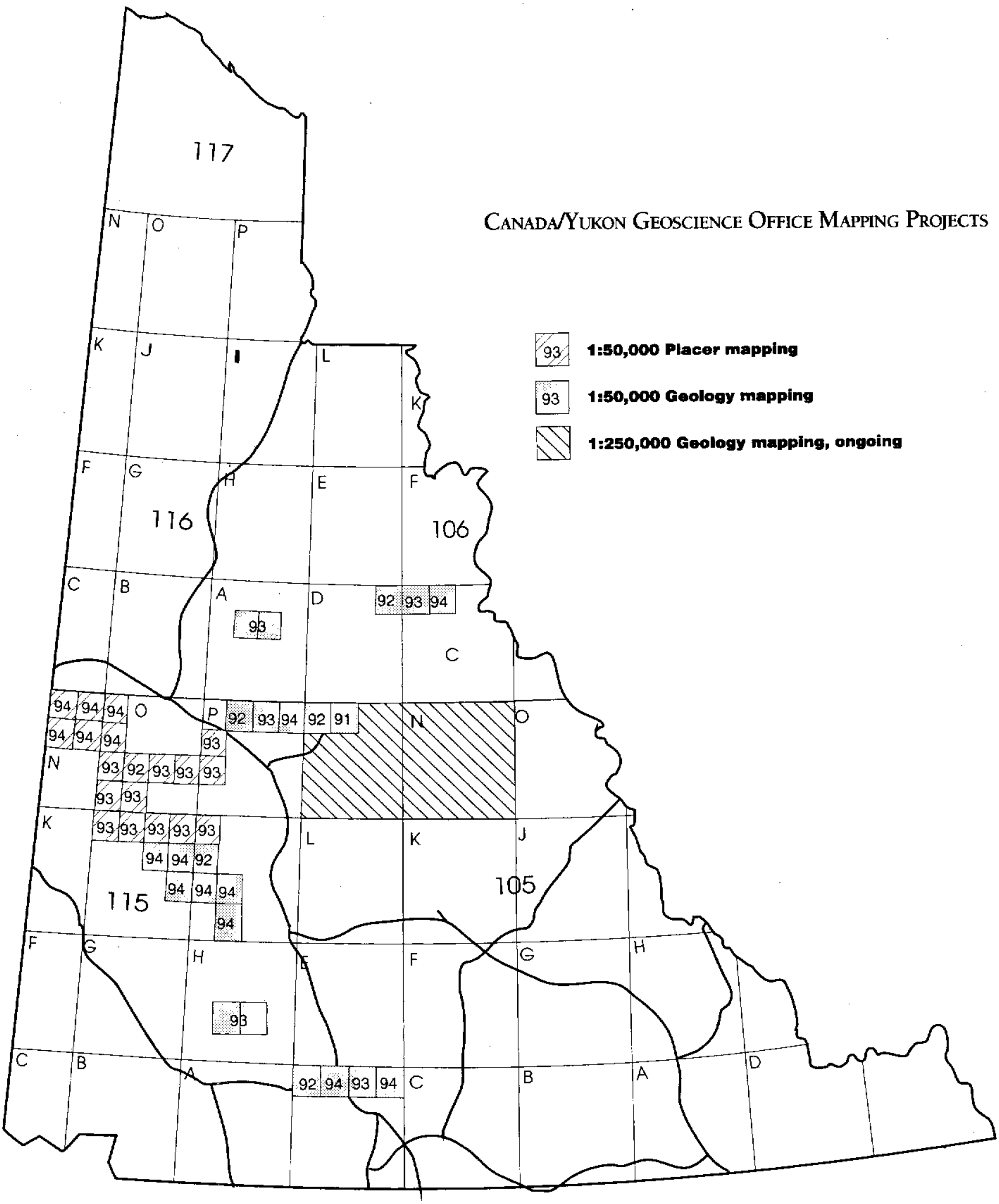
A limited number of independent research proposals are also funded under the Geoscience Element. Two completed projects are: Fine Gold Literature Research and Orientation Survey - program submitted and administered by Gord MacKay; and Placer Mining and Exploration Compilation (NTS 105 Manual 115p. This compilation forms the basis of a Placer Minfile and was submitted and administered by Bernie Kreft.

2) Technology Element

The objective of the Technology Element is to increase the economic and environmental efficiency of Yukon placer and hardrock mining operations by encouraging innovative exploration, mining and processing technology, as well as projects aimed at reducing or mitigating environmental impacts. A technical report suitable for publication completes each project. Completed reports that are released as open files are listed below. Ongoing projects are: The Use of Ground Penetrating Radar for the Evaluation of Placer Gold Deposits—submitted and administered by Amerok Geophysics; and Evaluation of the use of Excavator and Floater Dredging in Permafrost—submitted and administered by Forty Mile Placers.

3) Information Element

The objective of the Information Element is to communicate information about the mining industry to Yukon residents and to encourage businesses to take advantage of economic opportunities in the industry. One aspect is to inform students of the realities of the mining industry. Programs approved and operated under the information element include: Education, History of the Whitehorse Copper Belt (administered by McBride Museum); and Yukon Charlie Broadcasts by CKRW Radio.



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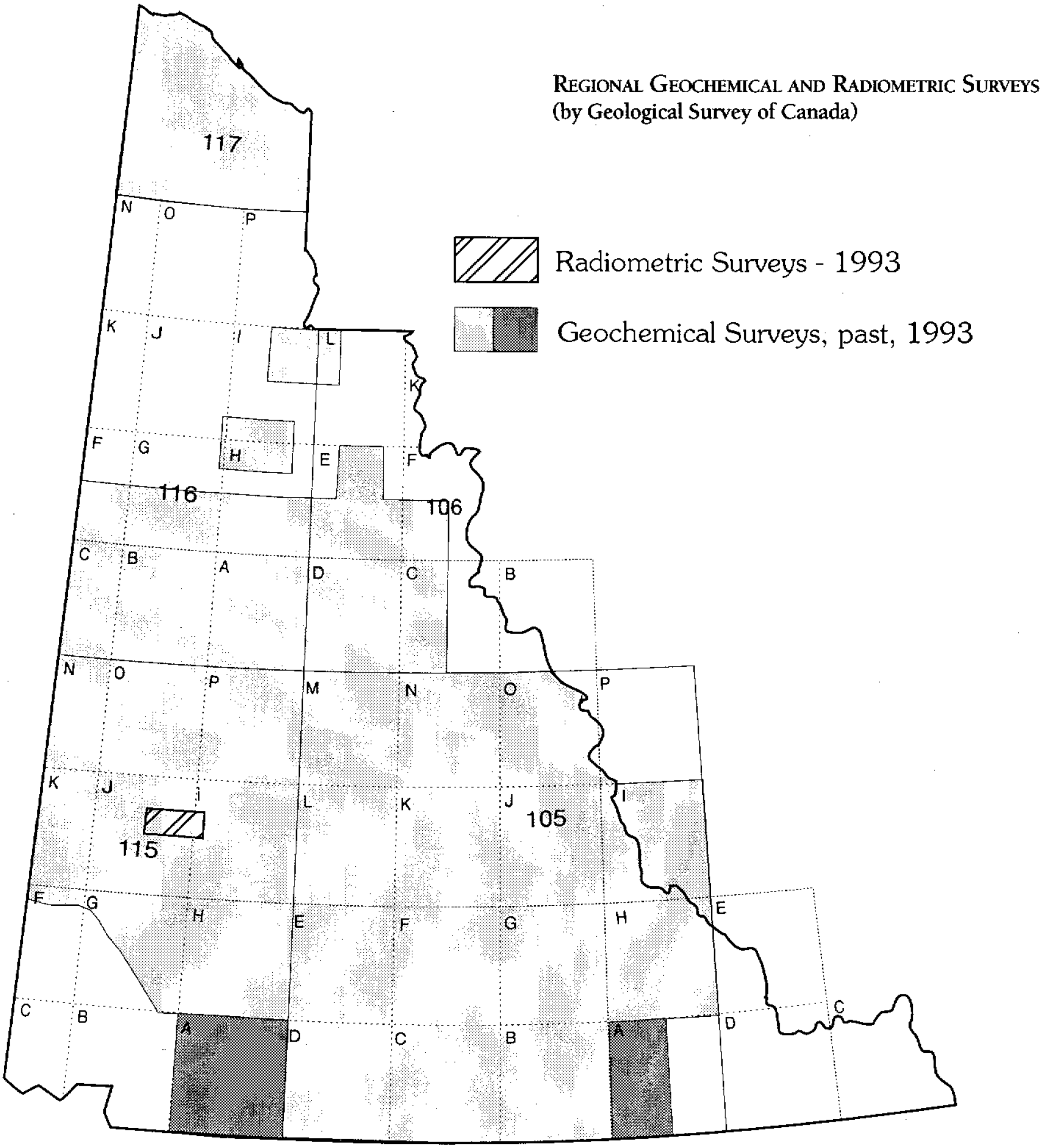
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PART C

GEOLOGICAL FIELDWORK

HIGH LEVEL TERRACES ALONG LOWER STEWART RIVER AND PARTS OF YUKON RIVER

Edward A. Fuller
Canada-Yukon Geoscience Office, Government of the Yukon
Box 2703 (F-3), Whitehorse, Yukon, Y1A 2C6

FULLER, E.A., 1994. High level terraces along lower Stewart River and parts of Yukon River. In: Yukon Exploration and Geology, 1993, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs, Canada, p. 15–28.

Abstract

Surficial geology mapping of the lower Stewart River valley and Yukon River valley has revealed sets of high level terraces formed when the paleo-Stewart River and the paleo-Yukon River were at higher base levels during the Pleistocene glaciations and during preglacial time. These terraces are composed of bedrock and a variety of gravelly alluvial fill, some of which are glacial in origin, others appear to be nonglacial in origin. The terraces are dominated by pebble and cobble gravel deposits which are typically covered by aeolian sand and silt deposits.

The age of these high level terraces was determined by paleosol development, height, and relationship to glacial limits. At best, these are crude correlations which serve to model drainage evolution. For example, inferences can be made about the aggradation of these main valleys. A regional base level was established possibly in late Tertiary time which is identified as a bedrock terrace level above the present flood plain level. The timing of this feature is probably older than White Channel gravel age (Pliocene-Early Pleistocene). Subsequent aggradation of valley fill gravel in the Stewart River drainage and Yukon River drainage followed. The style of deposition is considered nonglacial for this highest alluvial surface. The main rivers incised their valleys due to a lowering of base level; perhaps due to tectonic uplift and/or isostatic readjustment subsequent to a long period of stability.

Placer gold distribution on the terraces appears to be widespread. Gold grains are typically flat, smooth and smaller than 1 mm. Gravel sampling of lithofacies was conducted on these high level terraces followed by concentration of heavy minerals by sluicing and panning. Gold is present on many of these terraces. Favourable targets for placer exploration may be in tributary valley terraces which grade to the main trunk stream high level terraces or basal gravel overlying bedrock. Erosion of outwash terraces is believed to contribute gold to modern bars along the Stewart River.

INTRODUCTION

High level terraces have received scant attention in central Yukon for geological mapping and sampling studies with the exception of historic mining areas. However, these geomorphic features are prominent along the Yukon River and Stewart River and may be favourable areas for the exploration of new placer deposit reserves. In some historic areas, such as the Klondike (Morison 1989; Morison and Hein 1987; Dufresne and Morison 1984), Sixtymile (Hughes 1986) and Clear Creek (Morison 1983) high level terraces have been studied with respect to sedimentology and placer gold. Surface geology and soil studies have also been carried out on a regional scale on high terraces in central Yukon, particularly on McQuesten map area (NTS 115P) (Hughes et al. 1972; Smith et al. 1986; Tarnocai et al. 1985; Tarnocai 1987; Tarnocai and Smith 1989). No surficial geology studies have been carried out along the lower Stewart River or the Canadian portion of Yukon River below Selwyn River.

Previous to this work, there was little published information on the geology of terraces in the Stewart River. Various Geological Survey of Canada publications provide information on the general nature of valleys. McConnell provides a broad sketch of the geology of the Stewart valley (McConnell 1901), Keele (1906) reported on early bar mining (1883) and bar mining between Mayo River and Lake Creek. Bostock (1979) refers to some bench miners at Barker and Scroggie Creeks in his recollections of working in central Yukon. Cairnes (1917) reported on the geology and gold mining in present creek valleys and benches of Scroggie, Barker, Thistle, and Kirkman Creeks. Part of the Stewart River was mapped from airphoto interpretation (Fuller and Andersen 1993). High level terraces near the mouth of Black Hills Creek are believed to be outwash (Fuller 1993).

Physiography

Klondike plateau is characterized by deep narrow valleys amongst smooth ridges of uniform elevation which represent an old erosion surface and domes (Bostock 1948; Mathews 1986). The age of the low relief surface in which Stewart River valley lies may be Late Miocene and subsequent uplift led to valley formation (Tempelman-Kluit 1980). Bostock (1964) reported on Eocene sedimentary beds in Tintina Trench which helps date the Tintina graben. Tempelman-Kluit (1980) in his regional analysis of physiography refers to a low-relief stage with White Channel gravel deposited along the lower Stewart River and adjacent parts of Yukon River.

Glaciation

Glaciation chronology for central Yukon was constructed by Bostock (1966) and named, from oldest to youngest as, Nansen, Klaza, Reid, and McConnell. The distinction between glacial deposits older than Reid is not clear and hence are informally named pre-Reid in recent publications. Glacial limits for McConnell, Reid and pre-Reid glaciations in central Yukon have been regionally mapped (Hughes et al. 1969).

Selkirk Group basalt is dated at about 1 Ma by K-Ar determinations and is magnetically reversed (>0.78 Ma) in the Fort Selkirk area dating the younger pre-Reid glaciation (Jackson 1993). These volcanic rocks are mapped in Rosebud Creek, North Rosebud Creek, and Grand Valley Creek (Bostock 1948; Bostock 1964) implying the presence of valleys at that time. Brown gravels occur up to 3 000 feet elevation north of the site of Stevens Roadhouse (63°13'N, 138°00'W), south of Rosebud Creek (Bostock 1964). Bostock (1948) believed that the Flat, Rosebud, Valley Creeks and Indian River and White Channel gravels of the Klondike accumulated more or less contemporaneously as stream deposits. He noted that the Stewart River valley terraces contain distinct chert, chert breccia and conglomerate from Pelly River not found on upper Stewart River. Flat and Rosebud Creek valley have gravel deposits up to 2 500 feet and chert pebbles up to 3 000 feet. Ice contact features of the last glaciation (McConnell) and older glaciations (Reid and pre-Reid) lie within Stewart River valley (Hughes et al. 1969).

Placer Mining

A placer mineral inventory compilation for McQuesten map area by Kreft (1993) provides capsule comments on creek occurrences and Stewart River bar mining. Bostock noted gold in lower parts of branches of Rosebud Creek and on Independence Creek (Bostock 1948).

Placer mining activities in the study area include present mining and abandoned mines. During 1993, there was a limited amount of bar mining on Chapman Bar which was being mined by Neil Walters. In addition, an abandoned meander point bar at McQuesten airstrip was actively being tested by Bob Stirling. Terrace deposits were also being tested at Barker Creek on a high bench by Henry Calmegane. No other terraces along the Stewart River were being mined. In contrast, creek mining was carried out on Barker Creek, Maisy May Creek and Black Hills Creek. Evidence of earlier efforts were seen at several places along the Stewart as test pits and shallow workings.

Project Objectives

At the international boundary between Yukon and Alaska, high level terraces 50 to 180 m above valley bottoms, in the Fortymile River area (Fig. 1), were found to contain gold (Yeend 1990). This helped spur the present program of mapping high level terraces of the lower Stewart River valley and the Yukon River valley. There is very little information on these features and they have the potential to offer a key to drainage basin evolution in central Yukon and associated placer mineral concentrations. Part of the reason for lack of attention may be

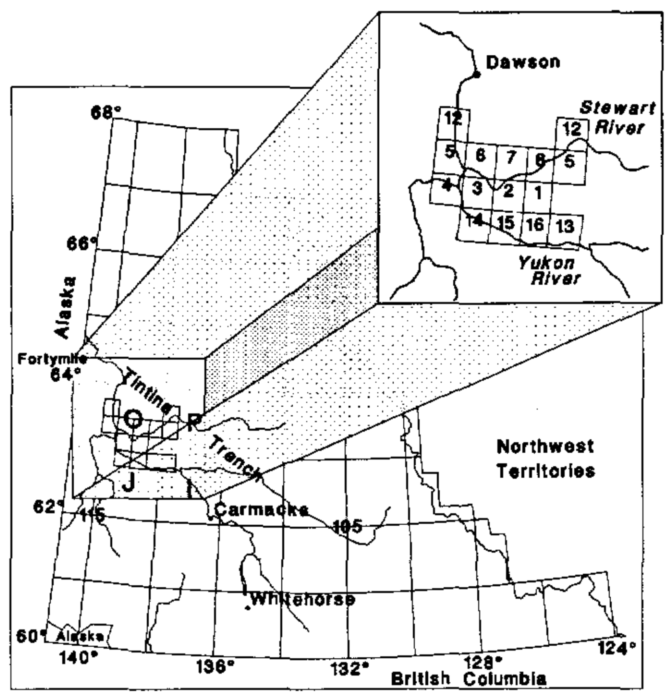

Figure 1: Location map of the 1993 high level terrace mapping project carried out on Stewart and Yukon Rivers in central Yukon. The 1:50 000 scale NTS map sheets are indicated in the blowup.

derived from the lack of road access for equipment and supplies to these high terraces. As well, exposures of gravel and the gravel/bedrock contact are rare hampering hand sampling activities. Drilling or mining methods would be required to test high level terraces in these areas.

River terraces offer the placer miner another target for prospecting. A look at the main terraces on streams like the Stewart River and the Yukon River may help identify which tributary terraces have placer potential by the reconstruction of ancient drainage systems. Erosion of terrace gravels may lead to reconcentration of heavy minerals in more recent stream gravels.

The objective was to map terraces along Stewart and Yukon Rivers by airphoto interpretation, followed by detailed mapping of exposed sections, detailed mapping of soil pits, measuring elevation of terraces and bedrock, and the collection of gravel samples for gold grain counts, geochemistry, grain size analysis, and pebble provenance. The genesis of these high benches was poorly understood; were they glacial or nonglacial?, how old are they?, what are they composed of? These are some of the questions addressed during examination and mapping of these geomorphologic features. No surficial geology maps were available for these areas.

Field Work

During 1993 field work, the lower reaches of the Stewart River, below McQuesten airstrip (Fig. 2) were mapped and sampled. The map is published separately as Open File 1994-7(G) and Open File 1994-8(G). In addition, a reconnaissance of Yukon River from Selwyn River to Dawson City was completed.

Field Methods

Field mapping was done by measuring terrace heights along the river based on the airphoto interpretation. Two digital altimetres were used (accuracy estimated at ± 15 feet) to measure the highest level of bedrock, level of gravel exposed in the terrace scarp, and height of terrace with reference to river level.

The most level part of the terrace surface was selected for soil pit sites. Preference was given to dry sites vegetated in aspen or mixed aspen and spruce where unfrozen conditions prevail. Soil pits were dug by hand and by Kubota excavator at several locations along the river valleys (Fig 3). One face of the pit was photographed and mapped on a bed-by-bed basis. Gravel samples were collected for analysis from different depths. Samples were collected in stratigraphic order with the first samples from the top of the pit (or exposure) and the remainder collected down the pit wall. If no gravel was found in the pit a sample was collected for soil geochemistry, grain size and heavy mineral analysis in the laboratory.

Heavy minerals were concentrated in the field by panning and sluicing. Samples were washed in a 14-inch gold pan (1–16 pans per sample). Samples for sluicing were collected in either one or two

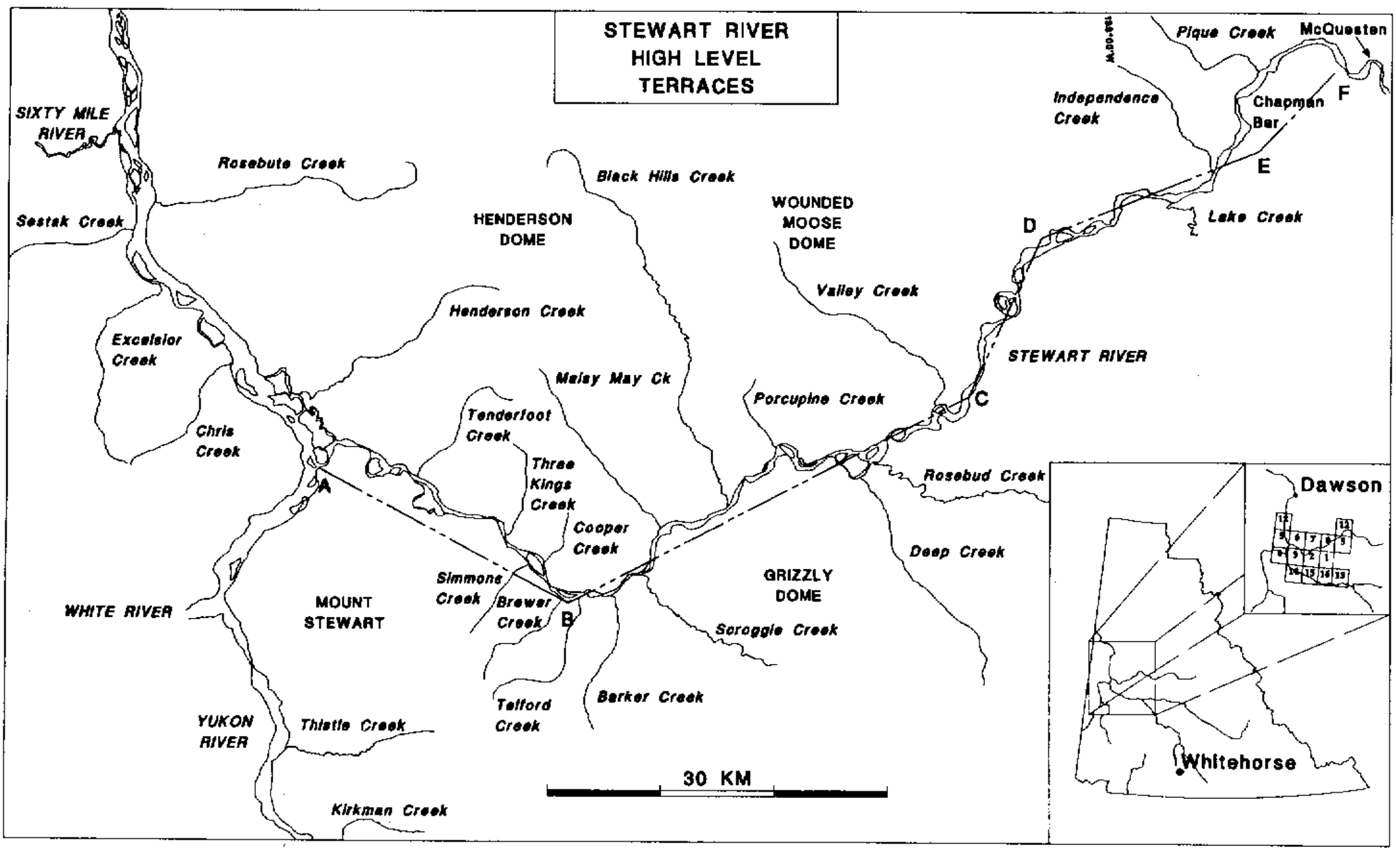

Figure 2: Lower reach of Stewart River and part of Yukon River showing major tributaries and long profile section line

Figure 3: Kubota excavator, operated by Terry Thompson, filling in soil pit at stn 93-068. This station is on a terrace 500 ft above the Stewart River on a south flowing tributary 2.7 km from Stewart River valley.

23 litre pails (or equivalent volume in sample bags). These samples were run through an 8 foot long sluice box lined with paper box conveyor belt and expanded metal riffles or panned out by hand. If stones were not completely washed because of high clay and silt content, the sample was run through the sluice a second time. The number of gold particles in the heavy mineral concentrate obtained were counted as well as a qualitative determination of other heavy minerals (garnet, magnetite, hematite, etc.). Gold particles counted include anything visible to the unaided eye so include minute specks as well as flakes.

Samples were also collected for grain size matrix (less than 2 mm size fraction) and geochemical analysis. Soil samples were collected for seven sites where gravel was not uncovered.

Pebble lithologies and overall shape were noted from the washed sample from both panning and sluicing to determine provenance area of fluviatile material. Overall pebble shape was determined as either; round, subround, subangular, or angular. Indications of glacial transport, if observed, were noted including faceted pebble surfaces and striations. Any occurrence of ventifacts (wind polished stones) and sand wedges was also noted.

Soil Descriptions

Soils were described by noting colours, texture, presence of silt and clay skins, degree of weathering, presence of secondary carbonate, and thickness of the solum for various parent materials. Colours were determined using the Munsell Soil Color Chart. Comparison with Reid and pre-Reid soils studied by the writer during work in McQuesten map area with O.L. Hughes (GSC) was also attempted.

ANALYTICAL METHODS

Laboratory Investigations

Grain size analysis was carried out on the matrix fraction (less than 2 mm) of gravel and sand samples. Samples were air dried, cone split, and 50 grams weighed on an analytical balance and processed through hydrometre column and nested sieves (2 mm, 1 mm, .5 mm, .25 mm, .125 mm and .063 mm).

Geochemistry samples were derived from the matrix rejects (61 samples) as well as seven soil samples collected specifically for chemical analysis. Sample splits were assayed by fire assay at Northern Analytical Laboratory and shipped to International Plasma Laboratory for multi-element induced coupled plasma (ICP) analysis.

TERRACE LEVEL DESCRIPTIONS

High Level Terraces

High level terraces are the focus of this report and are defined to occur at elevations in excess of 20 m (60 ft) above river level. They include gravelly fill from glacial streams (outwash) (Fig. 4), kame terraces deposited along the margin of glaciers, bedrock terraces produced by downcutting (Fig. 5), and nonglacial terraces. The bedrock terraces preserve a record of broad stable valley development

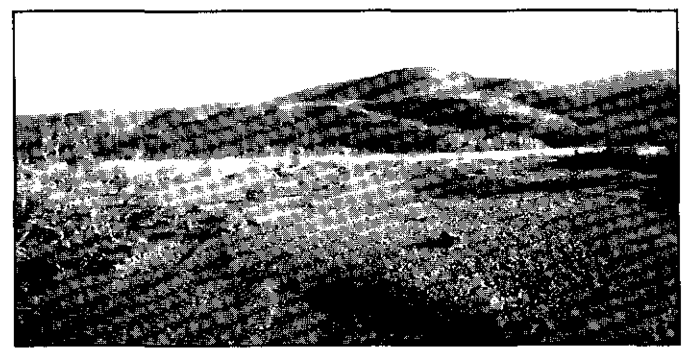

Figure 4: Looking northwest at high level terrace on right bank of Stewart River opposite valley of Lake Creek. A Kubota excavator pit (stn 93-66), uncovered pre-Reid soil on this terrace.

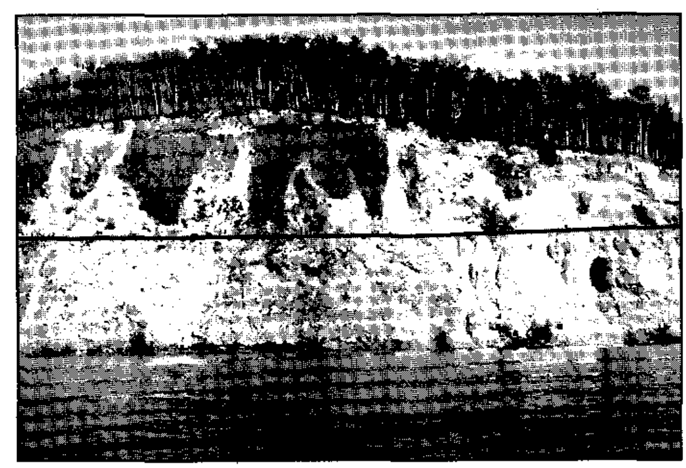

Figure 5: A rock cut terrace overlain by gravel and sand occurs five km downstream of Valley Creek on the right limit (stn 93-18). Black line marks the top of weathered bedrock at a height of 23 m (75 ft) above river level.

which were incised with changing base levels. Because the down valley gradient of terraces may be steeper than the present Stewart River, some high terraces merge with the flood plain of the present river. The terraces form a distinctive part of the valley geomorphology appearing as steplike features in the valley. Their distribution may show former valley bottoms, river gradients, extent of down cutting and aggradation patterns.

Terraces were analyzed by plotting their distribution in a long profile down the axis of the stream (Fig. 6 and 7). Data was taken directly from 1:50 000 scale topographic maps as a crude method and individual terrace elevations were measured in the field as spot heights above river level. The regional levels of terraces taken from Hughes and others (1972) (Table 1) is plotted for comparison in the Yukon River reach studied (Fig. 7).

Location	River	Bedrock	Alluvial	River	Bedrock	Alluvial
	(m)	(m)	(m)	(ft)	(ft)	(ft)
Stewart River	357	388	396	1170	1275	1300
Sixtymile River	341	411	485	1120	1350	1590
Indian River	332	395	501	1090	1295	1645
Dawson	305	375	525	1050	1325	1725
Ft. Reliance	315	365	541	1035	1520	1775
Fortymile River	301	403	543	955	1325	1780
Jackson Cut	NA	427	520	NA	1400	1715
Fortymile River	301	403	543	955	1325	1780
Jackson Cut	NA	427	520	NA	1400	1715

Table 1: Approximate levels of alluvial surfaces along the Yukon River. (data taken from Hughes et al., 1972)

At present there is no method of dating all the terraces because of lack of organic material for radiocarbon (and many terrace organics probably are beyond the dating limit of radiocarbon method or are post terrace development), lack of recognizable tephra for tephrochronology, paucity of vertebrate fossils partly due to lack of exposures, and lack of Late Tertiary and Quaternary volcanic rocks.

Bedrock terraces

Bedrock terraces are those whose base level is recorded as the height of bedrock/gravel contact above the valley bottom. These features occur along both Yukon River and Stewart River valleys as broad elevated valley features (Fig. 8). Their margins closest to the valley wall are commonly covered with slope deposits (colluvium).

Outwash terraces

Terraces related to glacial outwash are subdivided based on relative height. The distinction between glaciofluvial (outwash) terraces and nonglacial terraces was difficult to make because of lack of exposure, but some criteria were used. Specifically, the presence of striated and faceted pebbles, a wide variation in pebble lithology indicating distal source, presence of foreign lithologies not derived from present drainage basin, and margins traceable to ice contact features.

Glaciofluvial terraces in central Yukon were formed in braided river environments with multiple channels. They exhibit discoid clast imbrication, cross-bedding, scoured surfaces and a surface loess. Specific outwash terraces related to McConnell glacial limit and Reid and pre-Reid glacial limits were identified by tracing them upstream to ice contact features. Some earlier outwash sequences may be buried beneath younger valley trains.

The McConnell outwash terrace(s) was previously measured during fieldwork in McQuesten area with the Geological Survey of Canada in 1983. It is characterized by a weak soil developed in a surface loess capping over cobbly brown and grey gravel. At McQuesten airstrip this terrace was 5.5 m above river level (HHF83-60), one km upstream it was 6.6 m (HHF83-61), downstream of Chapman Bar it was 8.8 m (HHF83-62), and further downstream 6.14 m and 6.55 m respectively (HHF83-63 & 64). Exposures of McConnell terrace extend from upstream of Stewart Crossing to just downstream of Lake Creek. Its long profile is indicated in Figure 6 for the Stewart River. Farther upstream the McConnell terrace slopes much steeper than in the study area.

The Reid outwash terrace(s) was correlated to those surfaces in McQuesten map area which are believed to be of Reid age (Hughes 1987). The highest Reid terrace in Stewart River valley is north of McQuesten River bridge where a terrace is ~120 m above the valley floor (1983 field notes). It is characterized by soils with thin clay skins, weak chemical weathering, and brown colours. Their distribution is plotted in Figure 6. When seen in section they show thick gravel overlain by wavy bedded sand (Fig. 9). The slope of Reid terraces is steeper than the present Stewart River.

Pre-Reid terraces are known in McQuesten map area and adjacent Dawson map area (Tarnocai et al. 1985). Soils developed on outwash are strongly weathered, have thick clay skins, strong red colours and thick soils. Because pre-Reid terraces may include those of two or more glaciations and nonglacial periods various levels are possible. The widest distribution in height above river level is observed for these terraces. Subdivision is tentative but suggestive correlations are possible and are indicated on the profile (Fig. 6). The highest gradients are found in these presumed pre Reid terraces.

Paleosol Descriptions

Correlation of terraces was accomplished by plotting long profiles of terrace remnants, identifying their geomorphology and comparing their soil development (Fig. 6 and 7). The surface material with soil development was mostly gravel and sand with a loess veneer, but colluvium and diamicton (poorly sorted, unstratified clastic sediment) were encountered. Rutter and others (1977) determined soil development and correlation based on detailed studies of soil mineralogy and characteristics for central Yukon. In this way, broad features can be crudely related. In addition, the soils are correlated with Wounded Moose paleosols (pre-Reid), Diversion Creek paleosols (Reid), and the Stewart soils (McConnell) (Tarnocai and Smith 1989; Tarnocai 1987; Smith et al. 1986). The soil characteristics for

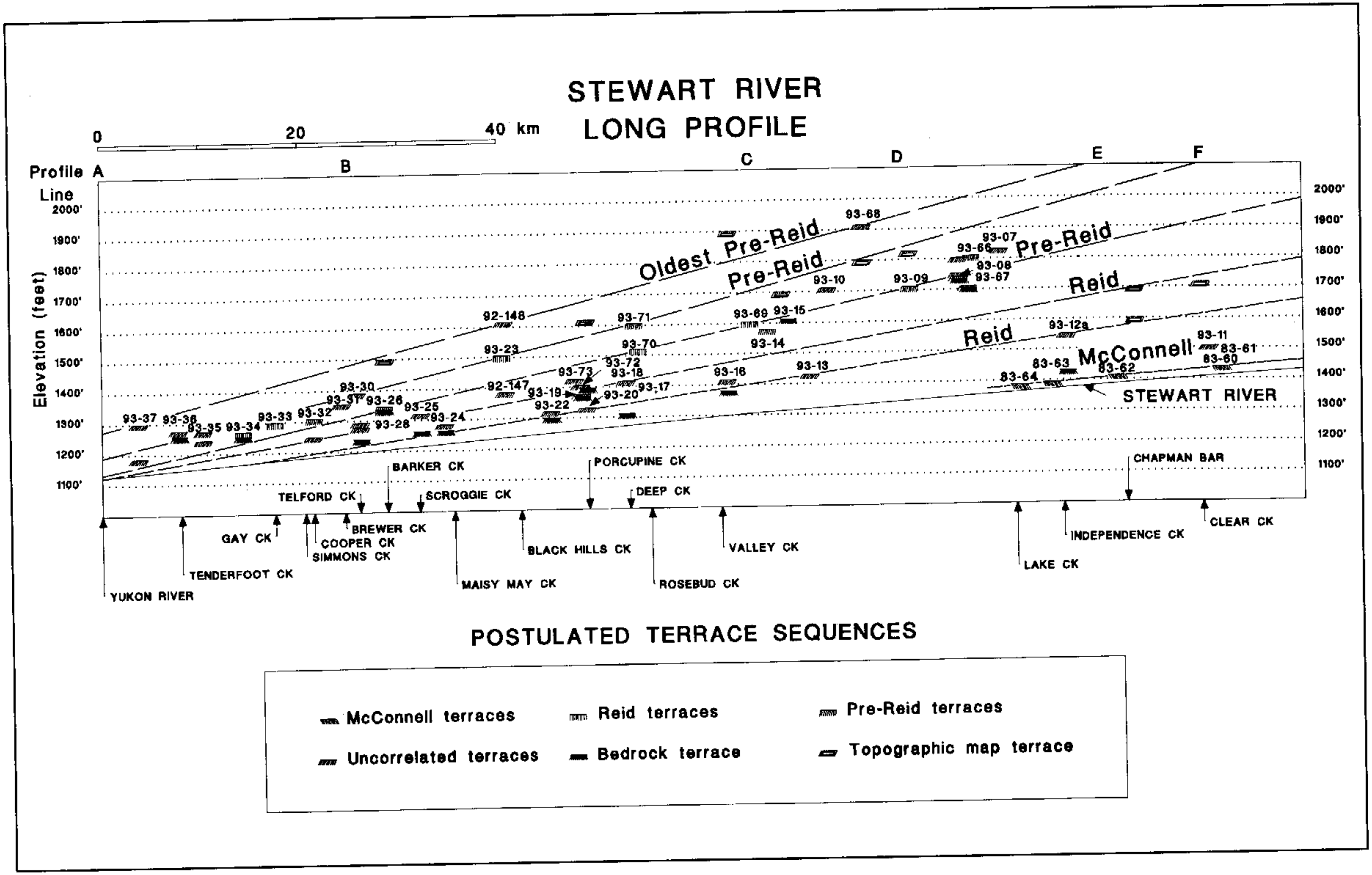

Figure 6: Long profile of Stewart River reach with terrace levels derived from field measurement and topographic maps. Postulated terrace sequences are shown with respect to glacial events and are subject to revision. Terraces show a general drop in elevation downstream probably arising from influence of glacial limits on outwash fans. Discrepancies in site correlations based on soil characteristics may be from deflation or removal of part or all of the soil subsequent to formation.

Wounded Moose and Diversion Creek paleosols are summarized below (Table 2).

Soil	Pre-Reid soils	Reid soils
name	Wounded Moose paleosol	Diversion Creek paleosol
age of material	1.2 Ma	Illinoian
age of soil formation	pre-Illinoian	Sangamonian
average thickness	109 cm	45 cm
range in thickness	58-205 cm	9-90 cm
uppermost colour	5YR	7.5YR
lower colour	7.5YR	7.5YR
clay skin percentage	100% thick	80% thin
sand wedge occurrence	34%	20%
ventifacts	common	common
chemical weathering	strong	weak

Table 2: Summary of pre-Reid and Reid soils developed on outwash. (from Tarnocai and Smith, 1989)

Pre-Reid Paleosols (Wounded Moose Paleosols)

The thickest soils were found along the Stewart River at stn 93-07, stn 93-14, stn 93-22, stn 93-66, and stn 93-71 in gravel deposits. Each of these soils had distinctive characteristics of thick clay skins on pebbles, strong red colour, and intense weathering of pebbles. Ventifacts and sand wedges were present locally. These are considered to have formed during a pre-Illinoian interglacial on material of about 1.2 million year age (Hughes 1987; Tarnocai and Smith 1989).

An example of pre-Reid soil is found at stn 93-66 on a high terrace at about 1860 ft elevation across from Lake Creek valley on map 115O/8 (Fig. 4 and 10). The paleosol has a red colour (2.5YR 5/8) and extends to 1.66 m. Clay skins are present down to 1.66 m. Some pebbles are fractured and can be broken with a knife. Coarse gritty sand holds together until broken up by hand (soil structure well

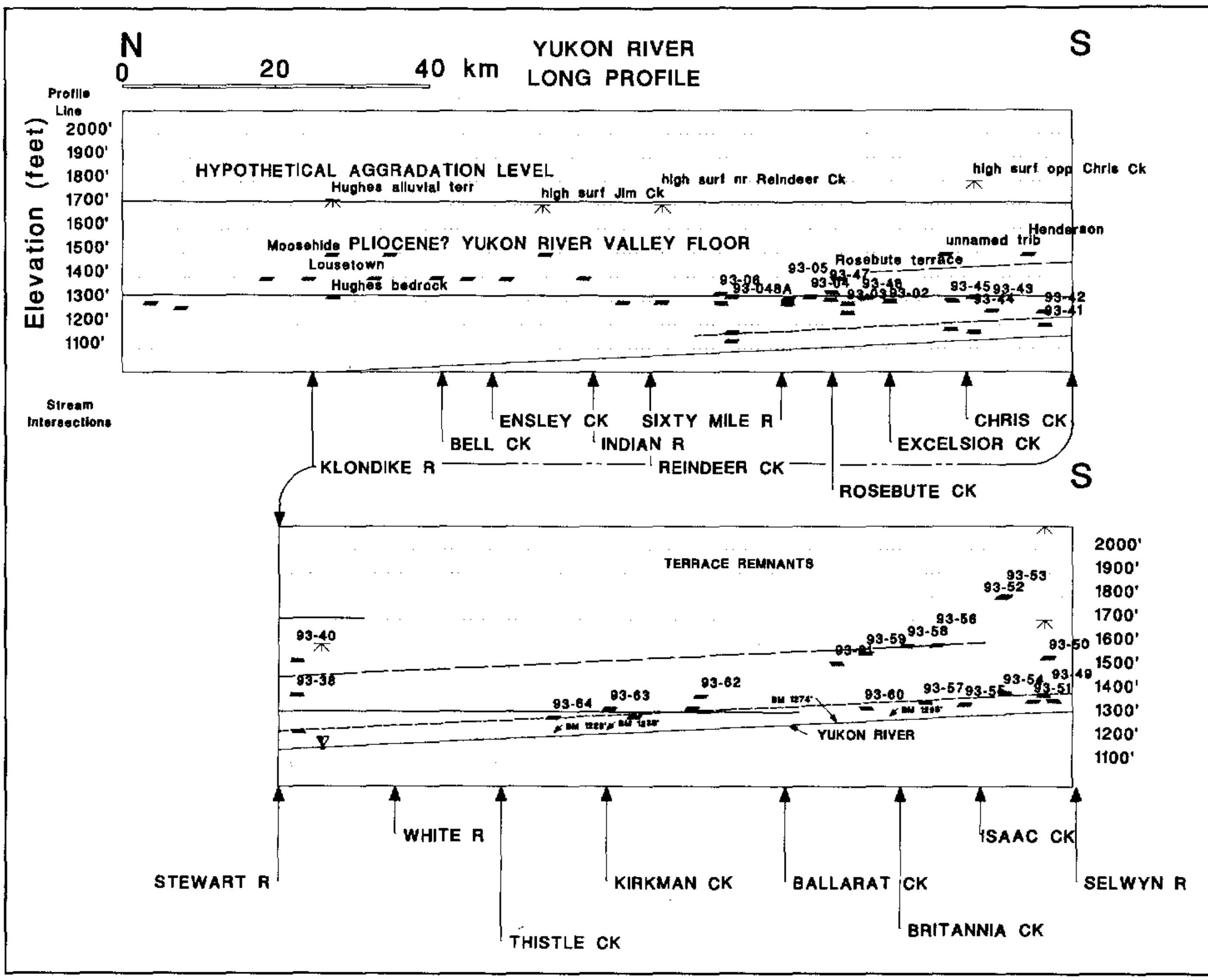

Figure 7: Long profile of Yukon River reach with terrace levels derived from field measurement, topographic maps, and data from Hughes and others (1972). A postulated aggradation level for the highest alluvial surface and a Pliocene? Yukon River valley floor are indicated as sloping opposite to the present drainage. A lower alluvial surface parallel to the present Yukon River slope is shown. A higher alluvial surface may have existed but data is scarce.

Figure 8: Looking southwest across Stewart River valley downstream of Porcupine Creek. Rock terrace on right limit (cliffs) is overlain by at least 3 m (10 ft) of gravel (stn 93-73) and may be up to 20 m (60 ft) thick. A rock cut terrace of equivalent height lies along the left limit of Stewart River valley.

developed). Terry Thompson, the Kubota operator, commented that this gravel would have to be ripped by a bulldozer because of its stiffness. A grey sand wedge cuts down through the gravel to at least 1.30 m.

The alternating clast support/matrix support gravel at stn 93-66 and lensy nature along with poor sorting and range in grain size up to a 40 by 21 by 16 cm boulder suggest an outwash genesis derived from one of the pre-Reid glaciations. The thick clay rich paleosol is presumed to be of pre-Reid age. The sand wedge attests to a former period of intense cold and dry climate.

Reid soils (Diversion Creek paleosols)

Soils with weaker clay skin development, weak chemical alteration, rotted clasts, and local presence of ventifacts and sand wedges (e.g. 93-70) are considered to be Diversion Creek paleosols. They have browner hues compared to the red pre-Reid colours. These soils are fairly common in lower Stewart River valley. The soil formed during the Sangamonian stage on Illinoian material (Tarnocai and Smith 1989).

McConnell Soils (Stewart soils)

The most recent soils on high level terraces were found in loess deposits overlying older material. They typically show weak zone development as described by Tarnocai et al. (1985). They tend to have a colour range from reddish brown (5Y4/4) or reddish yellow (7.5YR6/6) to yellowish brown (10YR5/4) to dark olive brown (5Y3/3). These soils have formed during Holocene time (Tarnocai and Smith 1989).

Figure 9: Natural exposure of fining-upward cobbly gravel overlain by wavy bedded sand with a surface veneer of loess from which tree roots project. This is the upper section from stn 93-18.

Results of Analysis

Gold Particle Counts

The distribution of gold particles for panned and sluiced samples is shown in Tables 3, 4 and 5. Gold grain counts varied from 0 to 41 in the study area. The highest concentrations are on high level rock benches upstream from the mouth of Black Hills Creek (shown in Figure 8). These sites were the furthest downstream Kubota excavated pits in Stewart valley. Placer gold was found in various gravel types (clast-supported pebble gravel, clast supported cobble gravel, and matrix-supported gravel facies).

Gold Geochemistry

Twenty-eight of the matrix samples analyzed contain detectable gold up to 580 ppb, while two of seven soil samples contained detectable gold (Tables 6 and 7).

STATION	NTS	EASTING	NORTHING	GRID	ELEV
93-001	115O/5	573132	7024836	7	1250
93-002	115O/5	564376	7034851	7	1360
93-003	115O/5	562989	7040096	7	1345
93-004	115O/12	564680	7043616	7	1270
93-005	115O/12	562121	7047279	7	1370
93-006	115O/12	561149	7054691	7	1295
93-007	115P/5	652200	7044120	7	1700
93-008	115P/5	649920	7040170	7	1750
93-009	115O/8	645082	7038388	7	1650
93-010	115O/8	641086	7031880	7	1900
93-011	115P/12	368397	7056797	8	1525
93-012	115P/12	359645	7045737	8	1550
93-013	115O/8	639214	7030898	7	1465
93-014	115O/8	638318	7026581	7	1580
93-015	115O/8	638845	7026516	7	1645
93-016	115O/8	633928	7024359	7	1410
93-017	115O/8	628620	7020832	7	1305
93-018	115O/8	625854	7020420	7	1420
93-019	115O/7	621514	7020185	7	1420
93-020	115O/7	621059	7023205	7	1320
93-021	115O/7	621064	7023406	7	1715
93-022	115O/7	618262	7019649	7	1315
93-023	115O/2	615385	7013516	7	1480
93-024	115O/2	609659	7012170	7	1365
93-025	115O/2	608582	7009315	7	1325
93-026	115O/2	605837	7005871	7	1345
93-027	115O/2	605708	7006457	7	1310
93-028	115O/2	602503	7007829	7	1275
93-029	115O/2	602477	7006683	7	1415
93-030	115O/2	602616	7006725	7	1400
93-031	115O/2	601050	7007044	7	1355
93-032	115O/3	599666	7010698	7	1365
93-033	115O/3	596032	7012027	7	1305
93-034	115O/3	593268	7014070	7	1285
93-035	115O/6	590354	7016710	7	1290
93-036	115O/6	588257	7018277	7	1315
93-037	115O/6	584844	7020127	7	1365
93-038	115O/6	577754	7017753	7	1395

STATION	NTS	EASTING	NORTHING	GRID	ELEV
93-039	115O/6	577573	7017805	7	1485
93-040	115O/6	577521	7017685	7	1535
93-041	115O/6	578219	7020482	7	1200
93-042	115O/6	577989	7020340	7	1320
93-043	115O/5	573132	7024836	7	1280
93-044	115O/5	571818	7026948	7	1300
93-045	115O/5	570012	7029340	7	1305
93-046	115O/5	562364	7027575	7	1340
93-047	115O/12	565168	7042350	7	1380
93-048	115O/12	563065	7054936	7	1325
93-049	115J/16	635316	6964169	7	1555
93-050	115J/16	635064	6964563	7	1560
93-051	115J/16	632856	6964074	7	1410
93-052	115J/16	630135	6967848	7	1805
93-053	115J/16	630385	6967533	7	1795
93-054	115J/16	630304	6968300	7	1400
93-055	115J/15	625131	6969067	7	1350
93-056	115J/15	622439	6971940	7	1610
93-057	115J/15	621066	6973140	7	1375
93-058	115J/15	618655	6972752	7	1635
93-059	115J/15	613500	6973750	7	1575
93-060	115J/15	613155	6973460	7	1310
93-061	115J/15	609370	6974025	7	1520
93-062	115J/14	592560	6978400	7	1400
93-063	115J/14	582140	6983928	7	1345
93-064	115O/4	575739	6988981	7	1320
93-065	115O/13	563000	7080950	7	1100
93-066	115O/8	649269	7043432	7	1860
93-067	115P/5	651000	7040150	7	1775
93-068	115O/8	637371	7038997	7	1855
93-069	115O/8	635091	7027242	7	1875
93-070	115O/8	627062	7020479	7	1525
93-071	115O/8	628154	7017712	7	1600
93-072	115O/7	621680	7019530	7	1350
93-073	115O/7	619896	7022369	7	1410
93-074	115O/5	561226	7039266	7	1290
93-075	115O/5	560960	7039511	7	1600
93-076	115O/5	560837	7039911	7	1720

Table 3: Station Locations

Discussion

Terraces

This discussion is based on the Stewart River reach of the study unless specifically noted to be Yukon River. There are only broad correlations of terraces which relate to glacial cycles at this time for lower Stewart River valley. Each of the Pleistocene Cordilleran Ice Sheet glacial advances appears to have left a record of high level outwash valley fills which slope down valley at steeper gradients than the present river. The least extensive and most recent glaciation, the McConnell, laid down the lowest terrace in the project area. The Reid glaciation has two levels of terraces with the upper terraces correlating to the maximum advance of Reid ice and the lower Reid terrace correlating to a retreating ice margin or a readvance. The pre-Reid advances offer the most extensive and highest level terraces. They can be crudely subdivided into three levels; an all time highest glacial advance, an intermediate advance or retreat, and a lower pre-Reid outwash. Terrace chronology is considered speculative at this time.

The presumed gradients of each successive glacial outwash sequence has lowered from the highest gradient associated with the oldest pre-Reid, to the lowest outwash gradient related to the McConnell glaciation. The present Stewart River gradient is the least. In the long profiles these are given as straight lines but they are more likely curves which flatten downstream.

The style of deposition based on the limited exposure of all the Reid and pre-Reid terraces seen suggests that the streams depositing these sediments had variable flow rates. Both matrix- and clast-supported gravel occurs with openwork fine gravel and granule beds. Flat pebble imbrication and cobble armoring of the channel deposits is locally present. The maximum clast size varies between 15 and 40 cm and probably reflects the limited depth where our samples were obtained.

STEWART RIVER DRAINAGE

NUMBER	SA	PANS	COUNT
93-007	a	1	0
93-007	a	16	7
93-008	a	1	0
93-008	b	1	0
93-009	a	1	0
93-009	b	1	0
93-010	a	1	0
93-010	b	1	0
93-011	a	2	0
93-012	a	2	0
93-012	b	2	0
93-013	a	2	2
93-014	a	2	4
93-016	a	4	2
93-018	a	1	2
93-018	b	1	0
93-018	c	1	1
93-018	d	1	1
93-019	a	1.3	2
93-019	b	1.5	0
93-022	a	1	0
93-022	b	1	0
93-022	c	1	2
93-023	a	1	0
93-024	a	3	3
93-024	b	1.5	2
93-025	a	2	1
93-025	b	1	6
93-025	c	2	0
93-026	a	1	1
93-026	b	3	1
93-027	a	1	5
93-027	b	1	2

NUMBER	SA	PANS	COUNT
93-027	c	1	5
93-028	a	1.5	1
93-028	b	1	1
93-028	c	1	2
93-030	a	1	0
93-030	b	1	1
93-030	c	1.5	1
93-032	a	1	0
93-032	b	1	0
93-033	a	1	3
93-033	b	1	1
93-033	c	1	0
93-034	a	1	2
93-034	b	1	1
93-034	c	1	3
93-036	a	1	0
93-036	b	1	0
93-066	a	1	0
93-067	b	8	0
93-068	a	8	3
93-068	b	9	8
93-069	a	8	3
93-069	b	5	6
93-070	a	8	0
93-072	a	4	10
93-072	c	8	0
93-074	a	1	2
93-074	b	1	3
93-075	a	1	0
93-075	b	1	3
93-075	c	1	0
93-075	d	1	3

YUKON RIVER DRAINAGE

NUMBER	SA	PANS	COUNT
93-001	a	1	0
93-002	a	2	0
93-003	a	2	0
93-004	a	3	4
93-005	a	3.5	2
93-005	b	2	0
93-006	a	1.5	0
93-006	b	1	0
93-006	c	1	0
93-039	a	2	0
93-040	a	2	3
93-041	a	1	2
93-041	b	1	0
93-041	c	1	1
93-042	a	1	0
93-043	a	1	2
93-043	b	1	0
93-043	c	1	1
93-044	a	2	0
93-044	b	1.6	0
93-044	c	1.5	1
93-044	d	1.5	0
93-044	e	1	1
93-045	a	1	0
93-045	b	1	0
93-045	c	1	0
93-046	a	1	1
93-046	b	1.5	1
93-047	a	1	2
93-047	b	2	0
93-048	a	1	0
93-048	b	1.5	0
93-050	a	1	3

NUMBER	SA	PANS	COUNT
93-050	b	1	0
93-051	a	2	0
93-051	b	1.5	0
93-053	a	1.7	0
93-053	b	1	0
93-054	a	1.5	0
93-054	b	1	0
93-055	a	1	2
93-055	b	1.5	1
93-056	a	1	0
93-058	a	2.7	0
93-059	a	1	2
93-059	b	1	0
93-060	a	1	0
93-060	b	1	0
93-060	c	1	0
93-063	a	1.5	0
93-063	b	1	0
93-064	a	2	0
93-064	b	1.5	0
93-065	a	1	0

Table 4: Gold grain counts (panned samples)

STEWART RIVER

NUMBER	SA	PAILS	COUNT
93-066	a	2	7
93-066	b	2	0
93-067	a	1	0
93-068	c	1	1
93-070	b	1	0
93-070	c	1	0
93-071	a	1	1
93-071	b	1	1
93-071	c	1	4
93-072	a	1	10
93-072	b	1	4
93-073	a	1	41
93-073	b	1	18
93-073	c	1	23

Table 5: Gold grain counts (Sluiced samples)

Above the White River, the Yukon River also appears to have outwash terraces downstream of Selwyn River traceable as far as below Kirkman Creek but not as far as Thistle Creek (Fig. 2 and 7). From Stewart River confluence downstream, there appears to be a set of alluvial surfaces and bedrock terraces which rise in elevation going northward (Fig. 7). The bedrock surface may mark a Pliocene? Yukon River valley floor. The highest surface is a hypothetical aggradation level based on topographic map and airphoto interpretation. Another poorly constrained set of lower terraces descend in elevation downstream or maintain their level. The higher surface starts at 1 600 ft elevation between Isaac Creek and Britannia Creek and is projected as far as Rosebute Creek. The lower surface extends from Selwyn River to between Reindeer Creek and Sixty Mile River.

The lower, and presumably younger terrace sequence which slopes parallel to the present grade of Yukon River may represent a Pleistocene aggradation. The southward sloping terraces may relate to a previous south flowing drainage system postulated by Tempelman-Kluit (1980) or may represent differential uplift in the Dawson area. Uplift in the Dawson area would account for the high level White Channel gravel and its deep incision to present creek valleys. High level terraces on Stewart River upstream of its confluence with Yukon River appear to grade to about 1 300 ft which is close to the level of terraces in Yukon River valley from Stewart River to Sixty Mile River.

Placer Deposits

Placer gold found in surface samples and above bedrock in Stewart River valley high level benches is typically fine grained, flat, far travelled and in low concentrations. Placer gold is present in 22 sites on Stewart River high level terraces. Because of the regional nature of our mapping not all terraces were sampled and many just had a few pans. There is still potential at the gravel/bedrock interface which was only sampled at a few sites. Tributary high level benches offer other targets. Placer gold is reported on many of the creeks entering Stewart River in this lower reach and terraces associated with those creeks may be auriferous.

Summary

High level terraces in the lower Stewart River valley have been mapped and sampled at 1:50 000 scale. Part of the terrace chronology can be fitted to Pleistocene glaciations beginning with the most recent Cordilleran glaciation, the McConnell, to the Reid and pre-Reid glaciations.

Previous to any Pleistocene glaciation, a low relief upland had developed broad flat bottomed valleys in Stewart River and Yukon River valleys. A period of stability (stillstand) resulted in deposition of high level gravel unrelated to glaciation. Subsequent uplift and downcutting produced elevated bedrock terraces which constrained lateral migration of these major streams.

The fluvial environment was dominated by cycles related to glacial-interglacial periods. During glaciation, outwash was deposited which built up valley trains thickest near the glacial margin and thinning down valley. Erosion of the valley bottom by valley glaciers and high meltwater flow may have destroyed preglacial gravels or covered them with drift. The terraces appear to correspond to periods of abundant sediment supply during glacial episodes and in the paraglacial period after glaciation when abundant sediment supply was available.

Following deglaciation a period of climatic amelioration resulted in formation of soils on terrace surfaces. The oldest terraces have the most developed and thickest soils. Rivers probably eroded and redistributed outwash sediment. A return to cold dry conditions superposed periglacial features on terrace surface sediments including sand wedges and ventifacts. Loess was deposited while gravel and sand bars remained free of vegetation. Deflation of part or all of the previously formed soil horizons may have occurred during this time.

This cycle was repeated for Reid and pre-Reid glaciations. The older the glaciation, the more extensive and higher level the deposits were. Hence, pre-Reid surfaces are most extensive.

Placer gold appears to be far travelled and may have been reworked through several fluvial episodes. Its occurrence in the near surface (within the top three metres) may be a function of heavy mineral accumulation in a bar setting similar to the present Stewart River.

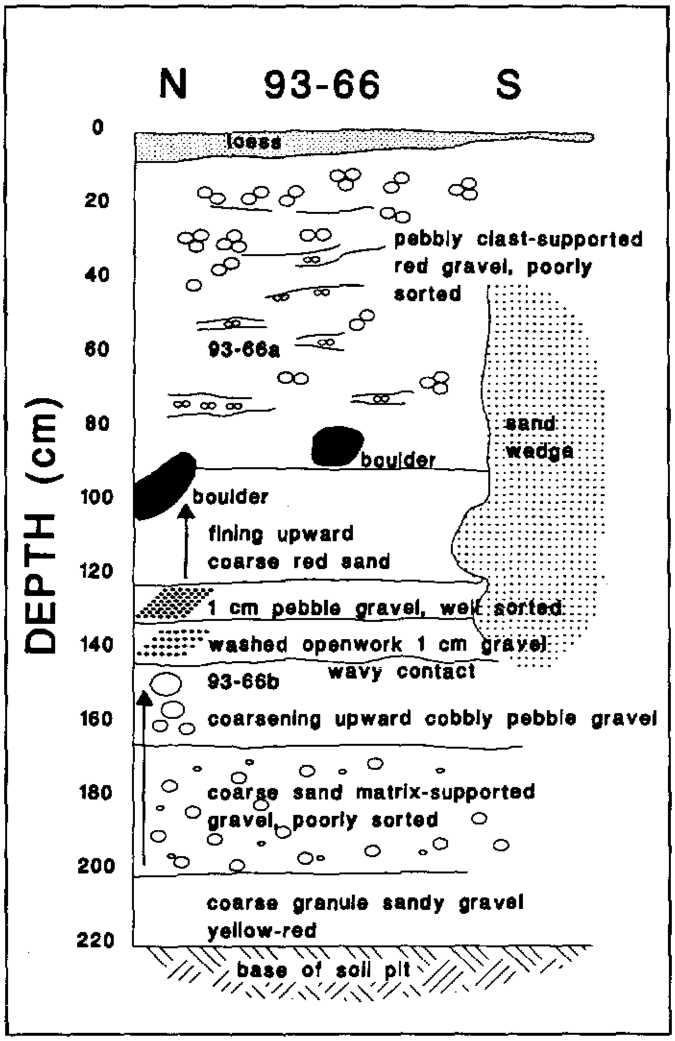

Figure 10: Schematic profile of soil pit with Wounded Moose paleosol from station 93-66, a 460 ft terrace opposite Lake Creek valley. Samples for gold grain counts are indicated (93-66a and 93-66b). This section is interpreted to be an outwash deposit related to the latest pre-Reid glaciation. The cross-cutting sand wedge is a cryogenic feature common in Wounded Moose paleosols.

STEWART RIVER		
NUMBER	SA	PPB
93-029	S	13
93-031	S	6
93-039	S	<5

YUKON RIVER		
NUMBER	SA	PPB
93-040	S	<5
93-048	S	<5
93-057	S	<5
93-062	S	<5

Table 6: Gold Assay (Soil Samples)

STEWART RIVER		
NUMBER	SA	PPB
93-007	a	10
93-007	b	<5
93-009	a	6
93-009	b	6
93-009	c	7
93-032	a	<5
93-032	b	<5
93-033	a	<5
93-033	b	6
93-033	c	5
93-034	a	13
93-034	b	<5
93-034	c	<5
93-036	a	<5
93-036	b	5
93-066	a	14
93-066	b	<5
93-066	c	72

STEWART RIVER		
NUMBER	SA	PPB
93-067	a	<5
93-067	b	<5
93-067	c	<5
93-068	a	<5
93-068	b	<5
93-068	c	<5
93-069	a	28
93-069	b	<5
93-070	a	6
93-070	b	13
93-071	a	8
93-071	c	14
93-072	a	580
93-072	b	8
93-072	c	<5
93-073	a	20
93-073	b	12
93-073	c	8

YUKON RIVER		
NUMBER	SA	PPB
93-075	a	12
93-075	c	31
93-041	a	<5
93-041	b	<5
93-041	c	8
93-043	a	17
93-043	b	9
93-043	c	<5
93-045	a	<5
93-045	b	<5
93-047	a	<5
93-048	a	<5
93-050	a	5
93-054	b	<5
93-055	a	<5
93-058	a	<5
93-059	a	39
93-059	b	<5
93-060	a	<5
93-060	b	<5
93-060	c	14
93-063	a	<5
93-063	b	<5

Table 7: Gold Assay (Matrix Samples)

Acknowledgments

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Geology and Mineral Occurrences of Sprague Creek Map Area (115P/15), Western Selwyn Basin

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Abstract

Sprague Creek map area is underlain by multiply deformed Upper Proterozoic to mid-Paleozoic metasedimentary rocks and undeformed Cretaceous felsic intrusions. The oldest and structurally deepest rocks underlie most of the southern two-thirds of the map area; these are medium-to coarse grained meta-clastic rocks, phyllite, marble and rare meta-igneous rocks correlated with the Upper Proterozoic Yusezyu Formation of the Hyland Group. In the western part of the map area and in neighbouring Clear Creek map area the Yusezyu Formation is overlain by a regionally persistent carbonate unit. In the northern part of the map area coarse-grained meta-clastic rocks, variegated phyllite and siltstone, and sandy limestone and limestone breccia correlated with the Narchilla Formation of the Hyland Group and unnamed mafic metavolcanic, quartzite and shale/phyllite, shale/phyllite and chert, and calcareous clastic units lie between the Yusezyu Formation and the regionally persistent carbonate unit. These observations point to the existence of a profound unconformity beneath the regionally mappable carbonate unit. On the basis of similarities with other parts of Selwyn Basin, the carbonate unit is tentatively correlated with the Upper Cambrian Rabbitkettle Formation; the unconformity is considered to be the sub-Upper Cambrian unconformity which underlies the Rabbitkettle Formation throughout much of the rest of Selwyn Basin. The unnamed Lower to Middle Cambrian sequence is inferred to have been preserved beneath the sub-Upper Cambrian unconformity by downdropping along the Sprague Creek normal fault. The Rabbitkettle Formation is overlain by two formations correlated with the Ordovician-Silurian Road River Group, a lower dark chert and shale/phyllite unit correlated with the Duo Lake Formation and an upper tan- to orange-weathering, locally calcareous/dolomitic and laminated or cross-laminated, locally bioturbated silty mudstone correlated with the Steel Formation. Unconformably overlying and locally truncating all or part of the Road River Group are dark shale/phyllite, coarse-grained meta-clastic rocks (including diagnostic chert-pebble conglomerate) correlated with the Devonian Earn Group. Three phases of regional deformation and a younger suite of faults and fractures are represented in Sprague Creek map area. The structure of the area is dominated by the D1 southwest-overturned Lost Horses syncline which has been traced across much of the northern part of McQuesten map area. D1 structures have been observed only in the northern third of the map area. In the southern two-thirds of the area, D1 structures are overprinted by intense foliations, lineations and folds associated with the Tombstone thrust zone, a crustal-scale shear zone accommodating initial northeast- then northwest-directed displacement on the Tombstone thrust.

D1 and D2 structures are folded by open N- to NE-trending warps. A NNW-trending zone of N- and NW-trending airphoto and map lineaments crosses the western part of the area. The most prominent of these is the Josephine Creek fault with about two kilometres of apparent dextral offset. The traces of N-trending lineaments commonly are marked by gossanous limonitic breccias.

Two suites of post-kinematic felsic intrusions occur in the area. The northern intrusive suite comprises hornblende-bearing biotite quartz monzonite, monzodiorite and diorite (and quartz syenite and syenite in adjacent Clear Creek map area). The southern intrusive suite comprises muscovite-bearing K-feldspar megacrystic biotite granite and quartz monzonite. Preliminary U-Pb dating indicates that the two suites may be different ages, the former being mid-Cretaceous, the latter Late Cretaceous.

Mineral occurrences in the area comprise veins, breccias, and skarns spatially and probably genetically related to Cretaceous intrusions, and gossanous breccias along NNW-trending lineaments. Samples of veins hosted by the northern hornblende-bearing intrusions suite (in particular, Red Mountain, Big Creek and 'Mahtin' stocks) are locally anomalous in Au (100–500 ppb); in this suite, anomalous Au is locally correlated with Ag, Bi, As, W, and Sn. Veins hosted by the southern muscovite-bearing suite are rarely anomalous in Au and commonly anomalous in Ag, Pb, Zn, As, W, and locally Sn. Veins and breccias peripheral to intrusions follow a similar pattern. A sample of lineament-hosted gossanous breccia was anomalous in Au, Ag, Pb, Zn, and As.

INTRODUCTION

Sprague Creek map area is the second of three contiguous 1:50 000 scale map areas in western Selwyn Basin selected for investigation during the term of the 1991–1996 Canada/Yukon Economic Development Agreement. Clear Creek area (NTS 115P/14) was mapped during 1992 (Murphy et al., 1993a, b); Seattle Creek (NTS 115P/16) is scheduled for 1994. This report describes the geology of the Sprague Creek area and accompanies Murphy and Héon (1994), a 1:50 000 scale open-file map.

Sprague Creek map area is located about halfway between Mayo and Dawson City (Fig. 1). The area is relatively remote with very limited road access. Placer mining roads found in parts of the area are generally impassable except by bulldozer. These roads go to Hobo, Gem, and Sprague creeks and are accessed via the Left Clear Creek branch of the Clear Creek placer mining access road. Our mapping program was supported by helicopters based in Mayo (about a 0.4 hr flight) and Dawson City (about 0.6 hr). Thirteen 1–5 day fly camps were established as bases for daily traverses by foot.

The area lies within the Stewart Plateau physiographic subdivision (Matthews, 1986) which is generally characterized by elevations ranging from under 2 000' (610 m) to under 6 000' (1830 m), moderate local relief, and few areas above treeline. Rock exposure is

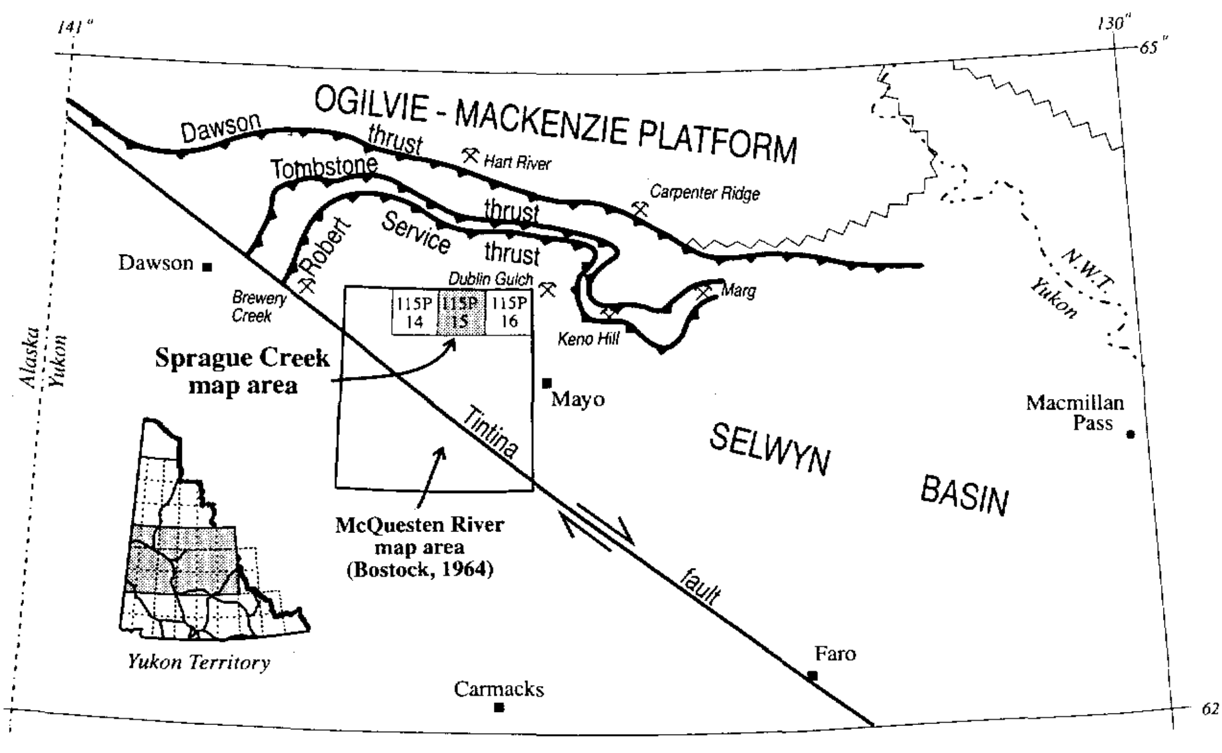

Figure 1: Location of Sprague Creek map area with respect to regional geographic and geological features and important mineral occurrences.

generally poor in the map area with little outcrop continuity except along some ridgetops, most notably near granitic intrusions. Felsenmeer is common on above-treeline ridgetops.

The area has been explored for minerals since the 1885 discovery of fine gold in bars of the Stewart River below the mouth of the McQuesten River. Placer gold has been mined in Hobo and Gem creeks. The area has been actively explored for lode occurrences, initially stimulated by the discovery of the rich silver-lead veins at Keno Hill in 1919. The area was the focus of tin and tungsten exploration in the 1970's and 1980's especially around and in known felsic intrusions. Most recently, many of these same granitic intrusions have been the focus of exploration for low-grade, bulk tonnage gold deposits like Fort Knox near Fairbanks, Alaska.

Previous Work

Bostock (1964) covered the Sprague Creek area for the Geological Survey of Canada in the late 1940's during systematic mapping of the 1:250 000-scale McQuesten River map area (Fig. 1). A more recent interpretation of the geology of the area is shown by Wheeler and McFeely (1991). Emond (1985, 1986), Potter (1987), and Emond and Lynch (1992) studied various aspects of vein, breccia, and skarn occurrences in the McQuesten River region. Emond (1992) investigated the igneous geochemistry and petrography of felsic intrusions in McQuesten River map area and evaluated the relationship of igneous geochemistry to mineralization. Mineral assessment reports include geological observations some of which are summarized in Yukon Minfile and Yukon Exploration and Geology, annually updated publications of Exploration and Geological Services, Yukon, Indian and Northern Canada.

Regional Geological Framework

Rocks of Sprague Creek map area are part of western Selwyn Basin, a locus of Late Proterozoic and Middle Paleozoic basinal clastic sedimentation which lay between coeval inner miogeoclinal sedimentary rocks of the Mackenzie-Ogilvie Platform to the north and east and Cassiar Platform to the south and west (Abbott et al., 1991 and references therein). Selwyn Basin and associated sub-basins (Misty Creek and Meilleur River embayments and Kechika Trough) are attributed to intermittent attenuation and rifting of transitional continental crust at or near the western margin of North America (Abbott et al., 1991 and references therein).

Selwyn Basin rocks are imbricated by the Jura-Cretaceous Dawson, Tombstone, and Robert Service thrusts (Tempelman-Kluit, 1970; Abbott, 1990 and references therein; Mortensen and Thompson, 1990; Fig. 1). Underlying and defining one of the largest thrust sheets in the Canadian Cordillera, the Robert Service thrust extends eastward from the Dempster Highway area east of Dawson to the Keno Hill district and into western Lansing map area (see Roots and Brent, in press). The Robert Service thrust typically juxtaposes Upper Proterozoic Hyland Group against Mississippian 'Keno Hill quartzite' (informal names shown in single quotation marks) and carries the bulk of Selwyn Basin rocks in its hanging wall, including those of Sprague Creek map area. The underlying Tombstone thrust sheet comprises Proterozoic and Paleozoic Selwyn Basin rocks and, locally, Mesozoic clastic rocks (Abbott, 1990 and references therein). It juxtaposes these rocks against an immediate footwall ranging in age from Devonian(?) to Late Jurassic (Poulton and Tempelman-Kluit, 1982; Abbott, 1990 and references therein). An intense strain zone affects much of the Tombstone thrust sheet, extending upward well into the Robert Service thrust sheet, including rocks in the structurally deeper parts of Sprague Creek map area.

Geology of Sprague Creek Map Area

Sprague Creek map area (Fig. 2) is underlain primarily by variably deformed and metamorphosed low- to very low-grade metasedimentary rocks of Proterozoic and Paleozoic age. These are intruded and hornfelsed by unfoliated felsic rocks that range in composition from granite to granodiorite (Bostock, 1964; Emond, 1992). On the basis of conventional K-Ar dating, the felsic intrusions in this area have been considered to be all mid-Cretaceous in age (Emond, 1992 and references therein; Wheeler and McFeeley, 1991), but new U-Pb age determinations show that a previously unknown Late Cretaceous suite is also present.

Metasedimentary Rocks

Stratigraphic units in the western part of Selwyn Basin (Bostock, 1964; Murphy et al., 1993a, b; Fig. 3). generally resemble formations described and formalized in Nahanni map area, 400 km to the southeast of Sprague Creek map area (Gordey and Anderson, 1993 and references therein). Although stratigraphic differences do exist between the two areas, the formal unit names used in Nahanni map area will be used throughout this report. Rock units similar to the lower Hyland, Road River and Earn groups recognized in Clear Creek map area (Murphy et al., 1993a, b) were traced into Sprague Creek area. Several additional units occur locally in Sprague Creek map area where they are inferred to be preserved in a fault block beneath an angular unconformity. The unconformity is at the base of a regionally persistent carbonate unit that has been traced eastward from the Clear Creek map area and tentatively correlated with the Rabbitkettle Formation. If this correlation is correct, the lower contact of the carbonate unit is probably the widespread pre-Late Cambrian unconformity. The units preserved beneath the unconformity include the Narchilla Formation of the Hyland Group and units possibly correlative with the Lower Cambrian Sekwi and Lower and possibly Middle Cambrian Gull Lake formations defined in the eastern part of Selwyn Basin (Gordey and Anderson, 1993 and references therein). Local preservation of these units beneath the unconformity is attributed to pre-Upper Cambrian normal faulting (Sprague Creek fault).

Hyland Group

Most of Sprague Creek map area is underlain by rocks of the Upper Proterozoic to Lower Cambrian Hyland Group (Fig. 2). As defined in Nahanni map area (Gordey and Anderson, 1993), the Hyland Group consists of the older Yusezyu Formation and the younger Narchilla Formation. The southern part of Sprague Creek map area, south of the Sprague Creek fault, is underlain by rocks correlated with the Yusezyu Formation. The Narchilla Formation is only present north of the Sprague Creek fault where it is inferred to overlie Yusezyu Formation.

Hyland Group rocks vary in character around Sprague Creek map area. In the southern part of the area, the Yusezyu Formation lies within the shear zone of the Tombstone thrust and is strained to the extent that original rectilinear bedding is deformed into shear-bounded sigmoidal domains of intensely foliated and folded compositional layering. In contrast, rocks in the northeastern corner of the map area lie above and outside the Tombstone thrust strain zone. At this structural level, original bedding is well preserved, bearing only the relatively weak axial-surface foliation associated with regional scale SW-vergent folds.

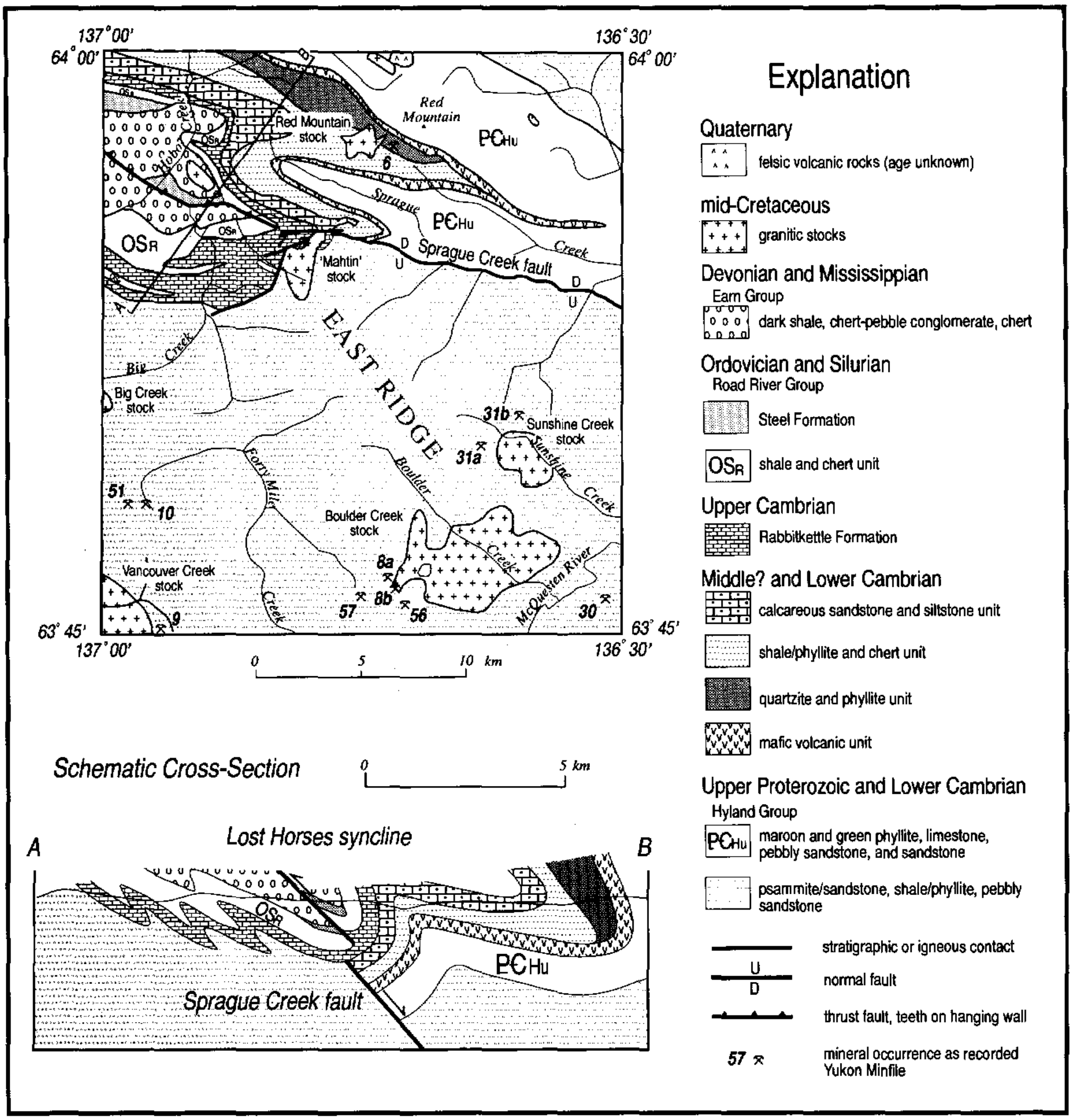

Figure 2: Geological map and cross-section of Sprague Creek map area.

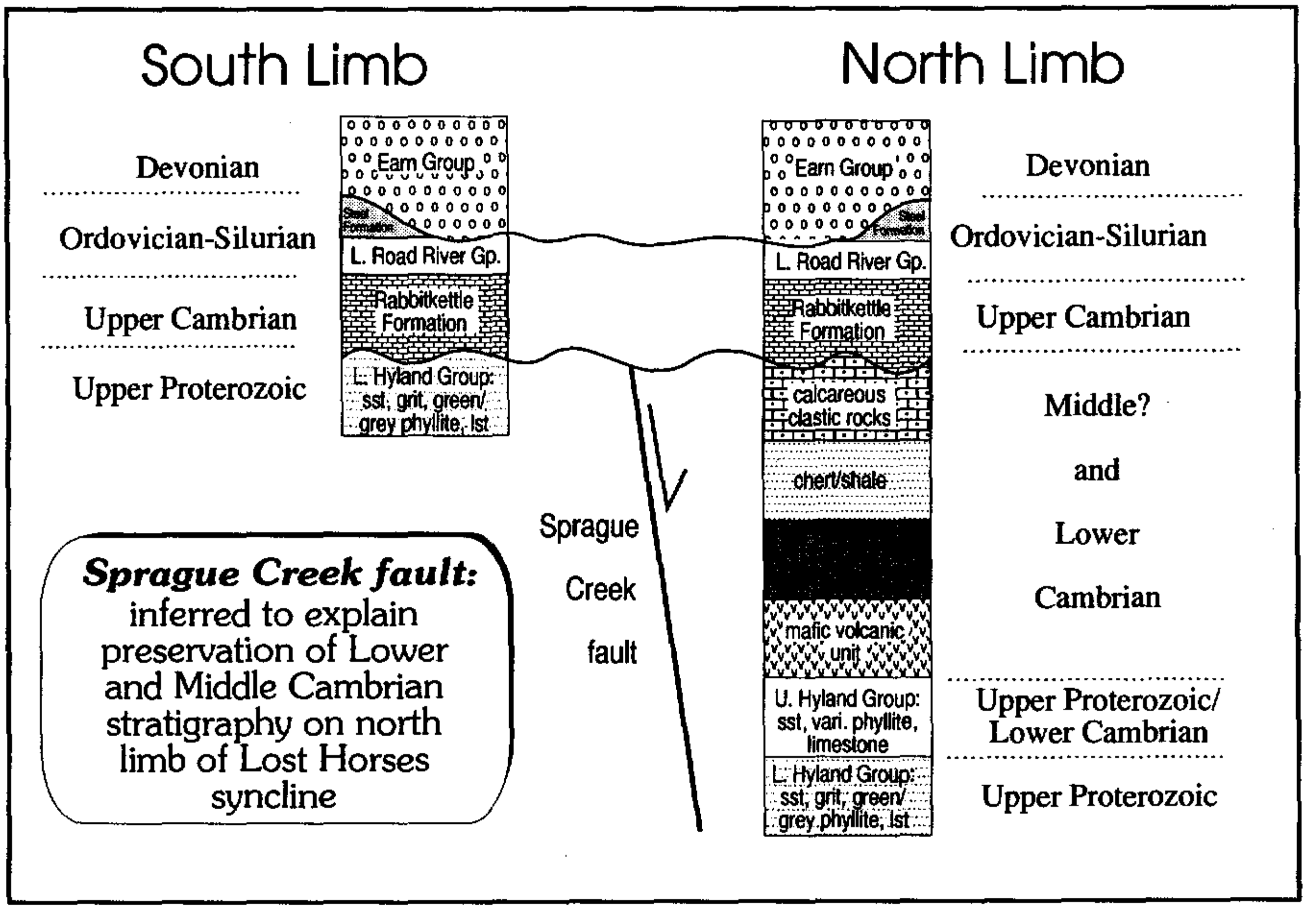

Figure 3: Stratigraphic columns illustrating the different rock units appearing on opposite limbs of the Lost Horses syncline. This difference is used to infer the presence of the Sprague Creek fault and the widespread pre-Upper Cambrian unconformity beneath the Rabbitkettle Formation.

Hyland Group rocks in Sprague Creek map area are in the lower greenschist facies of regional metamorphism, characterized by the presence of fine grained white mica (muscovite) and chlorite. Near felsic intrusions, pelitic rocks of Hyland Group rocks are metamorphosed to cherty reddish to dark maroon biotite hornfels and biotite, andalusite, sillimanite, cordierite, staurolite, and chloritoid occur locally within the thermal aureoles. Rocks of calc-silicate composition become massive or banded quartz-actinolite-epidote-diopside (±garnet, axinite) calc-silicate hornfels or skarn.

Yusezyu Formation

In the southern part of the area, the Yusezyu Formation comprises prominently foliated and lineated quartzofeldspathic and micaceous psammite (metamorphosed sandstone) and muscovite-chlorite (-biotite) phyllite. Less common but locally important are gritty or pebbly psammite (metamorphosed coarse grained or pebbly sandstone), metamorphosed pebble conglomerate, foliated phyllitic or sandy marble, and calc-silicate rocks. Sedimentary structures are rare although graded bedding and channel scours have been observed in the upper part of the formation, generally indicating an upright stratigraphy. The amounts of psammite, phyllite, and rocks of carbonate or calc-silicate composition vary throughout the area but due to structural and possibly stratigraphic complexity, the Yusezyu Formation is not subdivided at this scale of mapping. Nevertheless, carbonate rocks are more common in the Yusezyu Formation in the structurally and possibly stratigraphically deeper southern part of the map area than further north. This carbonate-rich belt within the Yusezyu Formation continues westward into Clear Creek map area (Murphy et al., 1993b).

Foliation-conformable bodies of foliated and lineated plagioclase-actinolite-biotite-chlorite rock occurs locally in the Yusezyu Formation. These rocks are interpreted as metamorphosed and deformed intermediate to mafic igneous rocks. It is not clear whether these rocks were originally of volcanic or plutonic origin.

In its type locality in Nahanni map area, the top of the Yusezyu Formation is marked by a prominent limestone member (Gordey and Anderson, 1993). This member was not observed in Sprague Creek map area.

In the western part of the map area, the Yusezyu Formation is overlain by a regionally persistent carbonate unit correlated with the Upper Cambrian Rabbitkettle Formation. The Yusezyu Formation is inferred to be overlain by the Narchilla Formation in the northeastern corner of the map area.

Narchilla Formation

The Narchilla Formation consists of medium- to thick-bedded quartzofeldspathic sandstone (Fig.4), green phyllite, maroon phyllite (green where in contact with common centimetre-scale tan-coloured siltstone interbeds), and sandy white-, grey-, and tan-weathering limestone and limestone breccia (Fig. 5). The Narchilla Formation is distinguished from the Yusezyu Formation by the occurrence of varicoloured phyllite. Metre-scale bands of limestone occurs throughout the Narchilla Formation; a mappable limestone member several tens of metres thick occurs in the middle part of the formation.

In its type locality in Nahanni map area, the Narchilla Formation is primarily varicoloured slate and phyllite (Gordey and Anderson, 1993). Although varicoloured slate is the distinguishing rock type of the Narchilla Formation of Sprague Creek map area, the formation also comprises a significant amount of coarse-grained meta-clastic rocks and limestone.

Unnamed Lower to Middle Cambrian Units

North of the Sprague Creek fault (Fig. 2), a distinctive sequence of mafic metavolcanic rock, quartzite, shale/phyllite, chert, and calcareous clastic rocks overlies the Narchilla Formation, apparently with conformable contact. This sequence has been traced from the northern boundary of the map area southward around the Lost Horses syncline. At its southeastern limit south of Sprague Creek, this sequence ends abruptly, in inferred fault contact with rocks of the Yusezyu Formation. The inferred Sprague Creek fault is interpreted as a north-side-down normal fault.

Mafic Meta-Volcanic Unit

Dark green massive to fragmental mafic meta-volcanic and volcaniclastic rocks (Figs. 6 and 7) are discontinuously exposed from the northern part of the map area in Hobo Creek southeastward and around the Lost Horses syncline to north of the 'Mahtin' stock (Fig. 2). The contact with the underlying Narchilla Formation is apparently conformable although the possibility of a disconformity cannot be ruled out. Massive and fragmental varieties occur in the lower part of this unit and turbidites consisting of interbedded volcaniclastic meta-sandstone and grey phyllite occur at the top. The unit is at most several tens of metres thick although a complete section has not been measured.

Quartzite and Phyllite Unit

Overlying the mafic meta-volcanic unit with apparent conformity is a discontinuous unit of quartzite (siliceous meta-sandstone) and grey phyllite dominated by two discontinuous thick bands of massive light to dark grey quartzite and rare pebbly quartzite. The unit has been traced from outcrops in Hobo Creek near the northern boundary of the map area southeastward to the area between Red Mountain and Sprague Creek. It was not observed at the same stratigraphic position beyond this area in the core of the Lost Horses syncline and may be lenticular or erosionally truncated. The lower thick quartzite band occurs several metres above a several metre-thick unit of grey phyllite which sits directly on turbiditic clastic rocks of the underlying mafic

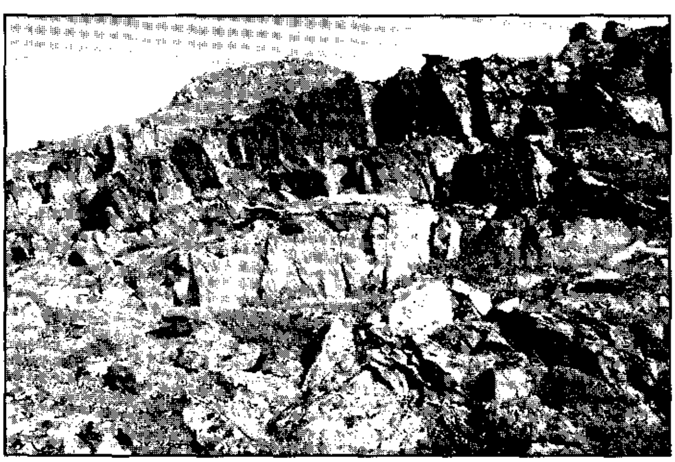

Figure 4: Medium-to thick-bedded meta-sandstone and pebbly meta-sandstone and interbedded phyllite of Narchilla Formation. View is to the west along the ridge east of summit of Red Mountain.

Figure 5: Limestone breccia in carbonate member of Narchilla Formation.

Figure 6: Coarse-grained volcanic breccia in mafic metavolcanic unit at base of unnamed Lower to Middle Cambrian sequence. Photo of boulder in southern tributary of Hobo Creek.

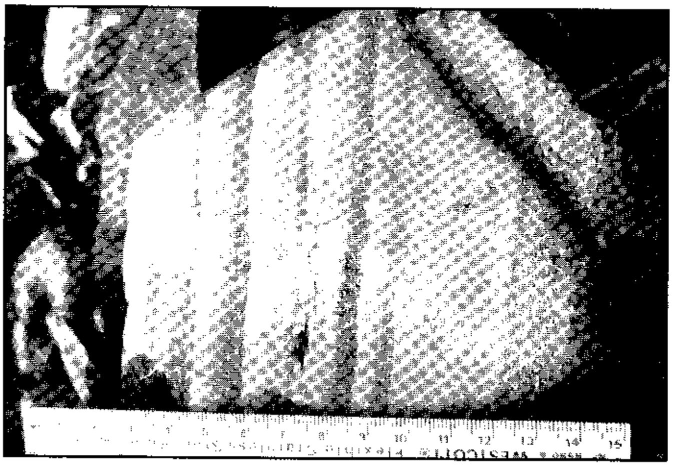

Figure 7: Thin-bedded turbiditic greywacke at top of mafic metavolcanic unit. Photo of boulder in southern tributary of Hobo Creek.

metavolcanic unit. The two bands of quartzite are separated by several metres of poorly exposed grey phyllite. The quartzite and phyllite unit makes up the upper part of the steep gossanous south-facing slope east of the Red Mountain stock where it is on the stratigraphically inverted limb of a second-order fold in the hinge zone of the Lost Horses syncline.

Shale/phyllite and Chert Unit

The upper band of quartzite is overlain and possibly partly laterally continuous with a monotonous sequence of greenish-grey phyllite, locally with millimetre- to centimetre-scale siltstone laminae and less commonly, metre-scale bands of sandstone and pebbly sandstone (Fig. 8). West of Gem Creek and at or near the same stratigraphic level as the quartzite bands described above are several tens of metres of thinly bedded (centimetre- to decimetre-scale) greenish chert. The lower part of the steep gossanous slope south of Red Mountain is underlain by pelitic hornfels of this unit. The best unhornfelsed exposure of this unit occurs in the floor of Hobo Creek where placer miners have excavated to bedrock.

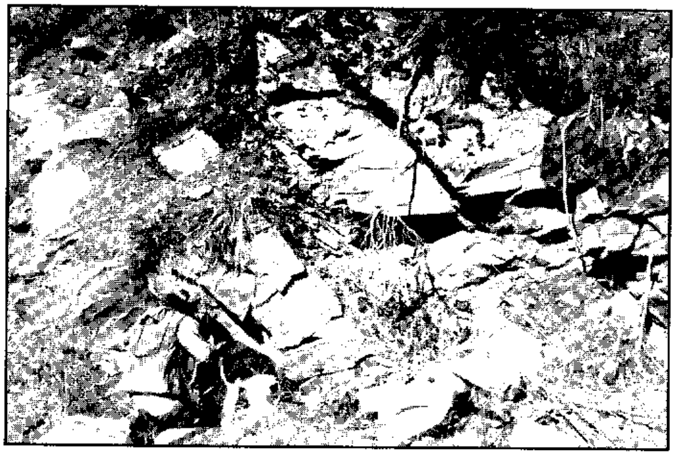

Figure 8: Thick-bedded pebbly meta-sandstone in shale/phyllite and chert unit of unnamed Lower and Middle Cambrian sequence. Stratigraphic top is to the left (south) indicating that the sequence is overturned. Photo taken in Hobo Creek valley west of its confluence with Arizona Creek.

Calcareous Clastic Unit

Above the shale and chert unit are thinly-bedded calcareous siltstone, sandstone, shale and limestone. Calcareous sandstone and siltstone weather tan to brown and locally resemble the Steel Formation of the Road River Group (see below). The contacts with over- and underlying rock have not been observed. Near felsic intrusions, this unit is metamorphosed to a layered, locally cherty calc-silicate hornfels and sandy marble with relict clastic quartz grains still visible.

Age and Correlation

The ages of the units in this sequence are constrained only to be Lower and/or Middle Cambrian by the ages of over- and underlying units. The underlying Narchilla Formation is Upper Proterozoic and Lower Cambrian (Gordey and Anderson, 1993). The sequence is overlain by a regionally persistent carbonate unit tentatively correlated with the Upper Cambrian Rabbitkettle Formation (see below). The mafic metavolcanic and quartzite units may correlate with similar units found in the Lower Cambrian Sekwi Formation; the upper two units resemble and may correlate with the Gull Lake Formation, also of Lower Cambrian and possibly Middle Cambrian age (G. Abbott, personal communication, 1993).

Rabbitkettle Formation

A white-weathering carbonate unit composed of calcareous (locally dolomitic) phyllite, thin- to medium-bedded marble, and rare limestone-pebble meta-conglomerate has been traced from the western side of Clear Creek map area (Murphy et al., 1993a, b) into Sprague Creek map area where it has been mapped around the hinge of the Lost Horses syncline and back into the northeast corner of Clear Creek map area. The carbonate unit overlies Hyland Group on the southern limb of the Lost Horses syncline and the calcareous clastic unit on the northern limb, suggesting a possible unconformable relationship. The contact between the overlying calc-phyllite-dominated unit and the underlying calcareous clastic unit is placed above the last appearance of sandy marble/limestone. Where the units are both metamorphosed to cherty calc-silicate hornfels near felsic intrusions, clastic sand grains preserved in the underlying unit permit their differentiation.

The carbonate unit resembles and is correlated with the Rabbitkettle Formation, an Upper Cambrian phyllitic/shaley carbonate unit that is widespread in Selwyn Basin (Abbott et al., 1991 and references therein). The Rabbitkettle Formation overlies a widespread pre-Upper Cambrian unconformity (Abbott et al., 1991 and references therein). The lithological correlation with the Rabbitkettle Formation is further supported by the possible unconformity at the base of the calc-phyllite unit.

Road River Group

The Rabbitkettle Formation is overlain with apparent conformity by a poorly exposed sequence of rocks of the Ordovician-Lower Devonian Road River Group. In the northwestern part of the map area, and the adjacent Clear Creek map area, the group consists of two units, a generally recessive basal unit composed of grey to black shale/phyllite, cherty shale/phyllite, chert, and rarely quartz-augen phyllite (felsic metavolcanic rock?) and an upper unit composed of locally limy or dolomitic siltstone, shale/phyllite and sandstone. The upper siltstone unit weathers a distinctive beige-orange colour, is generally massive to well-laminated but locally ripple cross-laminated, and locally bioturbated with well preserved burrows.

These two units are correlated with the Duo Lake and Steel formations, respectively, as defined in Nahanni map area by Gordey and Anderson (1993). In Nahanni map area, these two units are known to range in age from Early Ordovician to earliest Devonian.

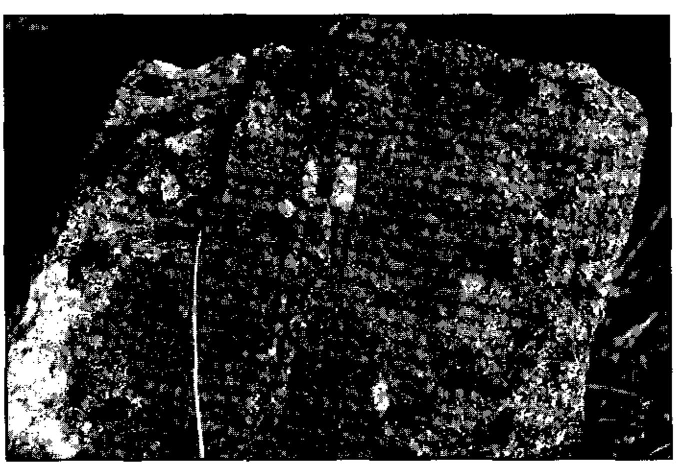

Figure 9: Biotite-hornblende monzodiorite of 'Mahtin' stock. Note prominent potassium feldspar megacryst cut by thin steeply dipping quartz vein.

Earn Group

Dark shale/phyllite, siltstone, sandstone, and chert-pebble conglomerate of the Devonian to Early Mississippian Earn Group occur in the northwestern corner of Sprague Creek map area. Shale/phyllite is the dominant rock type; less common coarse clastic rocks form prominent strike ridges and cuestas. The Earn Group is best displayed along the north-trending ridge south of the confluence of Hobo and Big creeks where the northernmost summit is underlain by conglomerate, sandstone, and fossil-leaf-bearing shale/phyllite.

Throughout Selwyn Basin, Earn Group strata overlie a profound regional unconformity. In Sprague Creek map area, the Earn Group overlies different stratigraphic units in different places. On the south limb of the Lost Horses syncline, the group lies either on the Steel Formation or on lower shale/phyllite and chert unit of the Road River Group. In the hinge zone of the syncline, Earn Group is inferred to overlie the lower shale/phyllite and chert unit of the Road River Group and, further north, the Rabbitkettle Formation.

Igneous Rocks

Felsic intrusive rocks occur throughout Sprague Creek map area, occurring in bodies ranging in size from metre-scale dykes to stocks several square kilometres in area. Emond (1992) noted that two compositionally and geographically distinct suites are represented in this area, a northern biotite- and hornblende-bearing suite ranging in composition from quartz monzonite to diorite (Red Mountain, Mahtin, Tramp, Big Creek, and West Ballard Creek stocks) and a southern biotite and muscovite-bearing suite ranging in composition from granite to quartz monzonite (Vancouver Creek [Lugdush stock of Murphy et al., 1993a, b], Boulder Creek, and Sunshine Creek stocks). Fine- to coarse-grained generally porphyritic dykes spanning a similar range of compositions are widespread in the area, most commonly near the larger bodies.

The two suites can be difficult to distinguish in the field because hornblende and muscovite are not everywhere coarse-grained enough to recognize. Both suites contain prominent and locally megacrystic potassium feldspars (Figs. 9 and 10). The southern suite usually exhibits large, smoky quartz phenocrysts and milky equidimensional feldspars while the feldspars in the northern suite are generally glassier and tabular and the rock generally has a bluish-grey cast to it.

New U-Pb dating by Jim Mortensen at the University of British Columbia shows that the two intrusive suites are locally of different ages. Two members of the northern biotite-hornblende suite are mid-Cretaceous (Lost Horses stock, 93+2.7/-0.8 Ma and Pukelman stock, 91+/-0.8 Ma, in Clear Creek map area), as suggested by earlier K-Ar work (Emond, 1992 and references therein). The ages of these bodies place them in the range of the Tombstone suite, not the Selwyn suite as indicated by Wheeler and McFeely (1991). Two members of the southern muscovite-bearing suite are Late Cretaceous-Paleocene in age

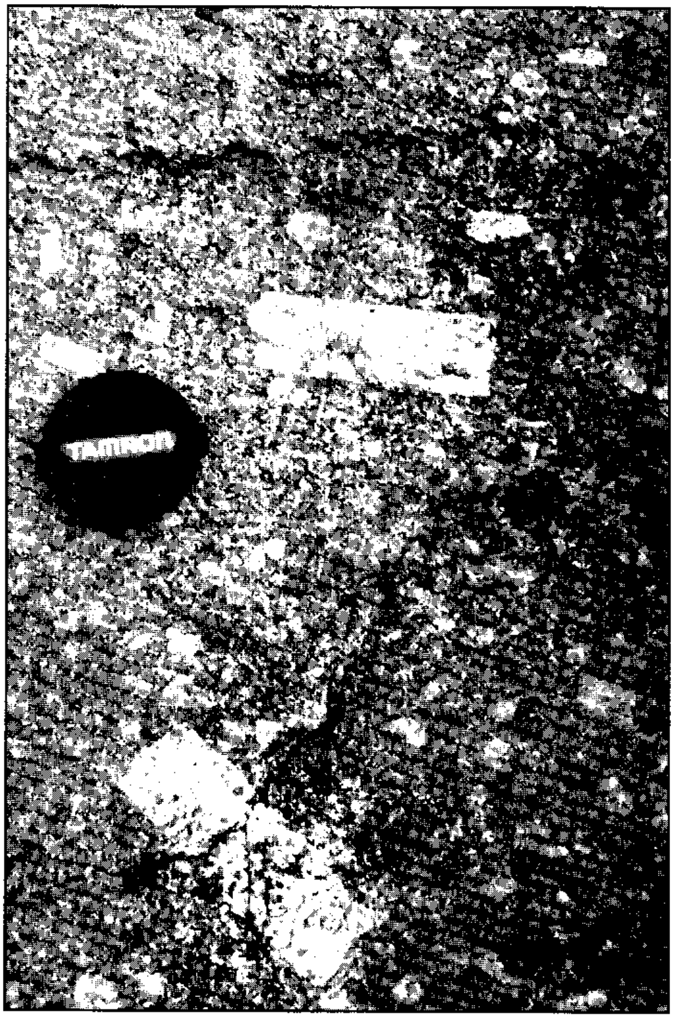

Figure 10: Potassium feldspar megacrystic biotite-muscovite granite of Vancouver Creek stock. Thin steeply dipping quartz vein transects the largest two megacrysts in centre of photo.

(Vancouver Creek stock, ca. 66 Ma and Two Sisters stock [incorrectly referred to as Twin Sisters in Murphy et al., 1993a, b], 64 +/-0.3 Ma). More U-Pb dating is planned to determine the extent of the newly identified Late Cretaceous-Paleocene suite and to evaluate whether composition may be used to differentiate the two suites.

Volcanic rocks mapped by Bostock (1964) as Tertiary or younger are exposed near the northern edge of the map area, north of Hobo Creek. These rocks are composed of unsorted silt- to boulder-sized angular to subrounded lithic clasts and locally strained monocrystalline quartz fragments embedded in a felted greenish-grey matrix of uncertain origin. Pore spaces visible in thin section may be vesicles or alternatively, plucked lithic fragments. The margins of the pores are lined by fine grained greenish prismatic minerals suggesting either a reaction relationship or open space filling. These rocks may be altered crystal lithic tuffs or a volcanic debris flow.

Structural geology

The structure of Sprague Creek map area results from pre-Upper Cambrian normal faulting, at least three phases of regional deformation which vary in intensity across the area, and late brittle fracturing and faulting in the western and southern parts of the area. Older rocks lie in the structurally deeper southern part of the map area and younger rocks generally appear towards the north. This trend reverses in the hinge zone of the composite Lost Horses syncline in the northern part of the map area.

Pre-Upper Cambrian Normal Faulting

Normal faulting prior to the deposition of the Rabbitkettle Formation is inferred from two considerations: 1) the observation that on the southern limb of the Lost Horses syncline the Rabbitkettle Formation directly overlies the Yusezyu Formation while elsewhere around the syncline, the units of the several kilometre-thick unnamed Lower to Middle Cambrian sequence intervene between the Rabbitkettle and Yusezyu formations; and 2) when followed around the southern hinge of the composite syncline, the units of the Lower to Middle Cambrian sequence trace abruptly into rocks of the Yusezyu Formation. In the area where the different rock units converge, there is insufficient space to allow the younger sequence to gradually disappear beneath the proposed sub-Rabbitkettle unconformity. The Sprague Creek fault was inferred to accommodate the abrupt juxtaposition.

Earliest Phase of Regional Deformation, D1

D1 structures have been found only in the younger, structurally shallow rocks in the northern part of the map area. The Lost Horses syncline is the most prominent D1 structure in the area. It is a composite tight to isoclinal southwest-overturned syncline outlined by the repetition of rocks younger than the Rabbitkettle Formation and the congruent change in vergence of parasitic folds and cleavage-bedding relationships. On the northern limb, the sequence of rock units and stratigraphic facing criteria indicate that the sequence is overturned to the southwest; parasitic folds and cleavage-bedding relationships on this limb verge to the northeast. The southern limb is upright stratigraphically and characterized by southwest-vergent minor folds and cleavage-bedding relations.

Second Phase of Deformation, D2

A distinctive suite of shear zone-style structures and fabric elements occurs throughout the southern part of the map area. This suite of D2 structures gradually overprints bedding and SW-vergent D1 folds and fabric elements, is geometrically and kinematically distinct from D1 structures, and is absent on the northern limb of the Lost Horses syncline and therefore not folded by it. These observations suggest that D2 deformation post-dates and is unrelated to D1 deformation.

D2 deformation progressively increases in intensity to the south, into deeper structural levels. At the top of the D2 strain zone, at the approximate structural level corresponding to the base of the Road

River Group, D1 folds are folded by NE-vergent folds and where bedding is identifiable, a NE-vergent cleavage-bedding relationship generally exists. At slightly deeper structural levels, over a transition zone less than two hundred metres-thick, bedding is not usually recognizable, being replaced by wavy discontinuous mica-rich (phyllite) and mica-poor, quartzofeldspathic (psammite) compositional domains. A foliation defined primarily by the parallel orientation of fine-grained micas and secondarily by the shape fabric of strained clastic grains in psammite (Sp) lies sub-parallel to the boundaries of compositional domains. NW-vergent folds of compositional layering are common, with an axial-planar fabric indistinguishable from Sp. The waviness of the compositional domains is imparted by systematic down-to-the-northwest deflection and thinning of compositional domains and foliation across discretely spaced, northwest, southwest or west-dipping planes (Sp'). Sp' planes are discontinuous, passing asymptotically both up- and down-dip into Sp. Deeper into the strain zone, Sp and Sp' are folded by gently inclined neutral to S-vergent open to tight kink folds (Fc). The intensity of folding of Sp and Sp' increases to the south to the extent that an axial-planar solution cleavage, Sc, develops and becomes the most prominent planar fabric. At the deepest observed structural levels, Sc is itself folded by gently inclined, tight, neutral to S-vergent folds (Fc+1, Fig. 11); at this level, it is impossible to distinguish different phases of folding and foliation development. At all structural levels, Sp, Sp', and Sc contain Lp, a prominent NW-trending elongation, quartz fibre, and mineral-streaking lineation (Fig. 12). Lp is sub-perpendicular to tension cracks and the long axes of boudins. Where Sc and later folds are prominent, hinge line and intersection lineations occur, trending slightly but consistently more westwardly than the NW-trending Lp.

D2 fabrics and the sequence of fabric development are typical of those found in shear zones and may be used to infer a sense of displacement across the zone. Sp' planes are morphologically identical to shear bands or extensional crenulation cleavages. The relationship of Lp to boudinage, tension cracks, and shear bands suggests that it is parallel to the direction of finite extension and it is therefore likely to closely approximate the sense of displacement across the shear zone. The sense of inclination of Sp' to Sp and Lp consistently indicates top-to-the-northwest displacement parallel to Lp. This sense of displacement is further supported by the sense of truncation of Lp fibres on Sp, the vergence of asymmetric isoclinal folds of compositional layering, the sense of subtle obliquity of tension cracks to Lp, the geometry of rare sigmoidal tension gash arrays, and difference in style of deformation of differently oriented pre-and syn-kinematic veins.

The northeastward vergence of folds at the shallowest structural levels of the zone and southward vergence of Fc and Fc+1 folds at deep levels do not easily fit into a model of NW-directed displacement.

Figure 11: Folds typical of deeper structural levels of D2 deformation zone in Sprague Creek map area. Sc, the foliation being folded, is axial-planar to folds of an even earlier foliation, Sp. Sp is visible above fingertip in light coloured domains between dark Sc folia.

Figure 12: Top of Sp foliation plane showing Lp (parallel to the eraser), a prominent mineral streaking and elongation lineation. Note in the bottom part of the photo thin dark hairline cracks perpendicular to Lp. The surface of Sp is wavy due to Fc folding. The hinge of one such fold is below the eraser at about a 40° angle to it. Fc hinges are consistently more westwardly trending than the NW-trending Lp.

Perhaps NE-vergent folds reflect early NE-directed (cratonward) displacement that is progressively overprinted by later NW-directed fabrics. Although many alternatives are possible, S-vergent folds may reflect a strained hanging wall lateral ramp.

Later Phases of Deformation, D2+

All planar fabric elements in the southern part of the map area are warped into somewhat disharmonic regional-scale open folds. In the west-central part of the area, planar elements strike southwestwardly and dip moderately northwestwardly. In the central part of the sheet, the strike changes to eastward, with a moderate northward dip. In the east-central part of the sheet, strike is southeast and dips are moderate to the northeast. The moderate northward dip decrease to the south, becoming subhorizontal in the southwest corner of the map area. This simple pattern is complicated in the southeastern corner of the map area by a doubly plunging ENE-trending upright antiform that coincides with the outcrop area of the Sunshine and Boulder Creek stocks. Southeast of the antiform's axial-surface trace, planar elements dip moderately to the south. The axial-surface trace of the antiform is intruded by both the Sunshine Creek and Boulder Creek stocks suggesting that the stocks post-date it; however, the possibility of the antiform being an early intrusion-related dome that was subsequently intruded cannot be ruled out.

The changes in orientation of planar elements across the map area reflect interference between northerly trending warps, southward shallowing of foliations, and the ENE-trending antiform. The order of interference has not been determined.

Figure 13: Aerial photo of area along western border of Sprague Creek map area showing N-trending topographic lineaments (marked by heavy dashed lines). North is to the top of photo. The N-trending creek in western side of photo is Josephine Creek in which lies a fault with about 2 kilometres of apparent dextral offset.

Faults, Lineaments, and Breccia Zones

A several kilometre wide NNW-trending zone of N- and NNW-trending topographic and structural lineaments crosses the western side of the map area (Fig. 13). One N- to NNW-trending fault cutting across the head of Big Creek along the western boundary of the map area (Josephine Creek fault of Murphy et al., 1993b and Murphy and Héon, 1994) accommodates about two kilometres of apparent dextral offset. Several of the N-trending lineaments are marked by locally silicified limonitic breccias characterized by significant porosity. No offsets can be documented along many of the N-trending zones and they may be purely tensional in origin. The sense of inclination of the discontinuous N-trending, possibly tensional lineaments to the overall north-northwest trend of the zone and the apparent dextral offset along some of the NNW-trending lineaments are consistent with the interpretation of dextral displacement across the zone.

Mineralized ENE-trending breccias (TEE, SUNSHINE CREEK EAST and WEST, EDP and NHL; Emond and Lynch, 1992) occur in an ENE-trending zone across the southern part of the map area. This zone parallels and is along strike with the structural trend of the faulted McQuesten antiform as defined west of Keno Hill (Hunt et al., 1993) which has been implicated in Keno Hill Ag-Pb-Zn mineralization (Roots and Murphy, 1992a). No offsets have been documented across any of the features in Sprague Creek map area; Keno Hill mineralization is thought to be associated with sinistral strike-slip displacement along the faulted McQuesten antiform trend (Watson, 1986; Roots and Murphy, 1992).

The relationship between the NNW- and ENE-trending fracture zones in not clear. The ENE-trending zone is crossed by the prominent NW-trending topographic lineaments in Boulder, Sunshine, and Forty-Mile Creeks and other unnamed tributaries to the McQuesten River. The two zones intersect in the southwest corner of the map area and topographic lineaments are not obvious along strike from either zone south and west of Sprague Creek map, suggesting that they terminate against each other. A conjugate relationship between the two zones is possible, an interpretation supported by their angle of intersection, their apparent mutual termination, their opposing senses of displacement, and the base metal vein mineralization associated with both zones (Fig. 14).

The western and northern contacts of the 'Mahtin' stock are NE- to E-trending north-side-down normal faults. These faults cannot be traced beyond the immediate area of the stock and may be intrusion-related.

Ages of Structures in Sprague Creek Map Area and Regional Implications

The timing of deformations in Sprague Creek map area is constrained by both local and regional evidence. D1 and D2 structures in Sprague Creek map area are constrained locally to be pre-late Early Cretaceous in that they are intruded by post-kinematic stocks (Fig. 15) as old as 93 Ma. D1 structures in Sprague Creek map area resemble and possibly correlate with prominent SW-vergent folds found throughout the Omineca Crystalline Belt (Brown and Lane, 1988; Murphy, 1989; Brown et al., 1993) of early Middle Jurassic age (Ricketts et al., 1992; Murphy et al., in press).

Abbott (1990), Murphy and Roots (1992), and Roots and Murphy (1992a, b) described a suite of structures and fabrics in the Keno Hill area that resemble and probably correlate with D2 structures and fabrics in the Sprague Creek area. The regional distribution of these fabrics suggests that they are related to displacement on the Tombstone thrust (Abbott, 1990). Movement on the Tombstone thrust is Early Cretaceous based on the Late Jurassic age of the youngest rocks in the footwall of the thrust (Poulton and Tempelman-Kluit, 1982) and the late Early Cretaceous age of cross-cutting plutons (J. Mortensen, personal communication, 1993). Late warps of the Early Cretaceous D2 fabrics are intruded by the suite of late Early Cretaceous stocks, making them Early Cretaceous as well.

NNW-trending lineaments are post-late Early Cretaceous in that they cross the 'Mahtin' stock which is thought to be late Early Cretaceous based on lithological similarity to other dated members of the northern hornblende-bearing intrusive suite. ENE-trending breccia zones such as SUNSHINE CREEK EAST and WEST are thought to be associated with the nearby Sunshine Creek stock which may be Late Cretaceous based on lithological similarity to the ca. 66 Ma Vancouver Creek stock.

Mineralization

The region between Dawson and Keno Hill has seen sporadic exploration for silver, lead, tin and tungsten since the 1920's. More recently, Cretaceous granitic intrusives in the region have been investigated for low-grade, bulk tonnage gold mineralization similar to that found at the Fort Knox deposit, Alaska (Hollister, 1991). Big, Granite, Arizona, Hobo, Gem and Sprague creeks have been tested and/or mined for placer gold. None of the operations were active during the 1993 season.

Several mineral occurrences are known in Sprague Creek map area (Fig. 2, Table 1). Most are peripheral to felsic intrusions and belong to one of four types: 1) Au-Ag veins and breccias (HOBO, MAHTIN), 2) Ag-Pb-Zn veins and breccias (QUEST, BANDER, ORE, TEE, STERLING, JABBERWOCK), 3) tourmaline breccias (MAHTIN [Ag], SUNSHINE CREEK EAST [Sn, Ag], SUNSHINE CREEK WEST [Sn, Ag, Au, W], TEE [Sn]), and 4) skarns (MAHTIN [Sn], TEE [Sn, Au], SNARK [W, Sn, Au], LUGDUSH [W, Ag]). Several of these occurrences are described and discussed in Emond (1992) and Emond and Lynch (1992) and only new information is presented here. Significant new assay results are presented in Table 2. Results are still pending for samples collected on the TEE, BANDER, JABBERWOCK, and QUEST properties; the Oliver Creek occurrence (NHL) was not visited this year and will be examined during 1994. Our description below is framed in terms of where the mineralization occurs with respect to intrusions.

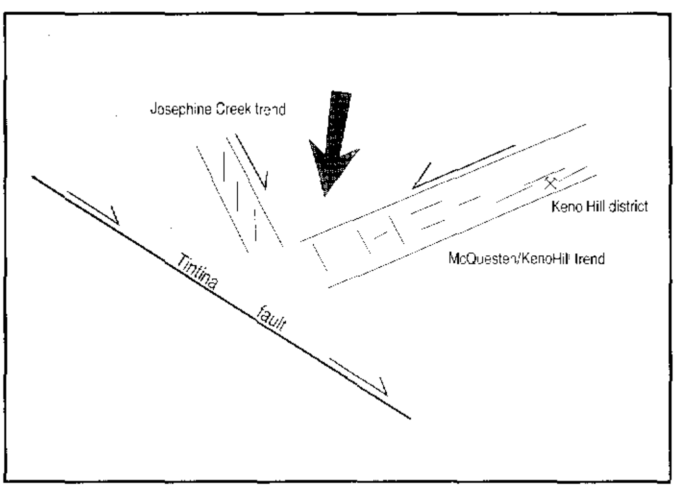

Figure 14: Diagram illustrating how the NNW- and ENE-trending fracture zones may be conjugate fracture systems. The relationship with the Tintina fault, also shown, is not known.

Figure 15: Eastern contact of post-kinematic 'Mahtin' stock where unfoliated biotite-hornblende monzodiorite truncates bedded and foliated calc-silicate hornfels of the Rabbitkettle Formation.

Table 1: Summary of mineral occurrences in Sprague Creek map area (I.N.A.C., 1992)

Occurrence	Minfile #	Metals	Description	Best assays
HOBO (Red Mt)	115P **006**	Au, Cu	Qtz veins in intr	
			Qtz veins in hfls	14.2 g/t Au, 8.8 g/t Ag
MAHTIN	115P **007**	Ag, Au, Sn	skarn	
			tourm-sulph breccia in intr	
			qtz-asp vein	3741 ppb Au, 50.6 ppm Ag, 1% Cu
TEE	115P **008a**	Sn, Ag, Pb, Zn, Au	tourm-qtz breccias	0.3% Sn
			qtz or tourm veins	250 ppm Ag, 17.8% Pb, 2.5% Zn
			skarn	0.41 % Sn, 2.38% Zn, 740 ppb Au
			vein + skarn	up to 2000 ppb Au
SNARK	115P **008b**	Au, Ag, W, Sn	skarn	2227 ppb Au, 28 ppm Ag, 1210 ppm W, 951 ppm Sn, 5553 ppm Cu, 3740 ppm Zn
LUGDUSH	115P **009**	W, Ag, Pb	skarn	2.2% WO_3/.2m
			galena veins	645 g/t Ag, 8% Pb
RIDGE (Sterling)	115P **010**	Ag, Pb, Zn, Sn	qtz-tourm veins (ga sph)	219.4 g/t Ag, 16.8% Pb, 3.7 % Zn, 1600 ppm Sn
SUNSHINE CREEK WEST	115P **031a**	Sn, Ag	qtz-lim-tourm breccias (vuggy)	0.28% Sn/7.6 m
SUNSHINE CREEK EAST	115P **031b**	Sn, Ag	" " cassiterite	2350 ppm Sn
JABBERWOCK	115P **051**	Sn, Ag	cass in tourm veins	8.8% Sn, 64 ppm Ag
			in vuggy qtz veins and dry fractures	
ORE (May Creek)	115P **056**	Ag, Pb, Zn	vein fault qtz ga angl py lim	962 g/t Ag, 73.9% Pb, 1.1% Zn, 0.8% Cu
QUEST	115P **057**	Ag, Pb, Zn, Au	qtz ga sider veins	11 381 g/t Ag, 1.6 g/t Au, 32.6% Pb/10 cm

Table 2: Significant Assay Results

Sample #:	Location	UTM E Zone 8	UTM N	Minfile # 115P	Au ppb	Bi ppm	As ppm	Sn ppm	Ag ppm	Cu ppm	Pb ppm	Zn ppm	W ppm	Cd ppm	Sb ppm	Te ppm	Mn ppm
Intrusion-hosted																	
93DH-8a	Big Ck diorite: vein	401420	7080740	new	377											N/A	478
93DH-19	Boulder Ck intr:dissem.	422106	7074061	new	186					295		669				N/A	517
93DM-68	Mahtin intr: qtz vein	411507	7088549	7	266	37	563			306						N/A	
93DM-69a	"	411659	7088485	7	195	59	7.3%						36		70	N/A	
93DM-69b	"	411685	7088543	7	166	48	2.2%	18	32.5	6927			270		101	N/A	
93DM-69c	"	411704	7088388	7	332	285	5.9%	28	15	1377					206	N/A	
93DM-70c	Mahtin intr: carb breccia	411890	7088384	7	118	5	757								1.4%	N/A	
93DM-98a	Red Mtn intr: qtz vein	414730	7093546	6	100		28										325
93 DM-98b	"	414730	7093546	6	210		114										300
93DM-98c	"	414612	7093641	6	170		662										345
93DM-98d	"	414612	7093641	6	335		20										345
93DM-98e	"	414390	7093738	6	205		128						10				390
93DM-98f	"	414208	7093752	6	220		62										460
93DM-99a	"	413884	7093916	6	390		572			574							365
93DM-99b	"	413884	7093916	6	150		166										395
93DM-299	Boulder Cr. intr:vein	416030	7072981	8			293				2101					N/A	330
93DM-307a	Boulder Cr.intr: dissem.	415452	7071954	8							3046					N/A	341
Country rock-hosted: vein, dissem.																	
93DH-13	S of Big Ck dior	401746	7079219	new?	435	72	88		15.3		242		303			N/A	
93DM-77a	qtzite adj RM dyke: diss.	415243	7093385	6	45		64			1245							
93DM-77b	" " " " "	415277	7093402	6	750	8	6730		2.2	240							
93DM-90a	Red Mtn qtz vein	416065	7093911	6	2300	24	>1%			825			12			12	
93DM-93a	" " " "	415777	7093794	6	2890	32	962		1.8	157	712				136		
93DM-93b	" " " "	415777	7093794	6	950	8	484		14.8		134				60		
93DM-99c	vein N of RM intr	413884	7093916	6	360		982										
93DM-99d	" " " "	413884	7093916	6	65		230			327							
Country rock-hosted: breccias																	
93DH-8	NE contact Big Cr. dior	401420	7080740	new	20		789								62	N/A	
93DH-13a	S " " "	401746	7079219	new	10		179		24				21			N/A	883
93DH-14	SE " " "	402154	7079663	new	27		484				472	1608	84	17.2		N/A	534
93DH-26d	W contact Sunsh Ck	421332	7077743	new	28	47	7879	200	48	727	2.1%	2408	90	25.3		N/A	758
93DM-95	RM adit mass asp	415537	7093517	6	9250	542	>1%	20	21.4	2350	>1%			23	3250	6.6	
93DM-95a	" " tourm'zd	415537	7093517	6	5330		570		1.2		90		18				
93DM-95b	" " q in ox qtzite	415537	7093517	6	95		1060				414				44		
93DM-114	N of RM intr	414173	7094750	6	527		1%		7.1	163					207	N/A	
93DM-200a	Van Ck/40 mi	406118	7076747	new	118	5	382		8.7	173	3882	2211	11			N/A	
93DM-310a	NE of Boulder Cr. intr	415142	7074427	new(8)	12		130		3		383	1749	8	14.6		N/A	1.5%
Country rock-hosted: skarn																	
93DM-66	Mahtin	411041	7088729	7	490	700	98%	88	55	183	1955				1081	N/A	
93DM-310b	NE of Boulder Cr. intr	415142	7074427	8 (new)	58	36	297		27.5		1438	2.9%	114	300		N/A	4610

Intrusion-hosted Mineralization: Veins, Breccias, and Disseminated

We have examined the intrusions themselves for evidence of the Fort Knox-style of mineralization. Au-bearing veins and locally breccias occur in several of the stocks outcropping in the northern half of the map sheet. Big Creek diorite (a new occurrence, sample 93 DH-8a), 'Mahtin' quartz monzonite (93DM-68, 69a, b and c), and Red Mountain quartz monzonite to monzodiorite (93DM-98a to f, 99a, b) all host quartz veins with anomalous Au content (100 to 400 ppb). They are usually also anomalous in As and, in the case of MAHTIN: Ag, Cu, Bi, W, Sb, and Sn. In these stocks, the veins occur as series of thin (centimetre-scale), steeply dipping ENE-trending quartz (-tourmaline-chlorite) veinlets locally containing arsenopyrite, pyrite, pyrrhotite, chalcopyrite and are associated with important Au-As soil anomalies. At the MAHTIN occurrence, the stock is cut by a carbonate breccia oriented parallel to adjacent Au-mineralized quartz veining. A sample of this breccia contained anomalous amounts of Au, As, and Sb (93DM-70c).

Our data so far indicate that intrusion-hosted Au-As-Sb +/- Bi mineralization is restricted to the northern suite of hornblende-bearing intrusions while the southern muscovite-bearing intrusions are more commonly anomalous in base metals. Veins in the muscovite-bearing Boulder Creek stock are anomalous only in Pb (93DM-299) and the dominant vein mineral is tourmaline. Anomalous Au, Cu, and Zn were found in a malachite-coated sample of a fine-grained border phase of the Boulder Creek stock (93DH-19). Hand-samples of Boulder Creek granodiorite containing disseminated sulphides are anomalous in Pb only (93DM-307a).

Metasedimentary Rock-hosted Mineralization: Veins, Breccias, and Disseminated

Veins, breccias and disseminated mineralization occur in metasedimentary rocks peripheral to intrusions and are probably related to them; proof of their igneous association would be their similar geochemical and isotopic signatures. Our geochemical data show that country rock-hosted mineralization mirrors that of the nearby intrusion in terms of metal types and associations. This association is being further investigated using Pb isotopes.

Mineralized quartz veins locally occur in metasedimentary rocks near intrusions. Slickenside-bounded quartz-tourmaline vein float collected near the southern margin of the Big Creek diorite is anomalous in Au, Ag, Bi and W (93DH-13). Breccia float also occurs nearby. Quartz veins, some trenched, occur in the extensive gossanous hornfels zone surrounding the Red Mountain intrusion; these are anomalous in Au and As and locally in Ag, Cu and W (93DM-90a, 93a, b, 99c, d). They are commonly vuggy with well developed cockscomb texture and locally contain tourmaline and show textures indicative of multiple injections.

Breccias are common throughout the map sheet, especially near intrusions, and are commonly mineralized. Breccias and veins commonly occur together. As vein quartz fragments are locally common in breccias and euhedral smoky quartz locally cements breccia fragments, it is likely that brecciation and veining are related processes. Emond and Lynch (1992) divided breccia occurrences of the McQuesten River region into rock flour breccias and crystalline matrix breccias (quartz or tourmaline dominant) and described the petrography of each type. We noted that both types are present at some mineral occurrences. Although most breccias are near intrusions and locally directly associated with felsic dykes, others lie along N- to NNW-trending lineaments, not apparently associated with intrusive rocks.

Most breccias cut metasedimentary rocks and these are commonly characterized by high limonite content (1–22% Fe), varying amounts of porosity, angular to rounded metasedimentary rock or vein quartz fragments, and local cockscomb-textured quartz. The breccias in the southern and southeastern part of the map area are noted for their extensive manganese coating. Two breccias were sampled in float near the northeastern and southwestern contacts of the Big Creek diorite. One was anomalous in As and Sb (93DH-8) and the other, a quartz-carbonate-hematite breccia, in Ag, As and Mn (93DH-13a). Several breccias occur with veins in the gossan east of the Red Mountain intrusive. Two SE-trending limonitic quartz-cemented fault breccias southeast of the intrusive were found to be anomalous in Au and As (93DM-91A and 91B). Massive arsenopyrite, tourmalinized host rock and vuggy quartz collected from the waste pile of an adit all showed anomalous results (up to 9250 ppb Au; 93DM-95, 95a, 95b). It was not possible to trace this structure beyond the adit. A composite sample of breccia marking a NE-trending fault north of the intrusion was anomalous in Au, Ag, As, Sb, Pb and Sn (93DM-114).

In the southern part of the map area, a small breccia located between sphalerite-bearing skarn (93DM-10b) and a small intrusive contains anomalous amounts of Cd and Mn (93DM-310a). The breccia at the SUNSHINE CREEK EAST occurrence was found to occur within a 3 km-wide NE-trending corridor of brecciation associated with tourmaline alteration and veinlets. Another breccia located near the western margin of the Sunshine Creek batholith returned values anomalous in Ag, As, base metals as well as Bi and Sn (93DH-6d).

Prominent N- and NW-trending lineaments in the western and southern part of the map area are commonly marked by limonitic breccias. These breccias are not obviously associated with intrusions. One of these, located west of Forty Mile Creek is anomalous in Au, Ag, As, Pb and Zn (93DM-200a).

Disseminated mineralization occurs locally near the Red Mountain intrusion. Samples of malachite-coated (93DM-77a) and oxidized quartzite (93DM-77b) adjacent to a large dyke are anomalous in Au and As.

Skarn mineralization

Skarn minerals occur in calcareous rocks of the Upper Proterozoic Hyland Group and overlying Cambrian strata. Skarn occurrences around the Vancouver Creek, Sunshine Creek, and Boulder Creek stocks are described in Emond and Lynch (1992) where the stocks intrude calcareous rocks of the Yusezyu Formation. Skarn mineralization occurs where the 'Mahtin' stock intrudes the calcareous clastic unit of the unnamed Lower to Middle Cambrian sequence and the Rabbitkettle Formation. A sample of quartz vein within skarn developed from the Rabbitkettle Formation at the MAHTIN occurrence is anomalous in Au, Ag, Pb, Sn, Sb and highly anomalous in As and Bi (700 ppm; 93DM-66). Calc-silicate hornfels are locally common around most intrusives but skarn mineralogy seem to be more prevalent adjacent to the smaller bodies, suggesting the smaller bodies were more volatile-rich.

Previously unreported skarn/calc-silicate hornfels occurrences have been located on the eastern contact of a small pluton east of Red Mountain as well as adjacent to the intrusion on the Tramp claims, located in the NW corner of the map sheet. One small sphalerite-bearing skarn, developed at the margin of the small intrusive west of the Boulder Creek stock returned values anomalous in Zn, Pb and Ag (93DM-310b)

Discussion

Documenting intrusion-hosted Au (As, Sb, +/- Bi) vein mineralization in the Red Mountain, 'Mahtin', and Big Creek stocks increases the number of stocks with potential for Fort Knox-style Au mineralization. Our work further affirms the conclusion of Emond (1992) that Au mineralization is associated with the hornblende-bearing northern plutonic suite rather than with the southern muscovite-bearing suite. The southern suite is associated with Ag-Pb-Zn mineralization. W and Sn mineralization occurs with both types. Although only four intrusions have so far been dated, the U-Pb dating provides some new insight into this difference in metal association: the two suites may be of two different ages and may reflect present different source areas and different tectonic environments.

We have also documented a new type of occurrence in the area. Breccias associated with N- and NW-trending structural lineaments and not obviously associated with intrusions are locally anomalous in Au. These may warrant further investigation.

Conclusions

1. Sprague Creek map area is underlain by multiply deformed low-grade Upper Proterozoic to mid- Paleozoic metasedimentary rocks and two suites of Cretaceous felsic intrusions.
2. A previously undescribed sequence of probable Lower or Middle Cambrian age occurs in the northern part of the map area. It is inferred to have been preserved by pre-Late Cambrian block faulting (Sprague Creek fault) before the unconformable deposition of the Rabbitkettle Formation.
3. Metasedimentary rocks were deformed by at least three phases of regional deformation before the emplacement of Cretaceous intrusions. Two zones of faults and fractures, one NNW-trending, the other ENE-trending, transect the area.
4. U-Pb dating of felsic intrusions shows that two members of northern hornblende-bearing intrusive suite are 91 and 93 Ma and belong to the Tombstone suite. Two members of the southern muscovite-bearing intrusive suite are 64 and 66 Ma, revealing the presence of a previously undocumented Late Cretaceous-Paleocene suite. These recent data make possible the interpretation that the two compositionally different suites are entirely of different ages.
5. Vein, breccia, and disseminated mineralization occurs within intrusions and peripherally, in the adjacent metasedimentary country rock. The northern, hornblende-bearing, suite of intrusions is more commonly associated with Au mineralization than the southern, muscovite-bearing, suite. The southern suite is more commonly associated Ag, Sn and base metal mineralization.
6. Breccias associated with the NNW-trending set of structural lineaments are locally anomalous in Au; this type of breccia is not directly related to intrusions.

Acknowledgements

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Geology of the Joe Mountain Map Area (105D/15), Southern Yukon Territory

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Abstract

The Joe Mountain map area, northeast of Whitehorse, is underlain by folded, Upper Triassic and Jurassic sedimentary and volcanic strata of the Whitehorse Trough which are intruded by north-trending Cretaceous plutons. Volcanic rocks previously mapped as "Volcanics of uncertain age" and Hutshi Group are Triassic in age and comprise three mappable units dominated by thick accumulations of basaltic and andesitic, aphyric pillowed volcanics. The volcanics, and associated sedimentary rocks dominate the eastern part of the map area whereas a thick carbonate assemblage dominates the Upper Triassic stratigraphy in the western part of the map area. The east-west transition represents either a sharp facies change across the map area or a structural juxtaposition. Numerous through-going, north-trending faults which cut the region may originate from motion along the interpreted Lake Laberge Fault Zone which underlies the Yukon River/Lake Laberge valley.

Potential mineral deposits in this map area include copper (gold-molybdenum-tungsten) skarns and gold-bearing quartz veins. Regional silt geochemistry indicates that the distribution of the Triassic volcanic suites is spatially coincident with regionally extensive, gold-in-silt anomalies. The source of these anomalies is uncertain and provide for intriguing prospecting targets.

Introduction

The Whitehorse Geological Mapping Project, a two-phase program initiated in 1987, encompass 1:50 000 geological mapping of the south central part of the Whitehorse (105D) 1:250 000 map sheet (Figure 1; 105D/2,3,6, 11 and part of 7; Doherty and Hart, 1988, Hart and Pelletier, 1989a, 1989b; Hart and Radloff, 1990). These map sheets cover regions with significant mineral potential in the Wheaton River, Carcross and Whitehorse areas. The second phase of this project involves the geological mapping of the northern portion of the Whitehorse map area (105D/13-16). The intent of this phase is two-fold: 1) to provide geological maps which may identify favourable geological settings similar to those which host the more southerly deposits; and 2) to provide a geological transect across a cohesive geological province—Stikinia. Map-sheet 105D/13 was geologically mapped during 1992 (Hart and Brent, 1993, Hart, 1993). Geological mapping of 105D/14 and 16 are proposed for 1994–1995.

The Joe Mountain map area (105D/15), northwest of Whitehorse, is underlain by large expanses of outcrop previously mapped as "Volcanics of uncertain age" (Wheeler, 1961). Since many mineral deposits in the southern Yukon are associated with specific groups of volcanic rocks (i.e., Mt. Skukum, Venus, Mt. Freegold, Mt. Nansen), the age and identity of these rocks is critical in assisting exploration efforts. With this focus, the Joe Mountain map area was geologically mapped during 1993. The results are presented here and accompany Geological Map 1994-4 (G). Since there are only six features with topographic names on the map sheet (Joe Creek, Joe Mountain, Cap Creek, Cap Mountain, Mount Slim and Laberge Creek), location references in the text are commonly made with respect to spot elevations which are listed for numerous mountain peaks.

Previous Work and Access

Large-scale regional geological maps by Cockfield and Bell (1926, 1944) and Wheeler (1961) are the only previous geological coverage of the Joe Mountain map area. Regional scale geological mapping of the adjacent Laberge map-area was completed by Tempelman-Kluit (1984). Detailed topical investigations of rock units found in the Joe Mountain map sheet are identified throughout this report.

Despite it's close proximity to Whitehorse, the Joe Mountain map area has seen very little previous exploration. Regional scale exploration programs undertaken by Hudson Bay Mining and Smelting in 1979 and by Dupont Exploration in 1981, were primarily directed towards the discovery of copper-gold skarns similar to those of the Whitehorse Copper Belt. Regional geochemical silt sampling of 105D was undertaken by the Geological Survey of Canada (1985). Gold anomalies revealed by that program spurred claim staking in the Joe Mountain map sheet by United Keno Hill Mines (INAC, 1987).

The Joe Mountain sheet is not traversed by roads or known trails. Foot access to the area can be gained from the Yukon and M'Clintock River valleys. Helicopter access from nearby Whitehorse is relatively economical.

Physiography and Glaciation

Joe Mountain map area is in the Teslin Plateau physiographic region (Mathews, 1986) which is part of the Intermontane Belt. Physiography of the region is characterized by rolling mountains and upland plateaus dissected by large valleys. Two broad, linear, north-trending, upland plateaus between 5 500 and 6 000' are separated by the Cap Creek valley and flanked to the west and east by the Yukon River and M'Clintock Lakes valleys, respectively. The northeast portion of the map-sheet is dominated by jagged mountainous terrane characterized by cirques and arrêtes. Approximately 4 300' in local relief separate the highest point in the map-area (Joe Mountain at 6 837') from the Yukon and M'Clintock River valleys at circa 2 500'.

The Joe Mountain map sheet has been extensively glaciated. Glacial striae on bedrock indicate that the continental ice sheet moved northwesterly across the region from the southeast. Southeast-facing slopes host numerous, boulder-sized, tectonized ultramafite erratics almost certainly derived from the oceanic rocks of the Cache Creek Terrane to the south and southeast. Glacial deposits are extensive below 4 500', the approximate elevation of tree-line. Kame terraces form numerous benches in the western part of the map area at elevations as high as 5 100'.

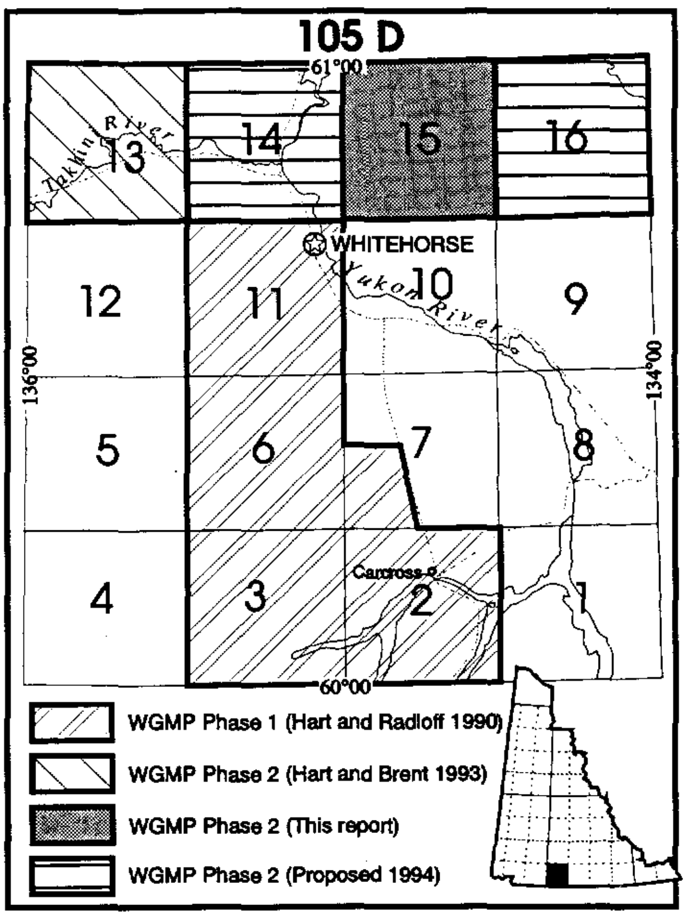

Figure 1: Locations of geological mapping undertaken by the Whitehorse Geological Mapping Project in the Whitehorse map area (105D). This report refers to mapping in the Joe Mountain (105D/15) map area.

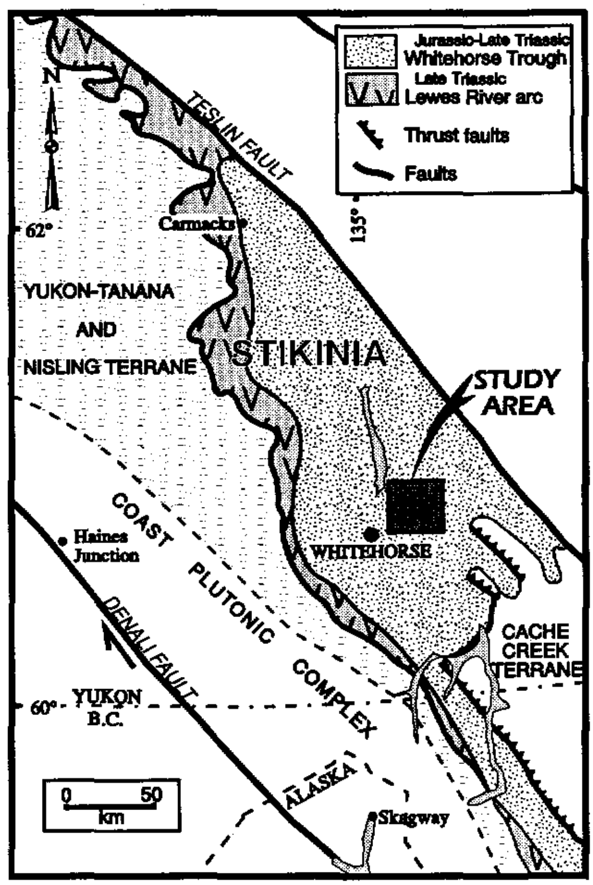

Figure 2: The regional tectonic setting of the study area showing the location of the map area in the Whitehorse Trough portion of Stikinia. Stikinia, Cache Creek and the composite Yukon-Tanana and Nisling Terranes are disparate crustal fragments that were amalgamated during Mesozoic time.

Tectonic Setting and Regional Geology

Yukon Territory southwest of the Tintina Fault consists primarily of fault-bounded crustal fragments, or terranes, that accreted to the ancient North American margin during Mesozoic time. Rocks underlying the study area belong to a crustal fragment known as Stikinia which comprises a northwest-trending belt of Late Triassic volcanic rocks that are flanked to the east by Late Triassic and Jurassic sedimentary rocks (Figure 2; Tempelman-Kluit, 1979). The volcanic rocks belong to the Lewes River Group and constitute the Lewes River arc. The sedimentary rocks belong to the Lewes River and Laberge groups, and constitute more than 7 kilometres of arc-derived basin fill which defines the Whitehorse Trough (Dickie, 1989 and references therein). Geological investigations of Whitehorse Trough strata have shown it to be lithologically diverse, stratigraphically complex and dominated by abrupt facies changes (Tozer, 1958; Wheeler, 1961; Tempelman-Kluit, 1984; Dickie, 1989; Reid and Tempelman-Kluit, 1987). A stratigraphic nomenclature was suggested by Tempelman-Kluit (1984). Although the application of layer-cake stratigraphic terms to Whitehorse Trough strata is inappropriate, they are used in this report as a foundation for discussion.

Subsequent tectonism has folded and faulted the Stikinian volcanic and sedimentary packages against one another, and with other exotic crustal fragments including the oceanic Cache Creek Terrane and the pericratonic Nisling and Yukon-Tanana Terranes (Figure 2; Tempelman-Kluit, 1979)

Magmatism during mid-and Late Cretaceous times resulted in the emplacement of numerous plutons and the deposition of extensive coeval volcanic successions in and among the deformed crustal fragments. Regionally induced stresses during Late Cretaceous to Eocene time reactivated old faults and created a series of through-going north and northwest-trending strike-slip faults. Caldera-style volcanic successions and related epizonal plutons of the Skukum Group were deposited during Late Paleocene time and are associated with extensional structures.

General Geology

The Joe Mountain map area is underlain by geology dominated by folded Late Triassic volcanic and sedimentary rocks of the Lewes River Group and clastic sedimentary rocks of the Early and Middle Jurassic Laberge Group which are intruded by several Cretaceous plutons (Figure 3). The Lewes River Group is composed of the volcanic Povoas Formation and the younger, sedimentary Aksala Formation (Tempelman-Kluit, 1984). The Lewes River Group may also include two suites of volcanic rocks ("Old Pillows" and Joe Mountain volcanic suite) which were previously mapped as "Volcanics of uncertain age" (Wheeler, 1961). In the map area, the upper part of the Aksala Formation exhibits a sharp transition from a thick, carbonate-dominated sedimentary succession in the western part of the map area to a dominantly volcanic sequence with clastic, and lesser limy sedimentary rocks in the east.

Three plutonic units form the four north-trending elongate plutons in the Joe Mountain map area (Figure 3). The M'Clintock Granodiorite is exposed in the M'Clintock Lakes and M'Clintock River Plutons. The Cap Creek Granodiorite forms the Cap Mountain Pluton and the Cap Mountain Granite and related quartz monzonite comprise The Cap Mountain Plutons. All of the plutonic rocks are probably Cretaceous in age.

Descriptions of rock units exposed in the Joe Mountain map area are given below, in order, from oldest to youngest.

Lewes River Group

Geology of the Joe Mountain map area is dominated by Lewes River Group sedimentary rocks (Aksala Formation). Although previous geological mapping identified regions underlain by volcanic rocks, none were thought to be part of the Triassic Lewes River Group (Povoas Formation) (Wheeler, 1961). New geological mapping and biostratigraphy indicate that some volcanic rocks are in fact Triassic in age, and thus, probably part of the Lewes River Group.

Late Triassic Volcanic Rocks

Volcanic rocks in the Joe Mountain map area were previously mapped as "Volcanics of uncertain age" (Unit A), their metamorphosed equivalents (Unit Aa), and Cretaceous Hutshi Group (Wheeler, 1961). Elsewhere in the Whitehorse (105D) map sheet, these rocks have been shown, or interpreted to belong, to the Lewes River, Mount Nansen, Carmacks and Skukum Groups (Tempelman-Kluit, 1984; Hart and Radloff, 1990; Wheeler and McFeely, 1991; Hart and Brent, 1993) and do not, in themselves, constitute a single stratigraphic unit. "Volcanics of uncertain age" and Hutshi Group rocks in the Joe Mountain map area can be grouped and divided such that they form three main lithologic, and possibly stratigraphic formations — the "Old Pillows", Povoas Formation and the Joe Mountain volcanic suite (Figure 3 and 4).

All three of these units are lithologically similar. They consist of massive, resistant, dark blocky weathering, aphanitic or fine-grained, basaltic and andesitic flows, pillows and autoclastic breccia. They are differentiated according to subtle lithological differences and inferred stratigraphic positions (Table 1, Figure 4). However, the paucity of diagnostic stratigraphic indicators or obvious distinguishing characteristics make it difficult to confidently assign any given outcrop to a particular formation.

"Old Pillows"

This volcanic package comprises a thick sequence of stacked pillows and lesser massive flows and breccia exposed in several locations south of Joe Mountain. Black and brown-green weathering, fine-grained, dense, generally aphyric, grey-green basaltic pillow flows are typically small (av. 60 cm.) and well displayed in three dimensions at the outcrop. The sequence contains rare, thin (max. 10 cm) and discontinuous interbedded sediments which are typically siliceous or limy (now recrystallized). Calcite veinlettes are common and chlorite is typical on the pillow surfaces. Chert and carbonate clasts as well as chert or carbonate interpillow fillings are not uncommon.

The "Old Pillows" are generally moderately to steeply dipping and are locally vertical. Pillows have been flattened and smeared out adjacent to horizontal faults. Fault zones in the "Old Pillows" are characterized by ankeritic breccias and gossans with quartz veining and jasper.

The "Old Pillows" are overlain by a chaotic package of limy, cherty and clastic sedimentary rocks which yielded a Triassic conodont assemblage (S. Irwin, pers. comm., 1993) and macrofossils identified as Late Triassic Halobia sp. (E.T. Tozer, pers. comm., 1993). Lower contacts were not observed. The "Old Pillows" are therefore Late Triassic or older.

Povaos Formation

Rocks assigned to the Povoas Formation are dominated by well developed pillows (av. 0.8 m across), massive flows and autoclastic and hyaloclastic breccia that underlie the Mount Slim massif and the lower hills northwest of Mount Slim. The volcanics are composed of dark grey-green weathering, resistant, strongly magnetic, dark grey, fine-grained aphyric, though locally feldspar-phyric, pillowed basalt flows that typically have vesiculated and calcite, quartz or jasper-filled amygdaloidal rims. They also locally contain interpillow, or thin (1–2 cm), discontinuous beds of micritic limestone (now sparite) but are otherwise devoid of interbedded sedimentary rocks. Epidote and chlorite alteration is common, as is patchy spilitic alteration.

Although not ubiquitous, the most diagnostic feature of this unit is locally pervasive hematitic alteration which has imparted a distinctive maroon colour to most of the rocks on the plateau and west-facing slopes west of the Mount Slim peak. The lower hills to the northwest typically contain similarly maroon-coloured jasperoidal veins, stockworks, interpillow fill and breccia matrixes. The maroon colouration is thought to result from oxidation of iron in the volcanic rocks during periods of subaerial exposure. The volcanics are however, submarine in nature (i.e., pillowed) suggesting that their exposure resulted from local uplift or eustatic sea-level drops.

Less altered volcanic rocks locally occur among Povoas Formation rocks but are difficult to discern. Relatively fresh volcanics Mount Slim peak is assumed to be rocks of the Joe Mountain volcanic suite which may be intrusive or unconformable on top of the Povoas Formation rocks.

Most exposures of Povoas Formation rocks are in fault contact with adjacent sedimentary rocks thus precluding any age constraints. However, since Lewes River Group sedimentary rocks in the "Limestone Range" are topographically above the basaltic flows, and such volcanics are unknown in the overlying Laberge Group, the volcanics are interpreted to be beneath the Lewes River Group sedimentary rocks. The stratigraphic relationship between the Povoas

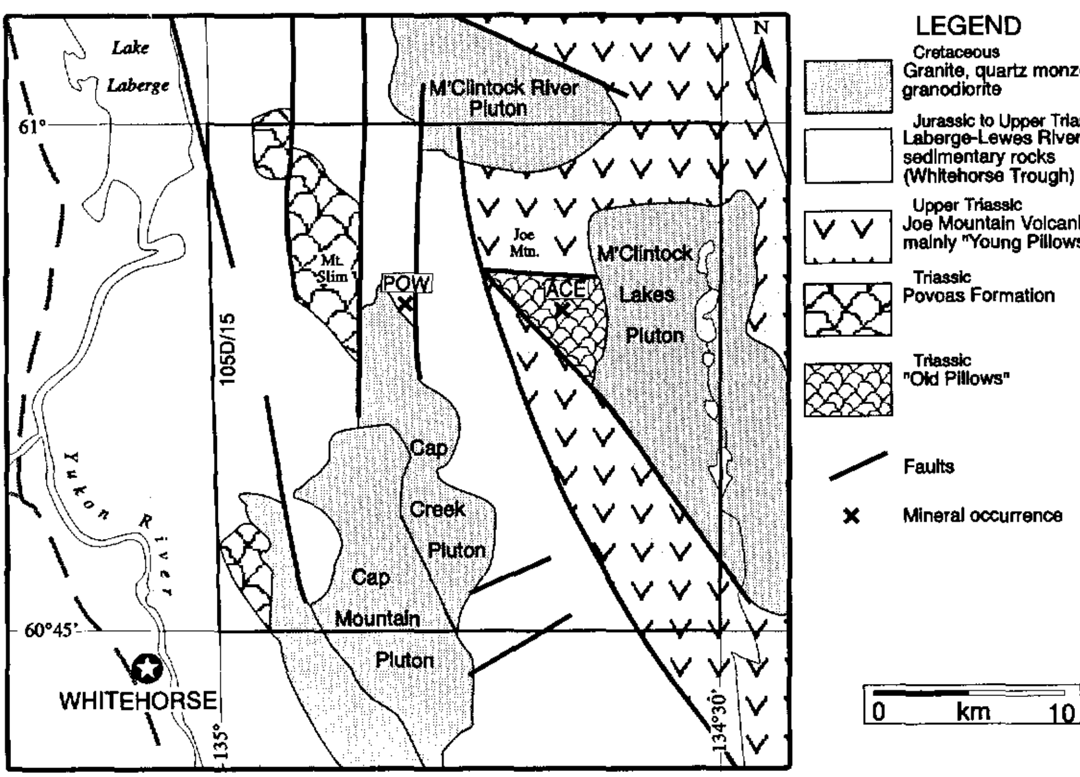

Figure 3: This generalized geology map of the Joe Mountain map area shows it to be dominated by folded Whitehorse Trough sedimentary strata of the Lewes River and Laberge groups. Numerous granitic plutons, presumed to be Cretaceous in age, intruded the strata. Rocks previously mapped as "Volcanics of Uncertain age" by Wheeler (1961) are divided into three suites of volcanic rocks which are Triassic in age and likely belong to the Lewes River Group.

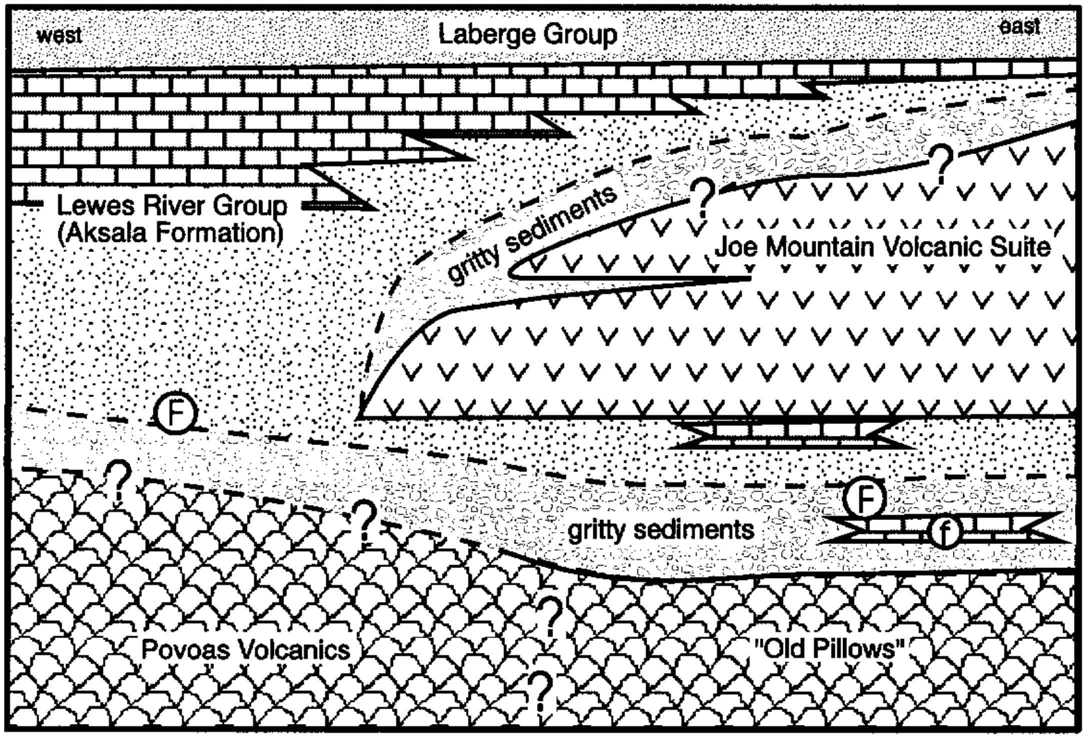

Figure 4: The Triassic stratigraphic framework, as deduced from geological mapping in the Joe Mountain area, indicates that: 1) the Povoas Formation and "Old Pillows" volcanic units may be stratigraphic equivalents; 2) the Joe Mountain suite is younger than the "Old Pillows"; and 3) there is a dramatic eastward thinning of the upper Triassic carbonate unit. F - macrofossil, f - microfossil.

Formation and the "Old Pillows" is not known. Although they are lithologically similar, they are spatially separate such that differentiating between them is not difficult. The "Old Pillows" are overlain by Halobia-bearing sediments; equivalent sediments are inferred to overlie the Povoas Pillows. This implies that the "Old Pillows" and the Povoas Formation may be stratigraphic equivalents.

Typical Lewes River Group volcanic (Povoas Formation) rocks are recognized elsewhere in the Whitehorse map-sheet, by their large, black, augite phenocrysts, and, to a lesser extent, the pervasive epidote-chlorite and hematitic alteration (Hart and Radloff, 1990). None of the volcanic rocks observed in the study area contained the diagnostic augite phenocrysts. Volcanic rocks in the Mount Slim area display Povoas-type alteration characteristics, and are located along strike with rocks mapped as Povoas Formation in the adjacent Laberge map-sheet (Tempelman-Kluit, 1984). In addition, the spatial association of these volcanic rocks with sedimentary rocks of the Lewes River Group further imply a Lewes River Group association — therefore the Mount Slim area volcanic rocks are assigned to the early Late Triassic Povoas Formation.

Joe Mountain Volcanic Suite

Dark grey weathering, massive and resistant rocks of the Joe Mountain volcanic suite comprise volcanic and sub-volcanic phases which dominate the resistant ridges in the eastern part of the map area. The volcanic phases are dominated by the "Young Pillows" with a subordinate, dark weathering phase and interbedded sedimentary rocks. The sub-volcanic phases include the massive microdiorite and the vari-textured gabbro (Figure 5).

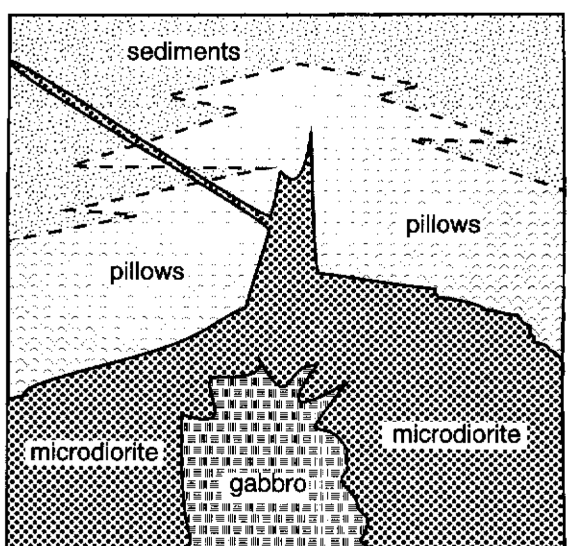

Figure 5: Diagrammatic interpretation of the various rocks that form Joe Mountain volcanic suite. This suite is thought to represent aerially extensive pillowed flows, locally interbedded with sedimentary rocks, which are intruded by sub-volcanic microdiorite and gabbro.

"Young Pillows"

Pillowed andesitic volcanics with massive flows and breccia informally termed the "Young Pillows" dominate the topographically higher part of the ridge east of Cap Creek. The volcanics are massive dark weathering, resistant, craggy ridge-forming, strongly magnetic, fine to medium grained, aphyric and feldspar-phyric and equicrystalline. The rock is composed of fresh, reticulate and felted texture hornblende/pyroxene-plagioclase. Plagioclase is most apparent on weathered surfaces since fresh surfaces are entirely dark grey and appear monomineralic. The thickness of this unit is unknown, however their distribution suggests a thickness of greater than 500 metres. Pillows are typically large (1–2 m across) and bulbous, locally with green, siliceous, interpillow fill (Figure 6). Most outcrops are dominated by vertical joint or fracture sets, which commonly makes it difficult to recognize the pillows.

Dark weathering volcanics consist of dark grey to black to chocolate brown weathering, recessive, flows of aphyric basaltic andesite. These rocks typically have a manganese oxide coating and are brittle such that it is difficult to obtain a fresh surface. This unit occurs within the "Young Pillows", probably as interbedded flows, but possibly as small intrusive plugs.

Interbedded sedimentary rocks form 10–200 m thick, chaotic packages of gritty, cherty, and limy sediments that are exposed in several locations. Poorly sorted, heterolithic diamictite with angular clasts forms massive units in the well-bedded sedimentary succession (Figure 7). These are thought to be formed as debris flows. It is uncertain as to whether there are several interbedded sedimentary successions or a single package whose exposures are repeated due to structural complexity.

Sub-volcanic rocks

The sub-volcanic phases of the Joe Mountain volcanic suite dominate the higher, resistant ridges and peaks in the Joe Mountain massif with smaller outliers on Mount Slim and in the southeastern part of the map area and include the microdiorite and vari-texture gabbro Microdiorite is lithologically similar to the "Young Pillows" except that it is consistently coarser grained and has few extrusive characteristics. Microdiorite dykes cut the "Young Pillows".

Resistant, dark weathering, massive microdiorite forms most of the Joe Mountain massif (Figure 8a). Coarse-grained and texturally variable, hornblende gabbro underlies and intrudes the microdiorite where it is exposed over much of the upland plateau north and east of Joe Mountain below 5 500'. The gabbro is recognized by its leucocratic weathering and by the presence of large acicular hornblende (Figure 8b). The textural variation and intrusive relationship with the microdiorite indicates that the gabbro may represent the hypabyssal portion of the magma chamber that spawned the Joe Mountain volcanic suite (Figure 5).

Most exposures of the Joe Mountain volcanic suite are in fault contact with adjacent units. Four kilometres southwest of Joe Mountain, the volcanics stratigraphically overlie a chaotic package of gritty and limy sedimentary rocks containing Late Triassic fossils. Cretaceous granitic rocks of the M'Clintock Lakes and M'Clintock River plutons intrude the volcanosedimentary package. A definitive upper contact of the Joe Mountain volcanic suite was not observed, however, it may be represented by overlying breccia, diamictite and associated gritty sediments and Upper Triassic Lewes River Group limestone exposed three-and-a-half kilometres southwest of Joe Mountain.

Aksala Formation

Lewes River Group sedimentary rocks of the Aksala Formation underlie most of the map area where they are is divisible into three lithological units: a) non-limy sandstone and siltstone; b) limy siltstone and shale (Casca Member) and c) bioclastic and massive micritic

Figure 6: Although pillows of the "Young Pillows" of the Joe Mountain Volcanic Suite are rarely this well displayed, this outcrop shows their large (1.5–2 metres) bulbous nature. Note the pack in the bottom centre for scale.

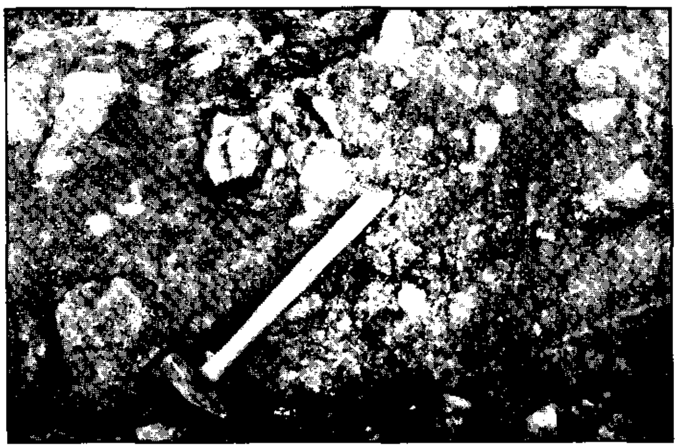

Figure 7: Diamictite forms massive beds among well-bedded gritty and limy sedimentary rocks which are associated with the Triassic volcanic rocks. The diamictite is composed of a heterolithic mixture of angular volcanic and sedimentary fragments in a volcanogenic wacke matrix. The light coloured fragments are felsic volcanic rocks which have not been recognized in the Triassic volcanic packages. The diamictite is thought to have been deposited as debris flows or lahars.

	Composition	Nature of Pillows	Alteration	Other
Joe Mtn. "Young Pillows"	andesite, diorite	obscure and large ≥1 metre	weak to none	interbedded sediments, green interpillow silica
"Old Pillows"	basalt	obvious and small ≥0.6 metre	calcite, chlorite	interpillow micrite
Povoas Formation	basalt	apparent, commonly brecciated, ≥0.8 metre	hematite, calcite, epidote	interpillow micrite

Table 1: Characteristics of pillowed Triassic volcanic rocks.

limestone (Hancock Member). However, given the facies dominated character of these rock units and the dearth of marker horizons in the clastic strata, lithologically similar rock units are not necessarily stratigraphically equivalent. The Hancock Member includes a thick succession of thick-bedded, massive limestone conglomerate and breccia which is exposed over most of Cap Mountain (Figure 9). Some beds are dominated by altered volcanic clasts in a limy matrix and others are composed entirely of carbonate clasts in a muddy matrix. These clastic rocks are thought to have been deposited as a series of debris flows.

Observations from previous mapping in the Whitehorse Trough (Wheeler, 1961; Hart and Radloff, 1990) indicate that the Aksala Formation: 1) was deposited unconformably upon Povoas Formation volcanics; and 2) is divisible into lower unsorted debris flows and immature clastic sediments (Annie Member of Hart and Radloff, 1990) and upper well-bedded, clastic and limy sediments capped by a thick carbonate sequence. The location of this unit is important since it hosts the copper-gold skarns of the Whitehorse Copper Belt. Carbonate strata of the upper part of the Lewes River Group has been studied north of the map area by Tozer (1958) and Reid (1981, 1982, 1985) and Reid and O'Brien (1983).

Figure 8a: Dark weathering, resistant and massive microdiorite forms much of the Joe Mountain volcanic suite. Albitic veinlets are a common feature of this rock. Also note that the microdiorite is being cut by coarse-grained gabbro (above and left of jack-knife.

The Lewes River Group is entirely Late Triassic in age. Traditionally, the Povoas Formation is thought to be dominantly Carnian while the Aksala is dominantly Norian in age (Tempelman-Kluit, 1984; Hart and Radloff, 1990). Halobia and megalodont were recognized in several locations in the map area. They occur in finely-laminated, limy black shale and massive grey limestone respectively, and indicate a Norian age for the host sediments and support biochronological data from elsewhere in the Whitehorse Trough (Tozer, 1958; M. Orchard, written comm. 1991; Tozer, pers. comm., 1993; Reid and Tempelman-Kluit, 1987).

Laberge Group

Laberge Group strata in the study area consists of orange weathering, green arkosic sandstone, brown sandstone-black siltstone couplets and black wacke and mudstone. Exposures are limited to two main regions east of Cap Creek and east of and Laberge Creek. These lithologies are neither distinctive nor exclusive to the Laberge Group and were previously mapped as Lewes River Group strata (Wheeler, 1961). However, because these strata locally overlie a thick succession of carbonate of the uppermost Lewes River Group, they are interpreted to belong to the Laberge Group. Distinctive, polymictic cobble conglomerate which characterizes Laberge Group west of the Yukon River (Dickie, 1989) was not observed in the study area.

Figure 8b: Coarse-grained hornblende gabbro is characterized by wide-ranging textural variations from cumulate to fine-grained to pegmatitic.

The Lewes River-Laberge Group contact is a sharp stratigraphic contact where observed north and south of the map area (Mt. Laurier and Mountain 6010' respectively). This contact was confidently observed in only one region in the Joe Mountain map area — east of Cap Creek, 2 km west of peak 5644'. Elsewhere in the study area, the contact is poorly exposed, faulted or hornfelsed. At Cap Creek, a thick, locally fossiliferous carbonate unit inferred to be the uppermost Lewes River Group carbonate, is overlain by limy black, flaggy shales which gradually become less limy upsection. These rocks are overlain, possibly disconformably, by locally conglomeratic arkosic sandstone which is typical of the Laberge Group.

Fossil evidence indicates that the Laberge Group ranges in age from Early Sinemurian (possibly as old as Hettangian) to as young as Bajocian (Smith et al., 1988; H.W. Tipper pers. comm., 1989, 1993; Poulton and Tipper, 1991; Dickie and Hein, 1992; Johannson, 1993). Laberge Group exposures in the study area are stratigraphically low in the section and assumed to be Early Jurassic in age.

Whitehorse Trough Sedimentary Rocks

Sedimentary rocks in the map area thought to be Jurassic and older, but which cannot confidently be distinguished as Lewes River or Laberge Groups are lumped together as Whitehorse Trough sedimentary rocks. These rocks probably represent a transitional unit between the two groups or a part of the Triassic-Jurassic stratigraphic section where carbonate units (thus Lewes River Group) are not present.

Granitic Rocks

Three dominant granitic lithologies and associated phases, form all or parts of four plutons which underlie approximately 30 % of the map area (Figure 3). They are the M'Clintock Granodiorite, the Cap Creek Granodiorite and the Cap Mountain Granite.

M'Clintock Granodiorite

The M'Clintock Granodiorite forms the M'Clintock River and M'Clintock Lakes plutons in the northeastern and eastern parts of the map area. It is coarse-grained, white to pale grey weathering and consists of 20–30% quartz, 60–70% plagioclase, 1–5% fine-grained potassium feldspar and 10% biotite and hornblende. Light grey quartz phenocrysts and aggregates of quartz phenocrysts are intergrown with plagioclase. Generally biotite and hornblende occur in equal amounts but locally hornblende is dominant. Hornblende phenocrysts are usually lath-like and up to 6 mm long, biotite is typically finer grained and up to 4 mm across. Grey and pink potassium feldspar phenocrysts up to 1 cm are rare.

The M'Clintock Granodiorite is intrusive into the microdiorite phase of the Joe Mountain volcanic suite. M'Clintock granodiorite has not been dated in the map area, but returned a biotite K-Ar date of 118 Ma just north of the map area (Tempelman-Kluit, 1984). This date is unusually old for granodioritic rocks typical of the mid-Cretaceous Whitehorse Plutonic Suite which yield dates approximating 110 Ma (Hart and Radloff, 1990; Woodsworth et al., 1991). Age determinations from plutons in the Teslin map area, indicate the presence of an older Cretaceous suite at circa 120 Ma (Gareau and Mortensen, 1993; J.K. Mortensen pers. comm. 1993) giving credence to the 118 Ma biotite date and allowing correlation with the unnamed (Teslin) suite.

Cap Creek Granodiorite

The Cap Creek granodiorite outcrops in a north-trending pluton west of Cap Creek. Four phases are recognized.

Phase 1: Medium to fine-grained, biotite-hornblende granodiorite is composed of 15–20% quartz, 60% plagioclase, 5–10% potassium feldspar and 5–15% biotite and hornblende, locally with minor disseminated pyrite. Quartz is equigranular and intergrown with

Figure 9a: Conglomeritic debris flow deposit of matrix supported sub-rounded sedimentary clasts in a limestone matrix on Cap Mountain. Note the large (1 metre) limestone clast in the bottom left of the photograph.

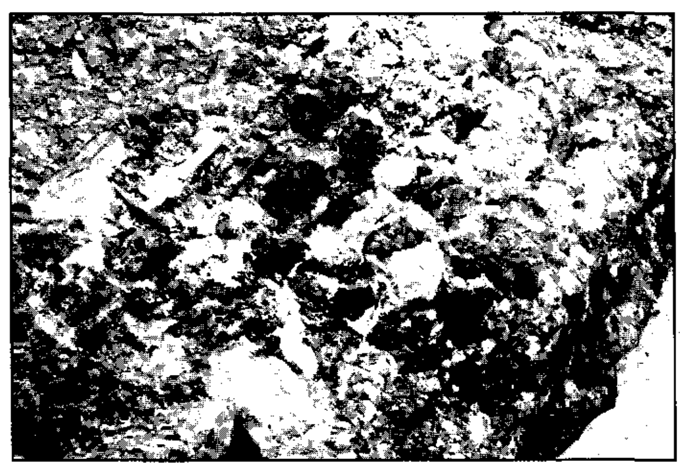

Figure 9b: Breccia or conglomerate? A heterolithic assortment of poorly sorted and angular limestone and volcanic fragments are set in a wacke matrix. These rocks are skarnified adjacent to the Cap Mountain pluton.

plagioclase. Potassium feldspar is fine-grained and not apparent unless stained or seen in thin section. This phase is distinguished from others by its predominantly medium grain-size, equigranular nature and greater percentage of quartz. This is the most voluminous phase of this pluton.

Phase 2: Dark, fine-grained granodiorite outcrops in the vicinity of peak 5 852', is composed of 50% grey plagioclase, 35% hornblende and 5–35% quartz. Fine-grained biotite-rich and hornblende-rich phases are locally common. This phase is cut by phase 1 granodiorite and by coarse-grained, pink granite dykes.

Phase 3: Medium-grained, white weathering, leucocratic, altered granodiorite crops out west of Cap Creek and consists of 65% altered plagioclase up to 4 mm across, 20% rounded, glassy, quartz phenocrysts, 5% chloritized lath-like hornblende phenocrysts up to 8 mm long and 5% chloritized biotite. The leucocratic and white weathering nature probably reflects pervasive propyllitic alteration of phase 1.

Phase 4: Dark, blocky weathering, coarse grained, hornblende quartz diorite and diorite outcrops in the vicinity of peak 5852' and is composed mainly of plagioclase (60%) and hornblende (40%) with rare quartz. This phase is cut by phases 1 and 2 and represents either the oldest phase of the Cap Creek granodiorite or an older intrusive. It is the most mafic and coarsest-grained phase in the Cap Creek pluton.

Exposures of the southeast portion of the Cap Creek pluton are foliated. The east-trending, steeply dipping, foliation is defined by parallelism of elongate minerals (plagioclase and hornblende). Quartz and potassium feldspar are not broken, flattened or smeared out. The foliation is interpreted as magmatic and is related to emplacement of the crystallizing magma.

The Cap Creek Granodiorite is cut by the Cap Mountain granite and intrudes sediments of the Triassic Lewes River and Jurassic Laberge groups. Cap Creek Granodiorite gave concordant K-Ar hornblende and Rb-Sr whole rock isochron (n=3) dates of 92.1±3.8 and 92±48 Ma respectively (Morrison et al., 1979). The Cap Creek Granodiorite is lithologically similar to intrusions of the Whitehorse Plutonic Suite (Hart and Radloff, 1990; Woodsworth et al., 1991; Hart, in prep.). However, these age determinations are younger than, and not correlative with the ca. 115 Ma Whitehorse Plutonic Suite. The Cap Creek Granodiorite is assumed to be part of the Whitehorse Plutonic Suite but has had its K-Ar isotopic systems altered such that it yields dates younger than its true crystallization age.

Cap Mountain granite and quartz monzonite

Pink granite and quartz monzonite form the Cap Mountain pluton in the south-central and southwest portion of the map sheet. Five granitic phases were recognized in the field. All of the phases are characterized by their pink colour and pale orange and white weathering.

Phase 1: The coarse-grained, quartz-rich granite phase has a general composition of: 20–40% quartz, 25–40% plagioclase, 20–50% potassium feldspar, 3–15% biotite and 1–5% hornblende and constitutes most of the pluton. Quartz is grey and forms clusters and aggregates. Potassium feldspar occurs as coarse-grained aggregates and locally as single, large (8 mm), zoned phenocrysts. Plagioclase ranges from 3 to 5 mm across, is typically sausseritized and weathers to a chalky white or greenish hue. Biotite is generally the dominant mafic phase with euhedral crystals (2 mm); lesser hornblende is lath-like (6 mm long). Accessory minerals locally include molybdenum and chalcopyrite.

Fine-grained mafic clots, 1–5 cm across, of hornblende and plagioclase are common features in this phase. Locally phase 1 contains xenoliths of fine-grained Cap Mountain granodiorite and/or coarse-grained hornblende granite. Pods of potassium feldspar with quartz and hornblende or epidote in the centre are rare.

Phase 2: The medium-grained, quartz-poor, quartz monzodiorite phase contains 1–10% quartz, 40–60% plagioclase, 15–30% potassium feldspar and 10–15% mafic minerals. Quartz and plagioclase are coarser-grained (3–5 mm) and along with slightly finer grained mafic clots are set in a finer grained anhedral matrix of potassium feldspar. The mafic mineral assemblage is dominated by hornblende but includes biotite. Alteration consists of locally sausseritized plagioclase and chloritized hornblende.

Phase 3: Granophyric quartz monzonite is characterized by plagioclase, hornblende and quartz phenocrysts set in a fine-grained, sucrosic, pink potassium feldspar and quartz matrix. The phenocrysts compose up to 50% of the rock. Euhedral plagioclase phenocrysts vary widely in size (up to 8 mm) and constitute 30 to 60% of the phenocryst population. Acicular hornblende up to 5 mm long, make up about 5% of the phenocrysts. Quartz phenocrysts are grey and glassy, locally up to 5 mm across and constitute 0–15% of the phenocryst population. Black biotite forms from 0 to 15% of the phenocrysts and is commonly present in the fine-grained groundmass. Locally, sparse lath-like potassium feldspar phenocrysts up to 6 mm long occur.

Phase 4: Fine to medium-grained aplite is siliceous, locally quartz phyric (up to 5%) and forms dykelets that cut all other phases of the Cap Mountain pluton. A few percent of fine-grained biotite or hornblende (rarely both) are typical components. White potassium feldspar locally forms phenocrysts or late-stage pegmatitic veins with quartz and hornblende.

Phase 5: The Laberge Creek monzonite is distinguished from the other phases by its dark pink groundmass and heavily chloritized hornblende phenocrysts. This phase was found near upper Laberge Creek in the southwestern part of the map area. Pale grey to cream weathering, this medium-grained phase is composed of plagioclase (40%) and hornblende (15%) phenocrysts in a finer grained dark pink potassium feldspar matrix with >10% quartz. Epidote and chlorite are common on fracture surfaces. Dykes similar in composition to this phase were found in the Joe Mountain area. This rock type was considered by Wheeler (1961) to form an entire pluton which extended south of the map area. In the map area however, its distribution is limited and much of the area mapped as this phase by Wheeler is actually Phase 1 granite.

The Cap Mountain Granite and associated quartz monzonite phases intrude the Cap Creek pluton to the east and north and Triassic-Jurassic sediments of the Whitehorse Trough to the west. Dykes associated with the Cap Mountain suite intrude all units in the map area except the Skukum rhyolite. The Cap Mountain Granite is lithologically similar and correlated with the mid-Cretaceous (circa 109 Ma) Mount McIntyre suite (Hart and Radloff, 1990; Hart, in prep.). The textural variation and numerous cross-cutting phases associated with this pluton suggest emplacement at a high crustal level. Biotite from Cap Mountain quartz monzonite yielded a K-Ar date of 98.6±3.4 Ma and three samples of quartz monzonite gave an Rb-Sr isochron of 92±5 Ma (Morrison et al., 1979). These dates are younger than U-Pb ages determined on other rocks of this suite (circa 107 Ma; Hart and Radloff, 1990). Oxygen isotopic analysis on the Cap Mountain and Cap Creek plutons give $\Delta^{18}O_{quartz\text{-}feldspar}$ values of +3.5‰ and +5.2‰ respectively, (Dagenais, 1984). These values reflect significant depletion in ^{18}O and probably reflect hydrothermal alteration by meteoric fluids. Alteration has apparently resulted in the isotopic rehomogenization of the rock and reset both the K-Ar and Rb-Sr systems — probably at the times given by their respective dates. Consequently these dates do not reflect the timing of crystallization which likely occurred at approximately 109 Ma.

Felsic volcanics

Light weathering, siliceous and quartz-phyric volcanic and sub-volcanic rocks form small, localized, poorly exposed exposures in the eastern and western part of the map area. Western exposures comprise cream-coloured rhyolite and rhyolite breccia. These rocks appear to be intrusive into Laberge Group sedimentary rocks as dykes and plugs. Eastern exposures are more diverse but equally enigmatic. They comprise monolithic and heterolithic breccias containing felsic volcanic and quartz-phyric volcanic fragments with either siliceous or tourmalinite matrixes spatially associated with Triassic volcanics and the M'Clintock Lakes pluton. Brecciated volcanic rocks with tourmaline are typical of mid and Late Cretaceous volcanism at Mount Nansen, Montana Mountain and Mount Freegold.

Skukum Group rhyolite

Light weathering, light grey to cream coloured flow banded rhyolite is exposed on southwest-facing slopes above the headwaters of Laberge Creek. Vertical flow banding indicates an intrusive origin as a flow dome. These rocks are similar to, and interpreted to be equivalent with Late Paleocene Skukum Group volcanic rocks. This exposure represents the most easterly limit of Early Tertiary rocks.

Dykes

Dykes are ubiquitous throughout the map-area. Five suites have been recognized. Although their ages are not directly known, they are listed below, oldest to youngest, according to field relationships and interpreted cogenetic relations with intrusives of known age.

1) Microdiorite—Dark weathering, dark grey and grey-green, resistant, locally strongly magnetic, fine- and medium-grained basaltic andesite and microdiorite dykes are found exclusively in the eastern part of the map area. Fresh surfaces appear equigranular and monomineralic but weathered surfaces show up to 50% white weathering feldspar. Accessory pyrrohotite and arsenopyrite characterize these dykes. This suite of dykes is lithologically similar to, spatially associated with, and cut the Joe Mountain Volcanic Suite. In addition, these dykes cut upper Triassic Lewes River Group sedimentary rocks but none of the Cretaceous plutons. The dykes are presumed to be Triassic or younger, and are probably comagmatic with the Joe Mountain volcanics.

2) Cap Mountain dykes—Light orange, orange-white and pink weathering, granophyric to porphyritic to equigranular, quartz monzonite and monzonite dykes, with varying percentages of euhedral plagioclase, quartz, biotite and hornblende in a fine-grained to sucrosic, pink, mauve and light grey matrix of alkali feldspar and quartz, are common in the western part of the map area. They cut units as young as, the mid-Cretaceous Cap Mountain pluton. These alkali feldspar-rich dykes are considered to be a late, but comagmatic phase of the Cap Mountain Granite.

3) Carmacks porphyry—Dark weathering, fine-grained to porphyritic, feldspar-phyric andesite to dacite dykes with a light grey matrix and about 40% euhedral, zoned plagioclase phenocrysts up to 5 mm across. Locally, small, dark smudges occupy up to 5% of the rock and may represent altered mafic minerals, possibly pyroxene. Two phases of the porphyry exist — an older phase with a granular matrix is cut by a phase with an aphanitic matrix. The dykes form resistant outcrops where they cut fine-grained sedimentary rocks and locally constitute the only outcrops in some regions giving the impression that volcanics dominate when in fact they are subordinate. These dykes cut all sedimentary and plutonic phases and are therefore younger than mid-Cretaceous. They are lithologically similar to some igneous phases of the Late Cretaceous Carmacks Group and may be genetically related to them.

4) Felsite—Light weathering, recessive, light grey and light greenish-grey, siliceous, aphanitic to fine-grained and porphyritic felsic dykes with euhedral, locally zoned plagioclase, acicular hornblende and clear, subhedral quartz phenocrysts are the most common dykes in the map area. Plagioclase or hornblende phenocrysts comprise up to 60% of the rock volume. Although these dykes are ubiquitous throughout the map area, they are in greatest density between and south of Mount Slim and Joe Mountain where they are dominantly north-trending (Figure 10).

5) Rhyolite—Light grey to creamy orange and locally rusty weathering or Liesegang banded, fine-grained, locally aphanitic or glassy, siliceous, quartz-phyric rhyolite dykes with accessory fine-grained pyrite, locally contain milky white quartz veins and stockworks. The rhyolite dykes may represent higher-level equivalents to the aforementioned felsite dykes.

Structure

Rocks in the Joe Mountain map area have been affected by two phases of folding and are cut by numerous faults. The region has not been affected by regional metamorphism, but contact metamorphism (i.e., hornfelsing) in sedimentary rocks adjacent to the plutons is common.

Folds

There are two styles of folds in the map area — neither phase has an obvious axial planar cleavage or ductile shear fabric and both are developed exclusively in the Triassic and Jurassic volcanic and sedimentary strata. These are: 1) Northwesterly-trending and southwesterly-dipping sedimentary rocks dominate the map area. These attitudes likely result from the development of large wavelength, northwest-trending, shallowly plunging open folds. Evidence of these folds are poorly displayed in the map area as their northeast-dipping limbs are not evident, suggesting that they may have been faulted out; and 2) Short wavelength, easterly-trending anticlines and synclines form several tight, upright folds in upper Triassic Lewes River Group strata in the area east of Peak 6 240' and south of Joe Mountain (Figure 11). These folds are characterized by closely spaced and apparently chaotic attitude changes likely associated with space problems in tight folds.

Timing constraints on folding is poor, and it is uncertain which series is older. Both series of folds affect rocks as young as Jurassic but do not appear to affect the mid-Cretaceous plutons. Recognition of folding in massive, essentially homogeneous plutons is difficult. Since northwest-trending folds are common throughout the Whitehorse Trough, these folds are inferred to have developed during a regional folding event in post-Middle Jurassic, pre-mid-Cretaceous time. The short wavelength folds are localized in a particular region of the map area and may have developed between, and as a result of strike-slip motion along parallel north-trending faults.

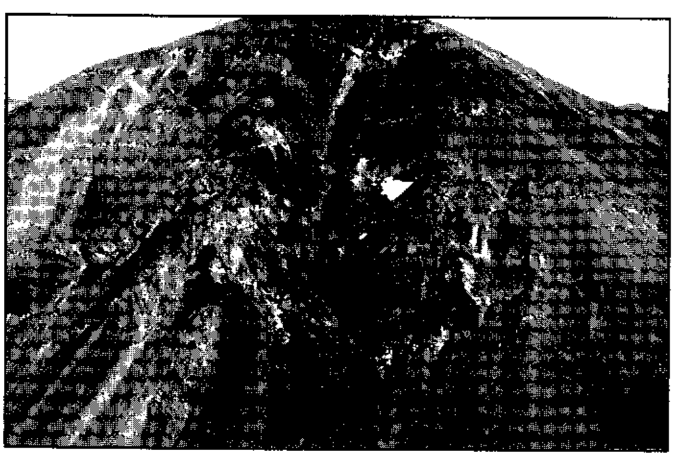

Figure 10: West (and east)-facing, steep rock faces such as this are common manifestations of the north-trending fault series. Although the mountain is composed of south-dipping Lewes River Group sediments, most of the resistant outcrops are composed of the numerous, north-trending felsite dykes which cut this face.

Faults and Shears

All rock types, except perhaps the youngest suites of dykes, are affected by faulting. Most faults in the map area are brittle, upper crustal features, however Triassic volcanic rocks are cut by ductile shear bands. The shear bands are continuous, up to a few metres wide (average 1 m) and anastomose. Steep to shallow-dipping shears trend northwesterly. The shears are particularly well exposed in the Joe Mountain area where they cut microdiorite and gabbro. Because these features were not observed in the granitic rocks, they may be pre-Cretaceous structures.

Most faults in the map area can be divided into one of three series—each defined by a particular set of characteristics (Figure 11):

1) The Lake Laberge fault zone (LLFZ) is represented by numerous, dominantly north-northwest-trending, anastomosing and through-going faults in the westernmost part of the map area. The western margin of this zone is likely hidden in the Yukon River and Lake Laberge valleys where the fault zone continues to the south and north respectively. None of these faults were recognized in the field but are inferred from strong lineations apparent on aerial photographs and satellite images and differences in geology across this zone. Geologically, this zone separates dominantly Triassic rocks on the east side from a thick succession of Jurassic strata west of the fault.

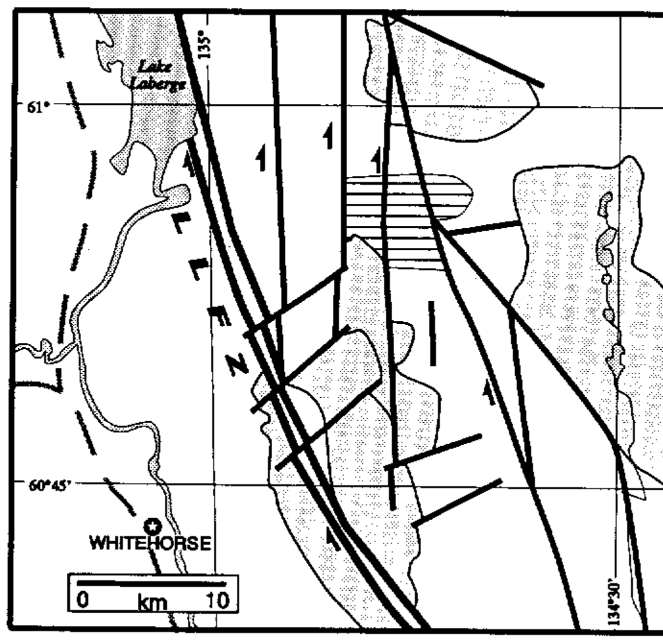

Figure 11: Structure in the Joe Mountain map area is dominated by a series of parallel, continuous, north-trending faults with up to 1–2 km apparent vertical displacements across them. This figure includes interpreted and embellished map information (i.e., offset direction) to display the interpreted structural regime. The vertical sense of offset is not consistent for all the north-trending faults suggesting that they may be strike-slip faults which juxtapose dissimilar units giving apparent vertical displacements. A structural zone (Lake Laberge fault zone—LLFZ) is interpreted to exist in the Yukon River and Lake Laberge valleys. The north-trending fault series may be related to the LLFZ (see text for discussion). Younger northeast-trending "cross-faults" cut the older structures. The east-trending tight fold series is indicated by the horizontal pattern. Plutons are shaded.

The array of several parallel faults is characteristic of a strike-slip fault zone, however west-side down motion is indicated by the deeper stratigraphic levels exposed east of the fault. It is not known if the vertical component represents an older motion of the fault zone or if it results from a vertical component associated with strike-slip motion.

2) Steep, north-trending, through-going faults are represented by strong lineaments on air photo and remote sensing images, steep canyons, and ankeritic and gossanous breccias where they cut volcanic rocks. These faults are observed east of the Lake Laberge fault zone but appear to grade southerly, into the LLFZ.

3) Northeast-trending, strike-slip "cross-faults" apparently offset the LLFZ and the north-trending series. Similar and parallel faults elsewhere in the Whitehorse region were called the Whitehorse Fault Series by Hart and Radloff (1990) who considered them to have a pre- and post-Early Eocene history.

The timing and motion along the LLFZ may have been similar to other parallel structural zones in the Yukon — Late Cretaceous and Early Tertiary dextral slip. Motion along this fault zone may have resulted in the formation of the north-trending fault series. There is approximately a 15° discordance in the strike of the north-trending series with the LLFZ consistent with the interpretation of north-trending faults as R1 Riedel faults. If so, these faults should: 1) have dominantly dextral offsets associated with them; and 2) trend northerly into another north-northwest-trending, (LLFZ parallel) fault.

Horizontal Faults

Nearly horizontal faults cut the "Old Pillows" in several locations . The fault planes consist of a 1 metre wide zones of quasi-ductile deformation which contain northerly-trending lineations and asymmetric kinematic indicators that indicate a northerly transport direction. Rocks in the hanging wall and footwall are the same lithology indicating a limited amount of offset. Faults of this nature are atypical in the Whitehorse Trough. However, they are proximal to, and may be related to, the tight east-trending folds, and may similarly result from stresses between strike-slip faults.

Mineral Deposits

Despite the region's proximity to Whitehorse, very little evidence of previous explorations are apparent. Yukon Minfile documents only 6 occurrences in the Joe Mountain map area. Of these, only the POW and the ACE (Yukon Minfile # 50, 51) have known mineralization. Selected, grab and chip samples of economically interesting rocks were taken at various locations throughout the map area. Their descriptions, locations and analytical results are listed in Appendix 1.

The POW occurrence is listed as a Cu (Mo, W) skarn with molybdoscheelite (Yukon Minfile, 1992). The property yields copper in soil anomalies (Downing, 1980), but is otherwise poorly prospected and has not been evaluated for gold potential. A brief examination of part of the property indicates that the area is geologically complex — two granitic phases and two dyke phases cut folded, limy Upper Triassic Lewes River sediments. These rocks are cut by north-trending faults. Numerous styles of mineralization were discovered, including: 1) garnet-diopside-epidote skarn; 2) quartz veins; 3) granite-hosted quartz stockworks; 4) hornfelsed and sulphidized sedimentary rocks; and 5) pyrite-chalcopyrite associated with porphyry-style alteration of granite. A grab sample (93CH 11–2; Figure 12) of silicified and sulphidized granite gave elevated Au, Ag and Cu values (310 ppb, 20 ppm, 3.0% respectively). A sample of calc-silicate skarn with quartz veining yielded anomalous As and W values. All phases of mineralization are associated with the contact region of the intrusive rocks except for the quartz veins which are likely associated with north-trending faults.

The ACE property hosts thin arsenopyrite-pyrite-galena-sphalerite and chalcopyrite-bearing quartz veins with high Au and Ag values (0.8 opt and 2.3 opt respectively; INAC, 1992), but were not seen by the authors.

Regional Silt Geochemistry

Regional stream silt geochemical data from Geological Survey of Canada (1985) and from the 1993 field season indicates that there are areas anomalous in one or more of Au, Ag, Cu, Zn, W, Hg and Sn in the study area. The distribution of anomalies suggests that metallogenic trends may be related to the various rock units in the map sheet.

Of the 83 silts sampled and analysed by the GSC, 12 are considered anomalous in Au (>10 ppb). Of these, five samples yield reproducibly anomalous values; the remaining seven anomalous values likely result from erratically distributed coarse gold. Anomalous Au values in the eastern part of the map area range up to 1 810 ppb and are spatially coincident with the distribution of the Joe Mountain Volcanic Suite (Figure 13) and may indicate a genetic relationship between these rocks and gold mineralization. On the west side of the map area anomalous Au values up to 1540 ppb occur close to intrusive

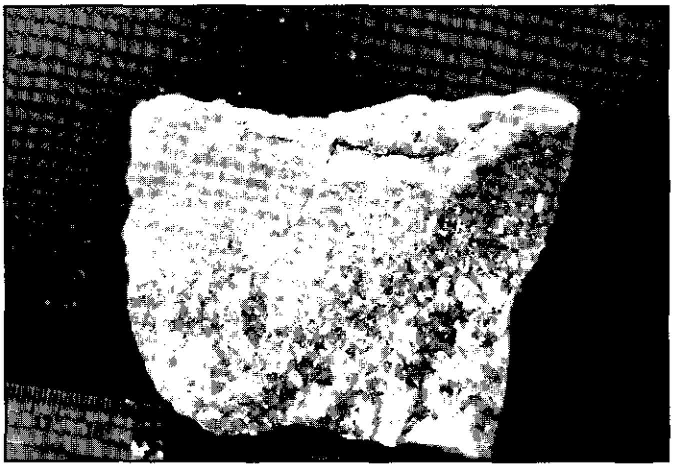

Figure 12: Cut surface of rock sample 93CH 11-2. This rock is a silicified and suphidized granite from the northern margin of the Cap Creek Granodiorite. The grey patches and veins in this otherwise leucocratic rock is fine-grained accumulations of pyrite and chalcopyrite.

contacts and may result from a skarn related deposits. Faults are common to both regions of the map area and may be responsible for the localization of gold hosted in vein or breccia deposits.

Regional geochemical silt anomalies in Cu and Zn (Cu>60 ppm, Zn>130 ppm) are spatially associated with the Joe Mountain and Povoas Formation volcanics. Tungsten anomalies (W>6 ppm) are spatially related to the Cap Creek Granodiorite and may be genetically related to skarns formed by this intrusion. Anomalous Sn values (Sn>7 ppm) occur in creeks draining the margins of the Cap Creek Granite. Mercury anomalies (Hg>100 ppb) are found proximal to faults and may have an origin in epithermal style veins.

Of the eight silt samples collected during this study (Appendix 1), three yielded anomalous metal values. Sample CH-161526 is anomalous in Ag (1.2 ppm), Cu (153 ppm), Pb (73 ppm), Zn (174 ppm) and Mo (6 ppm); sample CH-080555 has anomalous Cu (98 ppm) and Zn (189 ppm) values; and CH-178538 is anomalous in Zn (129 ppm). Values for Au are presently unavailable.

The majority of silt samples analysed as part of the GSC program were collected from helicopter accessible sites at or near the mouths of drainages. At these locations at the bottom of the drainage, potentially anomalous metal values are subject to down-stream dilution by other erosional debris. Even slightly anomalous values may therefore be worth following up with additional, up-stream sediment sampling and prospecting. Furthermore, since numerous, high grade mineral occurrences occur in the Whitehorse 105D map sheet, values considered anomalous in GSC study may be skewed to higher thresholds by extremely high values obtained from silts draining those deposits.

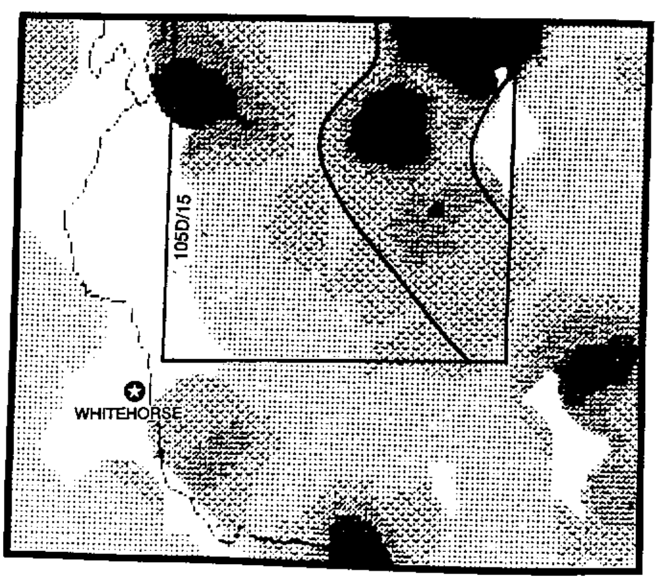

Figure 13: The contoured distribution of Au-in-silt geochemical anomalies in the Joe Mountain area (Geological Survey of Canada, 1985). A spatial co-distribution with the Joe Mountain volcanic suite (outlined) in the eastern part of the map area is indicated. These rocks have seen very little exploration attention and a genetic relationship between the volcanics and the gold anomalies has not yet been identified.

Exploration Targets

The Joe Mountain map sheet is considered to have high exploration potential for: 1) copper-gold-molybdenum-tungsten skarns; 2) gold-bearing quartz veins and 3) intrusion-hosted copper-gold (molybdenum) deposits. Skarns are hosted in limestone and limy siltstone of the upper Triassic Lewes River Group at, or near contacts with granitic rocks. Rusty-weathering, silicified, bleached or pyritic siltstone in hornfelsed regions around the plutons should also be considered as they locally contain arsenopyrite and may have associated gold. The Cap Creek Granodiorite and associated phases are considered to be the most likely granitic rock to induce mineralization due to its higher iron content and lithologic similarity with the Whitehorse pluton which formed skarn deposits in the Whitehorse Copper Belt.

Quartz veins and boulders of quartz vein-float, common throughout the map area were sampled and analysed (Appendix 1). Float boulders are commonly angular, occur in dense concentrations and are locally greater than one metre in diameter indicating a proximal source. Most of the quartz is milky white and either coarsely coxcomb or as anastomosing sets of veins (Figure 14). Typical epithermal vein characteristics are rare. Anomalous gold values are associated with veins that contain trace amounts of disseminated fine-grained arsenopyrite, small blebs of late-stage galena, or bladed calcite. These veins are most commonly associated with large, through-going, north-trending faults. However, since these faults commonly form valleys, smaller, parallel faults are also good prospecting targets. Many of these north-trending faults host felsic dykes which commonly contain quartz veining.

Quartz veins are also associated with faults in the Povoas and the "Old Pillows". Veining in these rocks is often associated with rusty Fe-carbonate alteration and jasper veins which yield anomalous Au values (612 ppb, sample 93CH 32-7).

Chalcopyrite and molybdenum were observed as fine-grained disseminations in relatively unaltered portions of the Cap Mountain Granite and related quartz monzonite. In addition, the Cap Mountain and Cap Creek Plutons have local zones of intense propyllitic and phyllic alteration with quartz-stockworks. These characteristics are similar to those found in porphyry deposits, but erosion has effectively removed any oxidized portions which may have existed.

Discussion and Conclusions

The Joe Mountain map area covers the axial portion of the Whitehorse Trough and is dominated by Upper Triassic Lewes River Group rocks. West of the map area and across the Yukon River valley, Jurassic Laberge Group rocks are dominant. A structural zone, here termed the Lake Laberge Fault Zone is inferred to have had a period of east-side up motion which accounts for the present juxtaposition. This fault zone trends northerly down Lake Laberge and southerly towards Marsh Lake.

Volcanic rocks in the Joe Mountain map area, previously mapped as "Volcanics of uncertain age" or Hutshi Group by Wheeler (1961) constitute three formations — the "Old Pillows", the Povoas Formation and the Joe Mountain Volcanics. Although all three volcanic units are probably Triassic in age, only the Povoas Formation has characteristics similar to other Lewes River Group rocks.

Three intrusive units form four, north-trending, Cretaceous plutons. The M'Clintock Lakes and M'Clintock River plutons are composed of the Early Cretaceous (118 Ma) M'Clintock Granodiorite that forms part of the informal Teslin plutonic suite. The Cap Creek pluton is composed of mid-Cretaceous granodiorite and forms part of the Whitehorse Plutonic Suite. The Cap Mountain pluton is composed of mid-Cretaceous granite and quartz monzonite and forms part of the Mount McIntyre plutonic suite.Despite region's proximity to Whitehorse, and numerous auriferous and metalliferous silt anomalies, there is little evidence of previous explorations and only two mineral showings have so far been identified. Exploration attempts should focus on the discovery of copper (gold-molybdenum-tungsten) skarns and gold-bearing quartz veins. Further consideration should also be given, but not limited to, intrusive hosted, disseminated gold and copper deposits. Gold in silt anomalies spatially associated with the Joe Mountain Volcanics do not have known sources and follow-up of these anomalies may indicate another prospective deposit type.

Figure 14: Large, angular boulders of massive and stockwork quartz veins such as these, are common throughout the map area, and indicate a proximal source for the quartz vein. The quartz in this boulder hosts disseminated fine-grained arsenopyrite and yields anomalous gold values (1150 ppb, sample 93CH 26-5A).

Acknowledgments

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Appendix 1: Geochemical assay data for rock and silt samples taken from the Joe Mountain map area (105D/15). Au by fire assay at NAL, Whitehorse, all other analyses performed at IPL, Vancouver using ICP except Hg by cold vapour.

SAMPLE	LOCATION UTM Zone 8V	DESCRIPTION	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	As (ppm)	Sb (ppm)	Hg (ppb)	Mo (ppm)	Ba (ppm)	NOTE
Detection Limits			*5*	*0.1*	*1*	*2*	*1*	*5*	*5*	*5*	*1*	*2*	
93CH-6-3	6736700N 516625E	Sparry calcite vein, with druzy and chalcedonic quartz and limonite in faults in Lewes River sediments		0.2	59	5	67	<	<	10	3	26	
93CH-11-1	6753060N 510325E	Rusty-weathering, silicified and bleached, hornfelsed Lewes River mudstone with a few percentage of fine-grained disseminated sulphides.	<5	0.2	177	11	15	6	<	10	3	18	
93CH-11-2	6753060N 510325E	Silicified and sulphidized leucocratic granitoid with stringers and blebs of pyrite cut by late veinlets of chalcopyrite (5%); trace disseminated arsenopyrite.	310	20.4	3.0%	17	348	6	<	5	4	55	
93CH-11-3	6753060N 510325E	Phyllically altered, silicified granite with sericite, chlorite and epidote alteration; . Cut by numerous quartz veins.	9	0.5	151	10	13	5	<	10	10	283	
93CH-11-4	6753060N 510325E	Localized float boulders of pale to medium green, mottled, silica flooded rock. Quartz-calcite altered with minor pyrite veinlets and disseminations.	5	0.4	31	24	53	<	<	10	3	159	
93CH-11-5	6753060N 510325E	Silicified garnet-epidote-diopside skarn with cross-cutting, open space-filling, coxscomb quartz - calcite veins with chalcopyrite and tetrahedrite(?).	5	0.4	117	7	19	264	<	10	84	8	0.2% W
93CH-11-6	6752450N 510150E	Local quartz vein float, massive white to rusty, argillically altered, yellow breccia fragments of intrusive host rock.	6	0.1	5	6	5	9	<	10	10	5	
93CH-11-7	6751525N 509850E	Rusty weathering granitoid with trace of finely disseminated arsenopyrite (<1%).	5	0.2	15	10	12	<	<	10	3	61	
93CH-13-1	6747550N 510375E	Silicified granodiorite cut by numerous grey-green quartz veinlets/stringers. Some of the quartz is vuggy with minor bladed calcite texture.	3	0.2	2	11	20	<	<	5	3	8	
93CH-13-2	6747550N 510250E	Argillic, feldspar altered intrusive cut by white coxcomb quartz veins with sparsely distributed, late, mostly weathered, galena blebs.	95	4.6	5	2128	22	<	<	10	2	72	
93CH-15-6	6746225N 518100E	Rusty quartz stockwork vein float in felsite dyke. Massive quartz with some layering and coxcomb; porous, vuggy limonitic pods.	6	0.3	29	17	35	6	<	5	3	19	

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Detection Limits			*5*	*0.1*	*1*	*2*	*1*	*5*	*5*	*5*	*1*	*2*	
93CH-25-3	6751850N 511200E	Chip sample across 1.1 m wide boulder of ankeritic fault breccia. Weathers bright orange with white and grey quartz veins,coarse grained, rhombohedral calcite stringers and silicified vuggy networks.	8	<	3	5	82	<	<	10	13	1715	
93CH-25-5	6753050N 511900E	Rusty, recessive weathering, light grey pyrrhotitiferous, silicified hornfels.	8	0.2	108	8	86	<	<	15	2	48	
93CH-26-1	6752500N 514450E	Medium grained, dark grey andesitic (microdiorite) dyke cutting limestone, with disseminated blebs of pyrite (5%).	7	0.1	35	18	49	<	<	10	3	354	
93CH-26-5A	6753600N 514750E	Quartz stockwork with trace disseminated pyrite and fine-grained arsenopyrite. Quartz veins are white and locally coxscomb and contain altered host rhyolite fragments.	1150	1.2	17	124	76	405	<	10	6	15	
93CH-26-5B	6753600N 514750E	White, massive quartz, some stockwork, locally coxscomb quartz. Host rock is green and altered.	90	0.2	3	7	12	20	<	10	4	20	
93CH-28-2	6751650N 515800E	Quartz vein hosted in a rusty dyke. The quartz is white and massive with minor disseminated pyrite and bands of tarnished pyrite.	74	0.4	11	13	93	42	<	5	5	14	
93CH-32-7	6752400N 517300E	Massive jasper vein in fault zone cutting "Old Pillows"; @ 5400'.	612	<	17	18	13	16	<	15	4	7	
93CH-32-8	6752400N 517300E	Rusty weathering white quartz vein with fine-grained, bladed calcite texture.	21	<	94	45	16	12	<	15	4	6	
93CH-32-9	6752400N 517300E	Gossanous, brecciated ankeritic quartz vein.	12	<	36	11	39	<	<	10	4	11	
93CH-32-10	6752400N 517000E	Rusty weathering, banded and massive, white and locally vuggy, locally derived quartz vein float.	520	2.0	23	312	71	122	<	40	6	12	426ppm W
93CH-33-1	6753300N 517850E	Large rusty weathering boulders of volcanic rock with veinlets and disseminations of pyrite; talus boulders.	7	0.2	71	20	174	<	<	45	3	3	
93CH-33-3	6753100N 517950E	Rusty, coxscomb, 10 cm wide, vuggy quartz vein with tourmaline; ACE property @ 5330'.	19	<	40	17	18	<	<	10	6	22	62ppm Bi
93CH-33-4		Gossanous volcanics with disseminated and blebby pyrite and minor arsenopyrite; ACE property @ 5040'.	12	<	132	18	90	<	<	25	3	2	

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Detection Limits			*5*	*0.1*	*1*	*2*	*1*	*5*	*5*	*5*	*1*	*2*	
93CH-34-2	6752300N 516200E	Pillow volcanics cut by a feldspar-hornblende porphyry andesite dyke, cross-cut by a 2 m wide gossanous limonitic shear zone with pyrite and quartz @ 5600'.	32	1.3	102	28	348	84	<	20	9	9	
93CH-40-1	6744850N 509300E	Coarse grained pink, quartz phyric granite, trace disseminated chalcopyrite and molybdenum.	<5	<	31	10	22	<	<	15	4	226	
93CH-42-1	6738400N 507350E	Rusty weathering, fine to medium grained, hornblende diorite with malachite staining and disseminated chalcopyrite.	<5	2.2	529	25	42	<	<	10	3	74	
J93-6-2	6761550N 483150E	Rusty weathering talus of intrusive rock, with 0.5% disseminated arsenopyrite.	11	0.9	51	163	31	6	<	5	9	128	
J93-13-1	6748350N 516600E	Quartz-calcite vein in pillow volcanics. The vein is banded with minor bladed calcite textures, and about 0.3 m thick.	618	0.2	23	2	10	6	<	5	5	9	
J93-24-6	6750900N 512550E	Rusty weathering andesitic dyke about 2 m wide with blebs and disseminations of pyrite and minor arsenopyrite.	6	0.2	230	21	22	8	<	10	2	15	
J93-27-2A	6753015N 518005E	Hornfelsed pillow volcanics near a quartz porphyry dyke with disseminated pyrite on some fractures. Magnetic.	5	6.8	97	1983	222	<	18	25	3	12	
J93-27-2B	6753015N 518005E	Massive to cockscomb, vuggy and druzzy vein quartz with brecciated volcanic wall-rock fragmentsx.	18	<	70	84	46	<	<	10	5	14	
J93-29-4	6756095N 514080E	Rusty weathering, ankeritic dyke in a fault.	10	<	7	78	54	<	<	5	3	38	
J93-32-11B	6753055N 510020E	Hornfelsed siltstone with minor disseminated pyrite.	51	<	96	58	37	14	<	5	50	124	
J93-32-11C	6753055N 510020E	Skarnified limestone - garnet, epidote, minor disseminated pyrite.	23	<	86	22	32	44	<	5	94	18	357ppm W
J93-34-3	6745035N 507065E	Limy, fine grained sandstone cut by numerous vuggy quartz veinlets.	19	0.4	38	11	48	<	5	5	5	31	
J93-36-6	6741060N 509020E	Quartz float, very rusty and vuggy, ankeritic with malachite staining.	5	<	4	8	18	166	18	5	6	58	343ppm Co 504ppm Cr
J93-37-2	6740055N 511015E	Coarse grained pink, quartz monzonite with disseminated molybdenum. Minor epidote alteration.	<5	<	5	9	27	<	<	5	2	93	

Appendix 1: Geochemical assay data for rock and silt samples taken from the Joe Mountain map area (105D/15). Au by fire assay at NAL, Whitehorse, all other analyses performed at IPL, Vancouver using ICP except Hg by cold vapour.

SAMPLE	LOCATION UTM Zone 8V	DESCRIPTION	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	As (ppm)	Sb (ppm)	Hg (ppb)	Mo (ppm)	Ba (ppm)	NOTE
Detection Limits			*5*	*0.1*	*1*	*2*	*1*	*5*	*5*	*5*	*1*	*2*	
J93-37-3	6740075N 511007E	Siliceous, felsic quartz-phyric dyke cutting pink granite. Dyke weathers white with rusty fractures and minor disseminated pyrite and arsenopyrite.	5	<	14	30	26	6	<	5	6	46	
J93-37-8	6741050N 512050E	Fine grained grey-green dyke, weathers rusty orange and is ankeritic. Cuts Cap Creek diorite.	<5	<	<	95	35	<	<	5	3	109	
J93-32-15	6754065N 509080E	Silt sample.		<	35	13	62	<	<	10	3	140	
CH-112626	6762600N 511200E	Silt sample.		<	28	23	95	<	<	10	5	348	
CH-163528	6752800N 516300E	Silt sample.		<	53	19	74	7	<	10	3	135	
CH-178538	6753800N 517800E	Silt sample.		<	48	29	129	12	<	10	2	120	
CH-080555	6755500N 508000E	Silt sample.		<	98	27	189	5	<	5	2	126	
CH-161526	6752600N 516100E	Silt sample.		1.2	153	73	174	26	<	40	6	155	
CH-075385	6738500N 507500E	Silt sample.		<	55	26	102	<	<	5	3	223	

< - indicates less than detection limit

Thermal Maturation and Hydrocarbon Source Rock Potential of Tantalus Formation Coals in the Whitehorse Area, Yukon Territory

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Abstract

Tantalus Formation strata at the Whitehorse coal deposit host eight coal zones of moderate to high ash, high rank coal, that range in thickness from 0.15 to 12.8 m. Vitrinite reflectance values (Ro_{rand}) vary from 1.68% to 3.45%, corresponding to a variation in rank from low volatile bituminous to anthracite. As vitrinite reflectance values are less than 4.0%, the upper limit of dry gas preservation, the generation of coal bed methane is possible. The coals are composed of structureless vitrinite and lesser fusinite. Some samples have a melting or coking texture indicative of rapid heating, possibly by contact metamorphism from local intrusions. Coals in contact with a rhyolite sill exhibit a progressive decrease in reflectance with increasing distance away from the sill. The deposit is well situated with regard to infrastructural requirements to support the exploitation of the coal. At present drill indicated reserves are in excess of 182 125 tonnes (200 800 tons) and open in all directions. Extensive faulting at the Whitehorse coal deposit likely precludes the preservation of any hydrocarbons (gas) which may have been generated.

Introduction

Southwest of Whitehorse, the Whitehorse coal deposit, hosted in Jura-Cretaceous Tantalus Formation siliciclastic rocks, is a potential source of readily accessible high grade coal (Figure 1). Historically coal from Tantalus Formation strata in the Yukon have been used to power river boats, provide heat at the Elsa mine and to dry concentrate at the zinc/lead mine at Faro. At present, the Division Mountain coal deposit is being evaluated as a potential fuel source to provide electricity to the Whitehorse-Aishihik power grid, to meet potential increased future demand. Coal fired thermal electricity may provide a readily available alternative to hydro-generated electricity.

This paper examines the setting, character and thermal maturation of coals at the Whitehorse coal deposit and speculates on the volatile hydrocarbon source potential of the Tantalus Formation in southern Yukon.

History

The first published report of coal in the Whitehorse area documented the presence of a high ash anthracite seam (McConnell, 1901). In 1901, the area around the Whitehorse coal deposit was surveyed and labelled the 'Black Diamond Coal Land'. By 1906, three seams 0.75 m, 3.15 m and 2.95 m thick were known in this area and an 18 m adit has been driven on the upper seam (Cairnes, 1908). Cairnes (1912) stated that the coal measures could be followed for over 8 km to the northwest of Coal Lake and were believed to continue in that direction for another 11 km (Figure 2). Cairnes also noted that coal measures outcropped to the east of Coal Lake.

No further work on the Whitehorse coal property was recorded until Spence Taylor and Associates Ltd. (1969) reported the presence of numerous test pits and trenches indicating that past prospecting work was more widespread than the literature suggests. In 1942, the U.S. Army Corps of Engineers examined the Whitehorse coal deposit, but there is no written record of this work (Johnny Johns pers. comm. in Spence Taylor and Associates Ltd., 1969).

In 1969, Coal Exploration Licenses 3, 4 and 5 were granted to Luscar Ltd. covering about 142 045 acres (~57 485 hectares). Luscar was able to trace the coal members, discontinuously, for 12 km: 9.6 km northwest of Coal Lake and 2.4 km southeast of the lake (Spence Taylor and Associates, 1969; Mineral Industry Report, 1969–70). More than 2 386 125 tonnes of recoverable coal, based on the underground mining of a 1.83 m seam, were estimated to lie above the level of the valley floor (Spence Taylor and Associates Ltd., 1969).

Savage (1976) carried out a prospecting and drilling programme in the Whitehorse coal area. However, no core was obtained due to the highly fractured nature of the coal seams.

In 1982 the Whitehorse Coal Corporation was formed and construction began on an access road to the Whitehorse Coal deposit; a trenching programme was also initiated (Hill, 1983). The property consists of three Coal Mining Leases (2989, 2990, 2991) and one Coal Exploration License (# 301). Combustion tests, carried out on three samples, indicated that the coals were meta-anthracites with an average 3.5% moisture, 38.2% ash and 8 500 BTU/pound (19 765 kj/Kg) heating value (Hill, 1983; Bremner, 1988). Further work was carried out in 1983 and potential in situ reserves of 85 million tonnes were estimated assuming a thickness of 3.05 m, a strike length of 10 km and a downdip extent of 500 metres (JHP Coal-Ex. Consulting Ltd., 1984). In 1985, six vertical holes were drilled along a strike length of 335 m. Good correlation between five of the six drill holes was shown by down-hole gamma-neutron, density, resistivity and caliper logs (Figure 3; Carlyle, 1985). Eight coal seams were found interbedded with conglomerate and shale. Some of the cleaner coal bands contained as little as 15% ash (Carlyle, 1985). Drill indicated reserves of 200 837 tons were calculated by Carlyle (1985).

Exploration in the Whitehorse Coal Property during 1986 consisted of test mining and bulk sampling (JHP Coal-Ex Consulting Ltd, 1987). Only minor work has continued to the present.

Geologic Setting

Outcrops of the Tantalus Formation are sparsely distributed throughout the south-central Yukon. Typically, only the more resistant conglomerate units are exposed. In the Whitehorse map area (NTS 105D), sediments of the Tantalus Formation were laid down unconformably on deformed Whitehorse Trough strata (Wheeler, 1961; Hart and Radloff, 1990). The Whitehorse Trough, which is

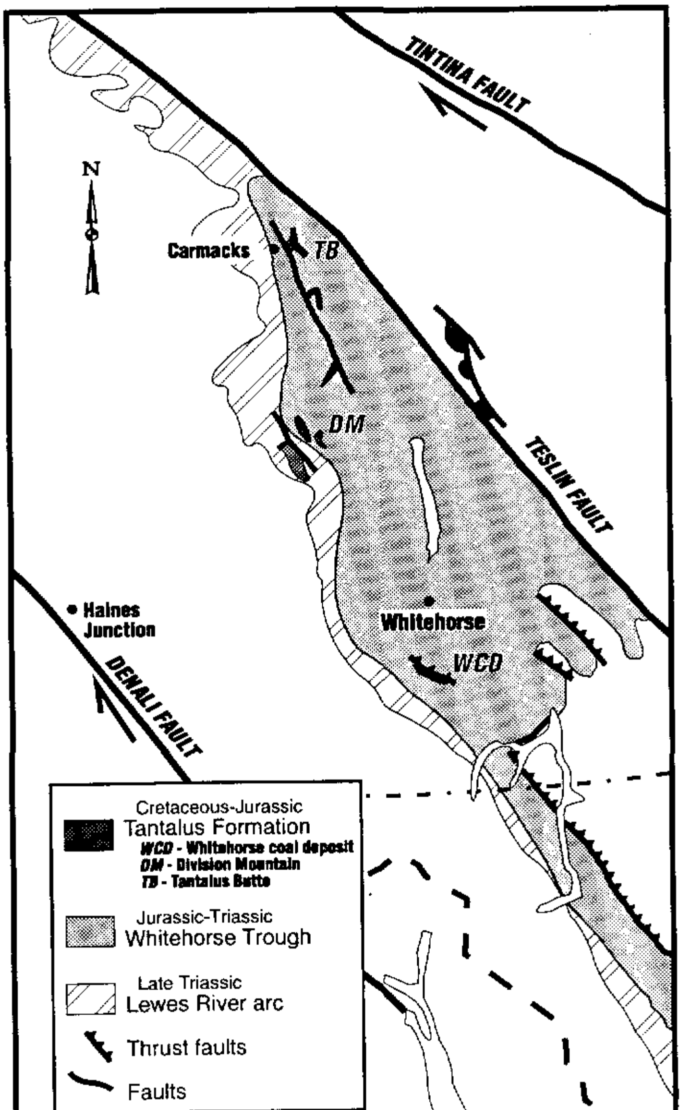

Figure 1. Location of the Whitehorse Trough.

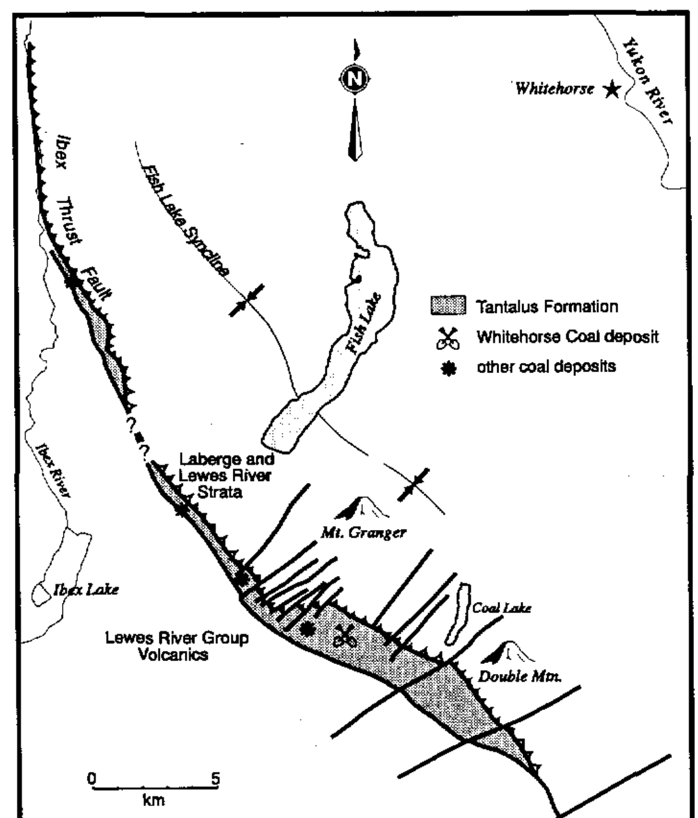

Figure 2. Location of the Whitehorse Coal Deposit.

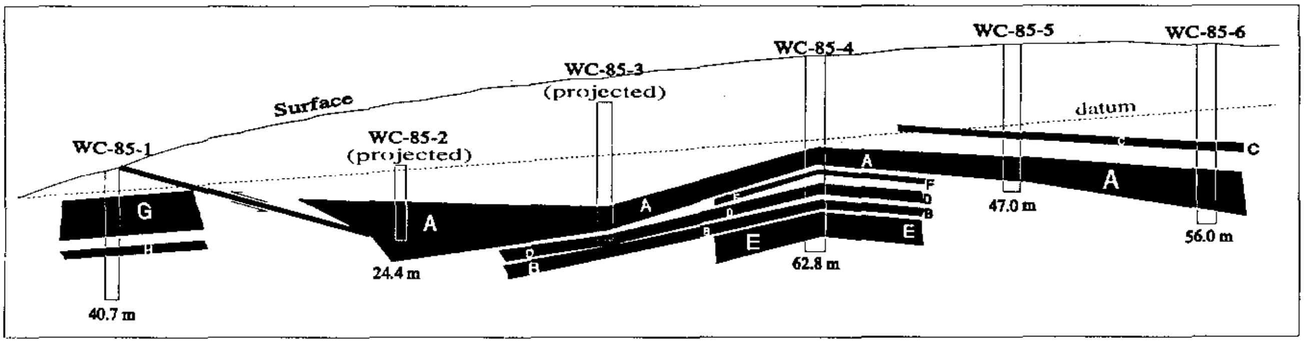

Figure 3: Diagrammatic longitudinal section of drill hole intersections at the Whitehorse Coal Deposit (from Carlyle, 1985). The drill holes span a strike-length of approximately 335 metres. Numbers beneath drill holes indicate depth of hole in metres.

believed to have been a forearc basin, is defined by upper Triassic arc-derived sediments of the Lewes River Group and Jurassic clastic strata of the Laberge Group (Tempelman-Kluit, 1979). The Whitehorse coal deposit is located on the west side of the Whitehorse Trough adjacent to the Coast Plutonic Complex. The Coast Plutonic Complex has in part a Cretaceous and early Tertiary magmatic history. Intrusions associated with the Complex may be responsible for thermally upgrading coals at the Whitehorse coal deposit.

The Tantalus Formation is made up of chert-rich, fluvial clastic strata up to 1200 m thick and locally includes at least three coal seams which, in aggregate, are up to eight metres thick (Tempelman-Kluit, 1974). The sediments are believed to have been deposited in small basins possibly related to transcurrent faulting (Gabrielse et al., 1991). Coal measures found in these basins are faulted, folded and locally cut by igneous intrusions.

Local Geology

Southwest of Whitehorse, exposures of the Tantalus Formation form a 30 km long, crescent-shaped, fault-bounded wedge which extends along the eastern slopes of the Ibex River to south of Double Mountain (Figure 2; Wheeler, 1961; Hart and Pelletier, 1989; Hart and Radloff 1990). The northeast margin of the wedge is marked by the westerly verging Ibex thrust fault which juxtaposes Whitehorse Trough strata south over the Tantalus Formation (Hart and Radloff, 1990). The southwest margin of the Tantalus wedge abuts Lewes River Group volcanic strata along an unnamed fault in the Ibex River valley (Hart and Radloff, 1990). A series of late northeast-trending cross faults, with variable but minor offsets, cuts the Tantalus wedge into small blocks (Figure 2).

Tantalus Formation strata, within this fault bounded wedge, are at least 600 m thick, and comprise chert-pebble conglomerate, cherty sandstone, shale, mudstone and coal (Hart and Radloff, 1990). Conglomerate is typically massive and clast supported with dominantly rounded clasts of grey, black and white chert that range from 2 to 10 cm in diameter. Trough and planar cross-bedded sandstone is composed primarily of chert and quartz with minor lithic fragments. Siltstone and mudstone are well bedded and occur at the top of fining upward sequences. Typically, coal occurs on top of, or interbedded with, dark grey to black mudstone or siltstone and is often overlain by scour based, channel fill conglomerate. More detailed lithological descriptions can be found in Hunt (1989), Hart and Pelletier (1989) and Hart and Radloff (1990).

The Whitehorse Coal deposit is located in this fault bounded wedge approximately 2 km south of Mount Granger where the mid Cretaceous (U-Pb age of 109 Ma) Mount McIntyre pluton is exposed. Dykes related to this pluton are known to cut strata of the Jurassic Laberge Group (Hart and Radloff, 1990) north of the coal deposit. Narrow felsic sills, possibly related to the Mount McIntyre Pluton or the Late Paleocene (58 Ma) Skukum Group, intrude the coal seams within the Whitehorse coal deposit (Fig. 4a) and are responsible for local contact metamorphism of the coal (Hunt, 1989; Goodarzi and Jerzykiewicz, 1989).

Age

Rocks of the Tantalus Formation have been assigned ages ranging from Late Jurassic to Tertiary. Fossil plant collections from the Whitehorse area were considered by Bell (1956) to be Neocomian (early Lower Cretaceous) in age, but a Portlandian age (late Upper Jurassic) was considered possible. On the basis of palynomorph collections, Lowey (1984) suggested that Tantalus (?) strata in the Indian River area, previously considered to be Tertiary, are Albian (Early Cretaceous) in age.

Palynomorphs obtained from Tantalus strata west of the Whitehorse coal deposit returned Kimmeridgian-Oxfordian ages (Table 1 samples A and B; G.E. Rouse in Hart and Radloff, 1990). Strata from the coal deposit itself contained palynomorphs of upper Cretaceous age (Table 1, Sample C). At present there is not enough data to clearly define the age of the Tantalus Formation, however, the above evidence suggests that the Tantalus Formation ranges in age from Late Jurassic to Late Cretaceous, or that there are two (or more) periods of deposition. Further palynological information is required to constrain accurately the age of the Tantalus Formation.

Depositional Environment

Proposed depositional environments for the Tantalus Formation in the Whitehorse area include: non-marine (Wheeler, 1961), braided fluvial (Bremner, 1988) and fluvial to marine shoreface transitions (Hart and Pelletier, 1989). A wave dominated delta-fan model has also been suggested and may account for the wide lateral distribution of the coal seams (Hart and Pelletier, 1989).

Evaluation of palynomorphs by G.E. Rouse (pers. comm., 1989) revealed the presence of dinocysts (Table 1) which indicate a marine influenced environment for some strata in the Whitehorse area. The limited data suggest that Jurassic strata (Table 1, samples A and B), have a marine depositional influence as indicated by the presence of dinocysts. Upper Cretaceous strata (Table 1, Sample C) do not contain dinocysts and likely have a terrestrial depositional environment.

Field Description and Petrology of Coals

Mapping, trenching and rotary drilling by the Whitehorse Coal Corporation has defined at least eight coal seams at the Whitehorse coal deposit that range in thickness from 0.6 to 13 m (Carlyle, 1985; Bremner, 1988). Bremner (1988) reports two continuous seams exposed at surface. The lower seam exposed in trenches is a minimum of 3.3 m thick and continuous for at least 1 km. The upper seam is 1.8 m thick and exposed almost continuously in trenches and pits for a strike length of 2 km. In outcrop, the coal is typically massive, black and lustrous with highly varying fissility.

Petrographically, the coal shows little variation in composition. Most samples examined were composed of structureless vitrinite and lesser amounts of fusinite (Hunt, 1989). Pyrite was evident in a number of samples and some samples show a melting texture indicating rapid heating, possibly due to the contact metamorphic effects of local sills and dykes.

Coal Quality and Rank

Coal quality data from all sources is summarized in Appendix 1. These data indicate that coal at the Whitehorse coal deposit is moderate to high-ash anthracite. Results from samples taken during drilling are consistently better than those for surface samples and range from: 16.66–25.96% Ash; 5.85–9.61% Volatile Matter; 66.99–77.06% Fixed Carbon; 0.42–0.68% Sulphur; and 10 450–12 005 BTU/lb Calorific Value. The best results are from the 4.3 m thick, B coal zone. Although ash contents range from approximately 17 to 26% in individual coal seams, a 14 tonne bulk sample taken from the main coal pit had a head grade of 46.28% ash (dry basis; JHP Coal-Ex Consulting, 1987).

Vitrinite reflectance measurements were carried out on 30 outcrop samples of Tantalus Formation coal collected from the Whitehorse coal deposit and surrounding area (Figure 2, Table 2). Samples were prepared by methods outlined in Bustin et al. (1985). Mean random reflectance (Ro_{rand}) was used instead of mean maximum

Location	Palynomorphs	Age
60° 32' 45" N 135° 22' 40" W A	*Gonyaulacysta jurassica*	Oxfordian-Kimmeridgian
	Nannoceratopsis pellucida	Oxfordian-Kimmeridgian
	Netrelytron stegastum var *longicornia*	Oxfordian-Early Kimmeridgian
	Gonyaulacysta jurassica	Kimmeridgian
	Pareodinia ceratophora	Bajocian-Albian
	Tenua pilosa	Oxfordian-Kimmeridgian
60° 30' 25" N 135° 19' 00" W B	*Vitreisporites pallidus*	Jurassic
	Gonyaulacysta jurassica	Oxfordian-Kimmeridgian
	Gonyaulacysta jurassica var *longicornis*	Oxfordian-Kimmeridgian
	Nannoceratopsis cf. *pellucida*	Oxfordian-Kimmeridgian
	Pareodinia minuta	Oxfordian-Kimmeridgian
60° 29' 30" N 135° 15' 30" W C	*Myricipites dubius*	Upper Cretaceous
	Inapertisporites	
	Ovidites-3	
	Alterbia acuminata	

Table 1: Palynomorphs in samples from Tantalus Formation rocks near the Whitehorse Coal deposit (determinations are by G.E. Rouse, Palynorox Consulting Inc.).

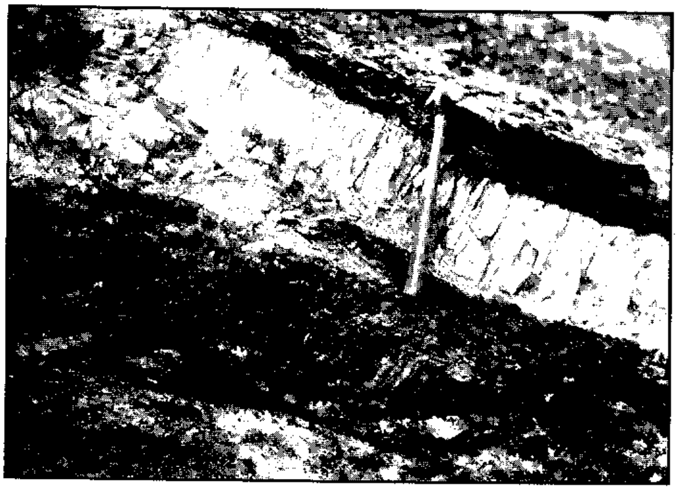

Figure 4a: A rhyolite sill cutting coal measures at the main pit of the Whitehorse coal deposit has resulted in adjacent columnar jointed coal and an increase in maturation due to metamorphism. See Figure 4b.

reflectance (Ro_{max}) as this is the usual standard for maturation used by the oil industry (Ro_{max} = 1.066 Ro_{rand}; Ting, 1978). Reflectance values range from 1.68 to 3.45% Ro_{rand}, corresponding to a variation in rank from low volatile bituminous coal (LVB) to anthracite (see Hunt, 1989 for all data). The coal is dominantly semi-anthracite to anthracite. Higher Ro values (3.81 Ro_{rand}) were found adjacent to (5 cm from) a narrow (0.2 m thick) rhyolite sill and decreased progressively, with distance, away from the sill (Figure 4; Hunt, 1989; Goodarzi and Jerzkiewicz, 1989). The sill had a contact metamorphic effect on the coal causing liquefaction and the production of a cohesive coke (Goodarzi and Jerzykiewicz, 1989). The coking effects reach at least 0.65 m away from the sill (Goodarzi and Jerzykiewicz, 1989; Hunt, 1989). The presence of fusinite in most samples analysed indicates that the coal was either charred in a swamp fire during peat accumulation or subjected to intensive and rapid biochemical alteration (Ting, 1982).

Based on mean maximum vitrinite reflectance three coal samples examined by R.M. Bustin (in Hill, 1983 and JHP Coal-Ex Consulting Ltd, 1984) would be classified as meta-anthracites. Two of these three samples have a coke like micro-structure suggesting they may have been heated for short durations at high temperatures possibly as a result of igneous intrusion or frictional heating (R.M. Bustin in Hill, 1983).

Petrographic studies (R.M. Bustin in Hill, 1983; Goodarzi and Jerzykiewicz, 1989; Hunt, 1989) indicate that coal at the Whitehorse coal deposit has undergone regional (due to burial, and intrusion of the Coast Plutonic Complex) and contact metamorphism. Regional metamorphism probably elevated the rank of the coal while contact metamorphism resulted in coking of the coal (Goodarzi and Jerzykiewicz, 1989). Coal that has been subjected to contact metamorphism by a felsic sill has been coked at a temperature of 600 °C and at a rate of heating of > 60°C/min (Goodarzi and Jerzykiewicz, 1989). Based on the coking behaviour of the altered coal

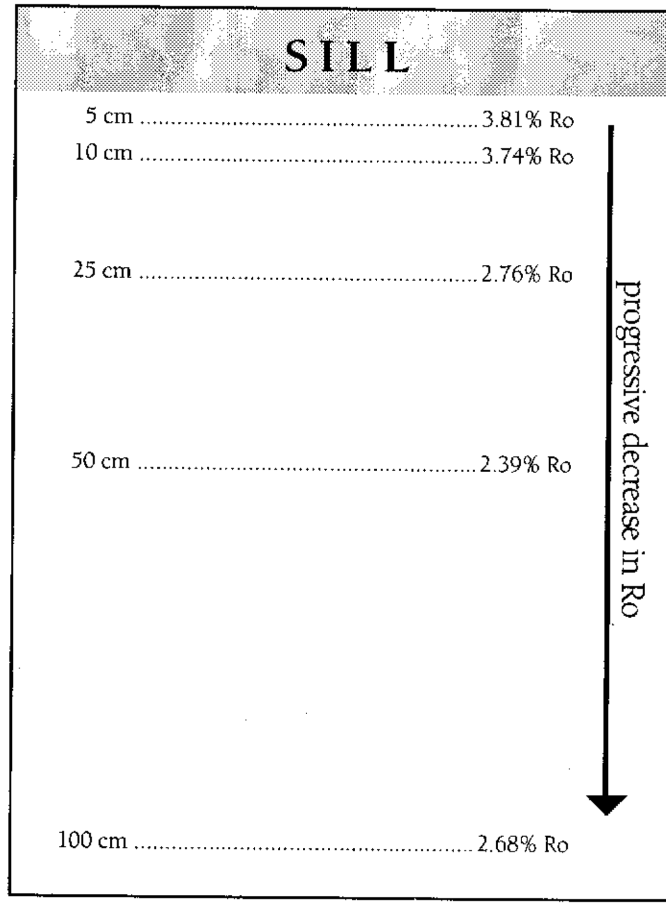

Figure 4b: Decreasing reflectance values with distance away from a sill in the Whitehorse coal deposit.

the rank of the unaltered coal is estimated to be in the range of medium to low volatile bituminous.

Petrographic analysis (R.M. Bustin, in Hill, 1983) indicates that much of the ash is finely disseminated in the organic fraction and would be difficult to remove without fine crushing. The use of a dense medium cyclone would probably be required to produce acceptable clean coal yields (R.M. Bustin in Hill, 1983 and JHP Coal-Ex Consulting Ltd, 1984). Because of the high ash content of the coal it can be expected that any amount of cleaning will markedly increase the value of the product for heating.

Hydrocarbon Source Rock Potential

In order to be considered a hydrocarbon source rock, a formation must contain sufficient organic material and the organic material must have undergone sufficient heating to generate hydrocarbons, but not so much heating that the hydrocarbons are destroyed; i.e., it must lie within the oil window. The oil window lies between approximately 0.5% Ro and 1.35% Ro (Figure 5; Dow, 1977). Once the organic material passes through the oil window (i.e., Ro > 1.35%) it reaches the gas zone. Gas will continue to be produced until the organic matter reaches a critical maturation level of about 4.0% Ro. Beyond this level no gas will be produced.

Sample	Locality	Location UTM Zone 8V	Random Reflectance (Ro_{rand}%)	Coal Rank
J36-4	Mt. Bush 5870'	496040E 6686045N	2.85	Anthracite
J36-7	Mt. Bush 5920'	496030E 6686050N	3.37	Anthracite
J42-1	Whitehorse Coal	485045E 6706054N	2.19	Low Volatile Bituminous
J42-4	Whitehorse Coal	485055E 6706047N	2.39	Semi Anthracite
J42-5	Whitehorse Coal	485079E 6706045N	2.48	Semi Anthracite
J42-6	Whitehorse Coal	485090E 6706042N	2.81	Anthracite
J42-7	Whitehorse Coal	486005E 6706052N	2.14	Low Volatile Bituminous
J42-8	Whitehorse Coal	486031E 6706050N	2.44	Semi Anthracite
J42-9	Whitehorse Coal	486030E 6706037N	2.43	Semi Anthracite
J42-10	Whitehorse Coal	486037E 6706042N	2.26	Semi Anthracite
J42-11	Whitehorse Coal	486037E 6706031N	1.73	Low Volatile Bituminous
J52-2	Whitehorse Coal	485073E 6705091N	2.21	Semi Anthracite
J52-10*	Whitehorse Coal	485050E 6706020N	3.81	Anthracite
J52-11*	Whitehorse Coal	485050E 6706020N	3.74	Anthracite
J52-12*	Whitehorse Coal	485050E 6706020N	2.76	Semi Anthracite
J52-13*	Whitehorse Coal	485050E 6706020N	2.39	Semi Anthracite
J52-14*	Whitehorse Coal	485050E 6706020N	2.68	Semi Anthracite
J52-17	Whitehorse Coal	485045E 6706027N	2.83	Anthracite
J52-19	Whitehorse Coal	485045E 6706027N	2.56	Semi Anthracite
J55-4	Whitehorse Coal	488055E 6705055N	2.52	Semi Anthracite
J55-7i	Whitehorse Coal	482060E 6708057N	2.99	Anthracite
J55-7ii	Whitehorse Coal	482060E 6708057N	2.56	Semi Anthracite
J55-9	Whitehorse Coal	484035E 6706065N	2.51	Semi Anthracite
J55-10	Whitehorse Coal	484025E 6706059N	1.98	Low Volatile Bituminous
J55-12	Whitehorse Coal	484025E 6706052N	1.68	Low Volatile Bituminous
J55-13	Whitehorse Coal	484030E 6706057N	2.77	Semi Anthracite
J55-14	Whitehorse Coal	485062E 6706021N	2.54	Semi Anthracite
J55-15	Whitehorse Coal	485059E 6706026N	2.69	Semi Anthracite
J-70	Whitehorse Coal	Trench on east hill	2.34	Semi Anthracite

* *Samples taken adjacent to rhyolite sill, see Figure 4b).*

Table 2: Vitrinite reflectance values from Tantalus Formation coals in the vicinity of the Whitehorse coal deposit.

All the examined samples of coal from the Tantalus Formation have reflectance values greater than 1.35% (the upper limit of the oil window) suggesting that oil generation is unlikely (Table 2, Figure 4). However, all samples have reflectance values less than 4.0% (the upper limit of dry gas preservation) making the generation of coal bed methane possible. However, the presence of complex and extensive faulting in the Whitehorse area probably precludes the preservation of any hydrocarbons that may have been generated.

Maturation

The generally high rank of the Whitehorse coals probably results from a combination of three potential heat sources: 1) Tantalus Formation rocks are in the footwall of the southwesterly-directed Ibex Thrust Fault which was responsible for burying the coals beneath at least 3 km of Whitehorse Trough strata, thus increasing the thermal gradient; 2) a wide zone of hornfelsed country rock around the Mount Granger pluton suggests that the pluton may have shallow margins and be responsible for thermally upgrading the coals in mid-Cretaceous time; and 3) the eastern Coast Plutonic Complex was a zone of high heat flow during Early Tertiary time due to the emplacement of epizonal plutons, volcanics and dyke swarms resulting from crustal extension (Hart and Radloff, 1990). Although the thermal gradient of the region was probably elevated during early Tertiary time, biotite from the Mount Granger pluton yielded a mid-Cretaceous K-Ar date (94 Ma, C.J.R. Hart, unpublished data) indicating that the area has not experienced temperatures above the Ar closing temperature for biotite (~280°C; Harrison et al., 1985) since 94 Ma.

CONCLUSIONS

The Tantalus Formation in the area of the Whitehorse coal deposit is Upper Jurassic and Upper Cretaceous in age, however, further data are required in order to provide greater constraints on this age range. The presence of dinocysts in the palynology collections indicates a marine influence on the environment of deposition, at least during the Late Jurassic. The lack of dinocysts in Upper Cretaceous strata suggest a distal or absent marine influence at this time.

Vitrinite reflectance values from Tantalus Formation samples around the Whitehorse coal deposit indicate that the coal is dominantly semi-anthracite to anthracite. The presence of melting texture in some samples indicates that heating was rapid and probably due to contact thermal effects from high points in underlying intrusions, including dykes and sills. Fusinite, present in most samples, indicates that the coals underwent charring or biochemical degradation during peat accumulation.

Coal (organic material) at the Whitehorse coal deposit is too mature to produce oil, but may still be capable of producing methane gas since the vitrinite reflectance values are less than 4%, which is the limit of dry gas preservation (Figure 5).

The Whitehorse coal deposit is well situated with regard to infractructural requirements to support the exploitation of this coal. There is potential for a mine-mouth power generation station using the fluidized-bed combustion process (JHP Coal-Ex Consulting Ltd, 1984) and opportunities exist locally for domestic and industrial heating. Potential in situ coal resources at the Whitehorse coal deposit are 23.5 million tonnes (26 million tons) with a dry ash content of 40% (JHP Coal-Ex Consulting Ltd, 1984). This estimate is for coal zone A only and does not include any additional tonnages available from other coal

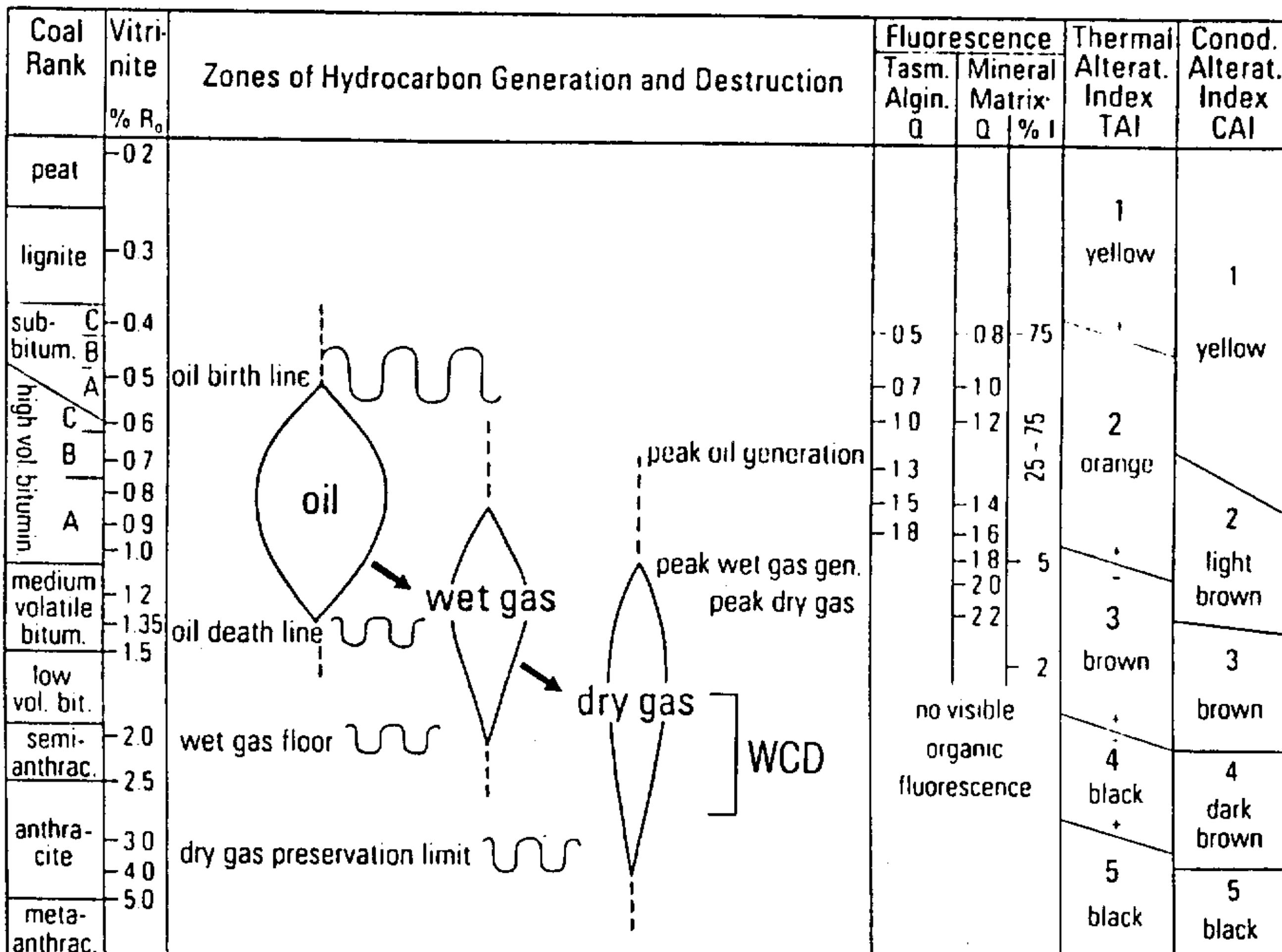

Figure 5: Correlation of coal rank, vitrinite reflectance and zones of hydrocarbon generation and destruction (adapted from Dow, 1977). WCD= Whitehorse coal deposit

zones. Current drill indicated reserves are in excess of 200 800 tons and open in all directions (Carlyle, 1985).

Investigations and exploration of the Whitehorse coal deposit has concentrated on surface exposures, particularly those exposed in the main pit. Drilling, however, has revealed the presence of seven other seams with ash contents potentially as low as 15%. Consequently, further investigation is justified to: 1) locate possible surface exposures of these seams; and 2) systematically evaluate these remaining seams to better determine their potential.

Acknowledgements

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Appendix 1
Coal Quality data for samples from the Whitehorse Coal Deposit

Sample	Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value btu/lb
Cairnes, 1908					
A	21.98	6.01	69.86	/	/
B	25.40	8.34	62.50	/	/
C	47.78	10.06	38.38	/	/
D	48.13	6.65	42.27	/	/
Taylor, 1969 (Dry Basis)					
Fisher Creek lower seam	35.4	12.7	51.8	/	8537
Fisher Creek middle seam	64.3	9.9	25.8	/	4479
Fisher Creek upper seam, lower bench	38.2	10.4	51.3	/	8501
Fisher Creek upper seam, upper bench	55.7	7.9	36.3	/	5901
West Hill	55.0	11.8	33.2	/	5710
East Hill, high trench-low pit	67.7	10.2	22.1	/	3153
Williams Hole (East Hill)	63.9	13.3	22.7	/	4000
Camp 4 trench (Coal Ridge)	39.0	11.5	49.5	/	7208
Double Mountain	63.5	14.2	22.2	/	4192
Hill, 1983 (Moist Basis)					
1	34.1	/	/	/	9650
2	37.4	/	/	/	8396
3	43.2	/	/		7452
JHP Coal-Ex Consulting Ltd., 1984 (Dry Basis)					
Fisher Creek 1	62.54	15.62	21.84	0.15	3222
Fisher Creek 2	76.39	9.08	14.53	0.06	/
Fisher Creek 3	69.05	10.06	20.89	0.15	/
Fisher Creek 4	40.60	8.88	50.52	0.28	7836
Fisher Creek 5	59.79	10.41	29.80	0.17	3966
Fisher Creek 6	40.66	14.04	45.30	0.26	7474
Coal Ridge	65.14	15.25	19.61	0.41	3967
West Hill trench A	60.91	14.99	24.10	0.17	4092
West Hill trench B	73.23	11.78	14.99	0.12	/
Double Mountain	63.79	13.26	22.95	0.15	3898

Sample	Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value btu/lb
			Carlyle, 1985 (dry basis) Drill Hole Cuttings		
1(46'–48') seam G	22.05	6.82	71.13	0.62	10695
1(58'–60') seam G	22.88	7.85	69.27	0.62	10450
1(82'–84') seam H	22.13	8.40	69.47	0.59	10693
2(14'–16') seam A	23.60	8.07	68.33	0.62	10773
2(54'–56') seam B	20.68	9.61	69.71	0.67	11196
3(70'–72') seam A	23.52	7.11	69.37	0.57	10673
3(78'–80') seam A	21.40	7.60	71.00	0.62	11096
3(126'–128') seam B	16.66	6.28	77.06	0.68	12005
4(96'–98') seam A	24.67	6.93	68.40	0.64	10496
4(102'–104') seam A	25.96	7.05	66.99	0.52	10471
4(116'–118') seam D	25.21	6.24	68.56	0.43	10412
4(183'–184')seam E	21.75	5.00	73.25	0.63	11042
5(120'–122') seam A	20.78	7.29	71.93	0.56	11070
5(128'–130') seam A	19.68	5.85	74.47	0.55	11203
5(136–138) seam A	24.61	7.70	67.70	0.47	10537
6(138'–140') seam A	23.64	6.17	70.19	0.42	10629
6(142'–144') seam A	22.93	7.73	69.34	0.54	10678
			JHP Coal-Ex Consulting Ltd., 1987 (Dry Basis)		
1	54.51	/	/	/	4186
2	53.14	/	/	/	5048
3	54.50	/	/	/	/
4	41.44	/	/	/	7143
5	21.32	10.98	67.70	0.44	*10789
6	25.71	10.74	63.55	0.56	9746
7	39.05	7.41	53.54	0.45	*8275
8	24.51	6.08	69.41	0.56	10719
9	50.02	7.89	42.09	0.37	*6399
10	32.09	5.99	61.92	0.49	9602
11	62.84	5.62	31.54	0.32	*4504
12	35.69	6.75	57.56	0.46	8784
Bulk Sample (14 tonnes)	46.28	8.56	45.16	0.37	11631 (3248 cal/g)

**—sample treated with benzene*
/ —not determined

Geological Setting of Mineral Occurrences in Fairchild Lake Map Area (106C/13), Wernecke Mountains, Yukon

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THORKELSON, D.J. and WALLACE, C.A., 1994. Geological setting of mineral occurrences in Fairchild Lake map area (106C/13), Wernecke Mountains, Yukon. In: Yukon Exploration and Geology, 1993. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 79–92.

Abstract

The Fairchild Lake map area is underlain by two principal sedimentary successions, Middle Proterozoic Wernecke Supergroup and unconformably overlying Middle to Late Proterozoic Pinguicula Group. The angular unconformity between the successions was caused by an intervening period of deformation known as Racklan orogeny. A third succession, herein named the Slab volcanics, is inferred to have been deposited after Racklan orogeny and before Pinguicula Group deposition. Mineralization occurs as sedimentary exhalative, vein, and intrusive breccia occurrences within Wernecke Supergroup. The sedimentary exhalatives contain Zn, Pb, Cu and Ag in shaley horizons within a mainly dolomitic sequence. The vein occurrences contain Zn, Pb, Cu, Ag, Au and U. The intrusive breccias, collectively known as Wernecke breccia, host Cu, Co, U, Ag and Au. Wernecke breccia was probably generated by explosive expansion of volatile-rich fluids. Brecciation was preceded by Racklan orogeny and intrusion of igneous dykes. The dykes and the breccia-related mineralizing fluids may have a common source in postulated underlying magma chambers. Local supergene enrichment of breccia mineralization was caused by Middle to Late Proterozoic weathering before deposition of Pinguicula Group.

Introduction

Geological mapping and research were carried out in the summer of 1993 in the Fairchild Lake map area (106C/13), herein called the study area (Fig. 1). This work is part of an ongoing investigation of the geology and mineral deposits in the Wernecke Mountains of northern Yukon. A 1:50 000 scale map (Thorkelson and Wallace, 1994), provides additional information on the geological relations described in this report. A simplified version of that map is shown in Fig. 2. Results of an earlier study on the Slats Creek map-area (106D/16), which lies directly west of the present study area, have been published as a map and companion report (Thorkelson and Wallace, 1993a, 1993b).

The Wernecke Mountains have been one of the principal regions of mineral exploration and claim staking in Yukon since the late 1960's. Exploration, mainly for Cu, Co, U, Zn, Pb, Mo, Ag and Au, in exhalative, vein and breccia occurrences, reached a peak in the late 1970's and early 1980's when about thirty prospects were evaluated by drilling. As a result, some of these occurrences now have defined grade and tonnage, and are considered deposits. Between the early 1980's and about 1992, exploration in the Wernecke Mountains was minimal. However, over the past two years the minerals industry has shown renewed interest in the region. Much of the recent activity, including systematic geochemical sampling and airborne geophysics, has been concentrated in and near the study area, within a few kilometres of the Bonnet Plume River. Intensive property evaluation in 1994 is anticipated.

Stratigraphy

The study area is underlain by two principal stratigraphic units, Wernecke Supergroup and overlying Pinguicula Group (Fig. 3). A third stratigraphic unit, herein named the Slab volcanics, is inferred to lie between the Wernecke and Pinguicula successions.

Wernecke Supergroup, as defined by Delaney (1981) and used in our investigations, consists of three groups. The lowest unit, Fairchild Lake Group, consists mainly of siltstone with minor carbonate interbeds. It is overlain by Quartet Group, comprising mainly siltstone and shale, which is overlain by Gillespie Lake Group, comprising mainly dolostone. Stratigraphic contacts within the Wernecke Supergroup are conformable and gradational. Stratigraphic details were provided by Delaney (1981) and Thorkelson and Wallace (1993a).

Pinguicula Group overlies Wernecke Supergroup with angular unconformity (Fig. 4)(Eisbacher, 1978, 1981). Near the study area, the Pinguicula Group is about 1300 m thick, and can be divided into a lower clastic unit, and two overlying carbonate units. The lower clastic unit is about 200 m thick, consisting of mainly maroon to green weathering siltstone and mudstone. The basal 15 m of the lower clastic unit comprises greenish grey weathering quartzose sandstone locally interbedded with granule to pebble conglomerate. At the PIKA Minfile occurrence (Figs. 1, 5), lenses of conglomerate in the basal sandstone (Fig. 6) contain clasts of Wernecke breccia, apparently derived locally from nearby breccia zones, discussed later. The lower clastic unit is equivalent to Unit A of Eisbacher (1981). An orange weathering silty dolostone and limestone unit, about 300 m thick, conformably overlies the lower clastic unit. The base of this unit is locally dominated by up to 25 m of conglomerate containing carbonate intraclasts, and maroon siltstone clasts derived from the lower clastic unit. The silty carbonate

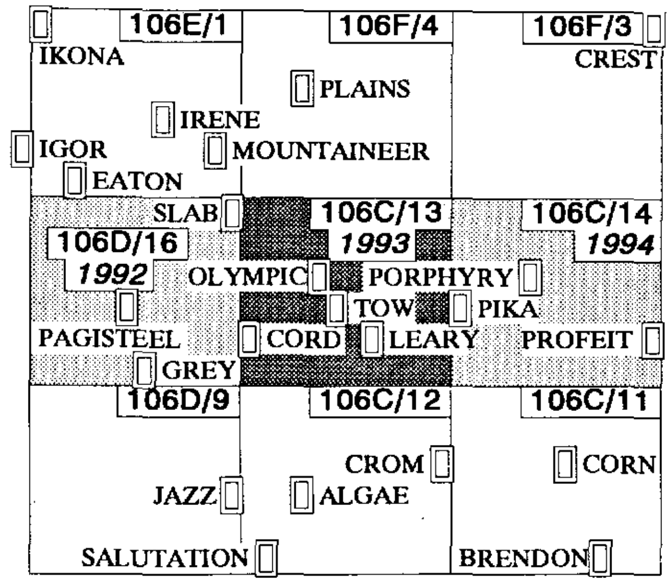

Figure 1: Wernecke Mountains Project—Location of study area and selected mineral occurrences in the Wernecke Mountains of northeastern Yukon. Darkly shaded area in centre is present study area, NTS map area 106C/13. Lightly shaded areas are former (1992) and proposed (1994) study areas. Occurrence names are from Yukon Minfile (INAC, 1993).

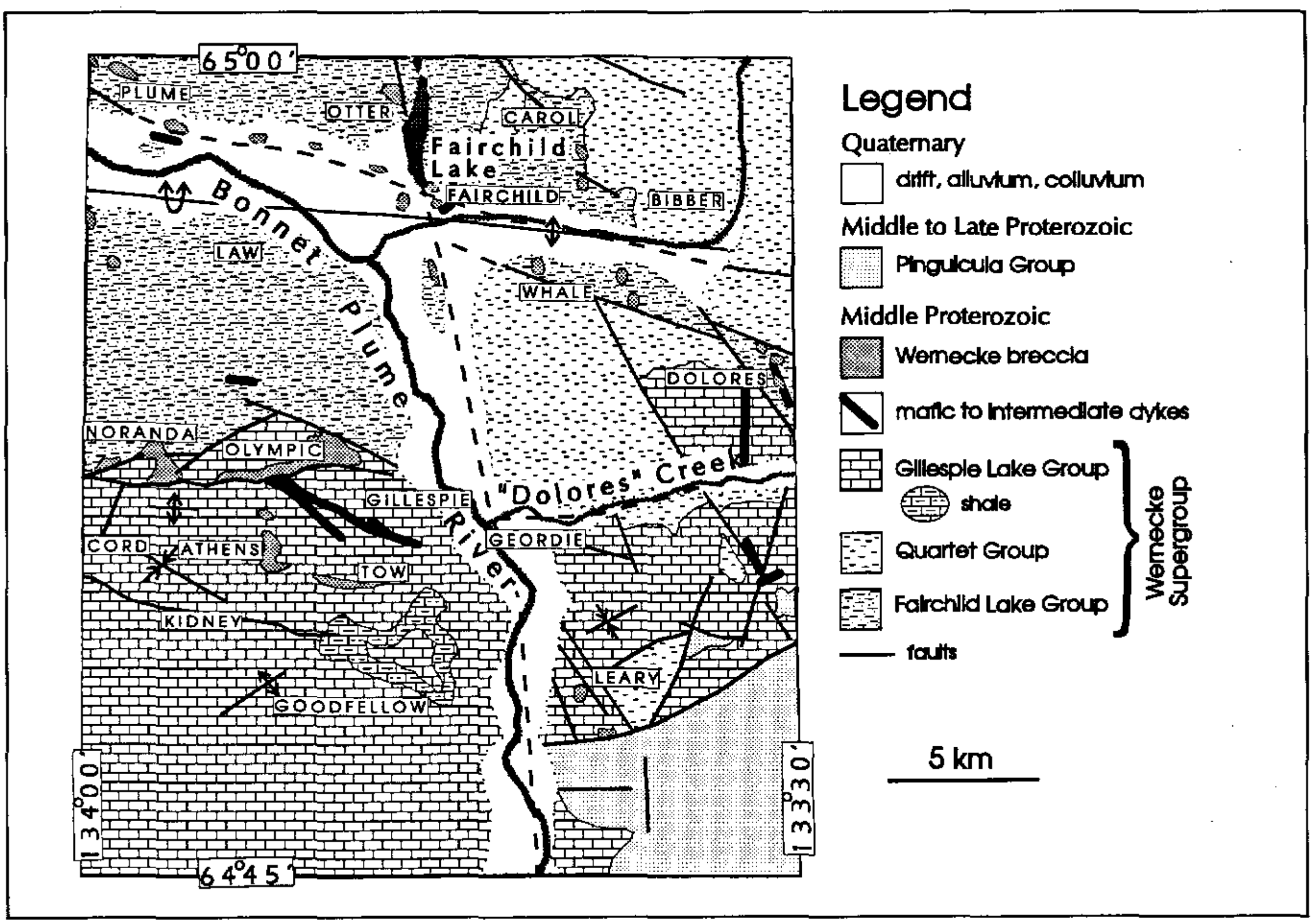

Figure 2: Geological map of the study area (106C/13), simplified from Thorkelson and Wallace (1994). Names inside rectangles are existing (INAC, 1993) and proposed Yukon Minfile occurrences.

contains at least two thin interbeds (3–5 m) of maroon siltstone. This unit is equivalent to Unit B of Eisbacher (1981). The orange-weathering unit is conformably overlain by a thick succession (up to 800 m) of light grey to orange weathering dolostone with minor interbeds of black weathering siltstone. This upper unit is equivalent to units C and D of Eisbacher (1981).

Wernecke Supergroup and Pinguicula Group belong to Proterozoic sequences A and B, respectively, of western North America (Young et al., 1979). Their deposition was separated by an interval of contractional deformation known as Racklan orogeny (Gabrielse, 1967; Cook, 1992). Wernecke Supergroup is presumed to have been deposited on crystalline basement of Early Proterozoic age, perhaps about 1.7 Ga (Delaney, 1981; Norris and Dyke, in press). The only isotopic date from Wernecke Supergroup was provided by Abbott (1993) who obtained preliminary U-Pb zircon ages of about 1.38 Ga from sills related to the Hart River volcanics, 150 km west-southwest of the study area. The volcanics lie within Gillespie Lake Group, near the top of Wernecke Supergroup. A minimum age of Wernecke Supergroup was provided by Parrish and Bell (1987) who obtained a U-Pb monazite age of 1.27 +/- 0.04 Ga from a crosscutting breccia (part of Wernecke breccia, discussed later) in the Richardson Mountains, 150 km north-northwest of the study area. Pinguicula Group was deposited after Racklan deformation and before initiation of Windermere Supergroup deposition at about 780 Ma (Ross, 1991).

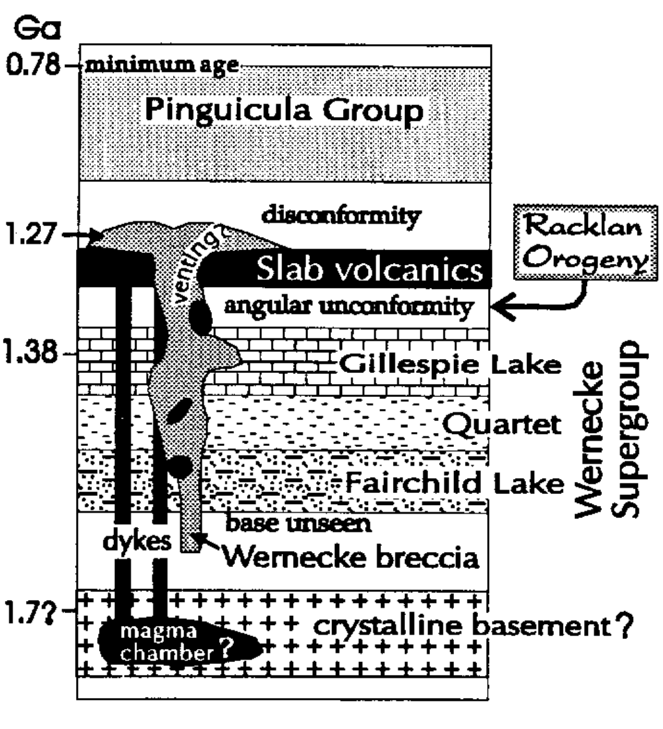

Figure 3: Schematic stratigraphic column of the study area, showing probable timing of Racklan orogeny relative to Wernecke Supergroup and Slab volcanics.

The Slab volcanics, named for "Slab Mountain" at the SLAB Minfile occurrence, are preserved as a small fault block (0.25 x 0.6 km) in the northeastern corner of our former study area (Figs. 1, 3, 7). These volcanic strata were tentatively assigned to the Pinguicula Group in our previous report, but are now regarded as relics of a previously unrecognized stratigraphic interval, younger than Wernecke Supergroup and older than Pinguicula Group. The volcanics were probably deposited in both our former and present study areas, covering tens or perhaps hundreds of square kilometres. The downfaulted block on "Slab Mountain" is apparently the only part of the succession which has not been completely removed by erosion. The absence of volcanic strata beneath the exposed base of Pinguicula Group implies that the erosion occurred before deposition of Pinguicula Group.

The Slab volcanics consist of about forty vertically dipping lava flows, 4–7 m thick, with minor interbeds of clastic rock including rounded pebble conglomerate, sandstone, and volcanic breccia. Many of the lavas have dense flow bottoms and scoriaceous flow tops which indicate stratigraphic tops-to-the-northwest, consistent with the facing direction of basal scours in the conglomerate and sandstone interbeds. The lava flows have a slightly maroon tint to their grey colour, and commonly contain amygdules of quartz, white and orange calcite, biotite, chlorite, and apatite. The flows are aphyric, except for a few which contain scattered phenocrysts (1–3 mm) of plagioclase and corroded pyroxene. Groundmass consists of weakly flow-aligned laths of plagioclase intergrown with biotite and interstitial quartz. In contrast to cleaved and kinked siltstone of the Fairchild Lake Group to the east of the faulted volcanic succession, the lavas are not folded and are devoid of secondary petrofabrics. A boulder size clast (0.5 m diameter) of biotitic amygdaloidal volcanic rock, apparently derived from the volcanic succession, was observed in Wernecke breccia immediately to the northwest of the fault block. The breccia and the volcanic fault block are separated by a narrow (0.1–1 m) fault zone of cataclasite and slickensides.

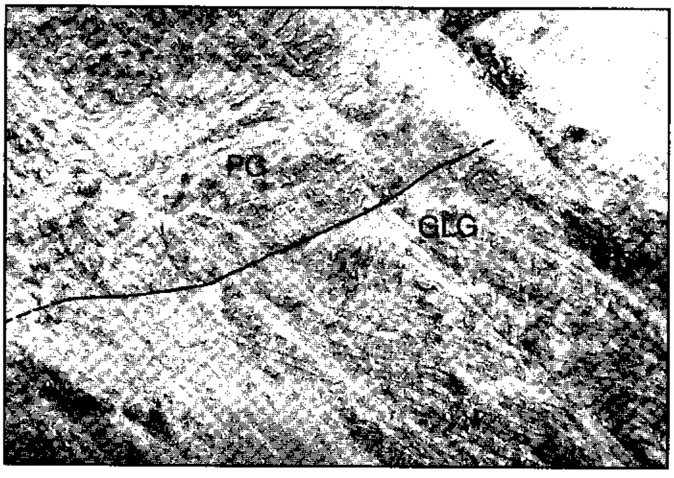

Figure 4-: Angular unconformity between Pinguicula Group (PG) and underlying Gillespie Lake Group (GLG), at eastern edge of study area near PIKA Minfile occurrence.

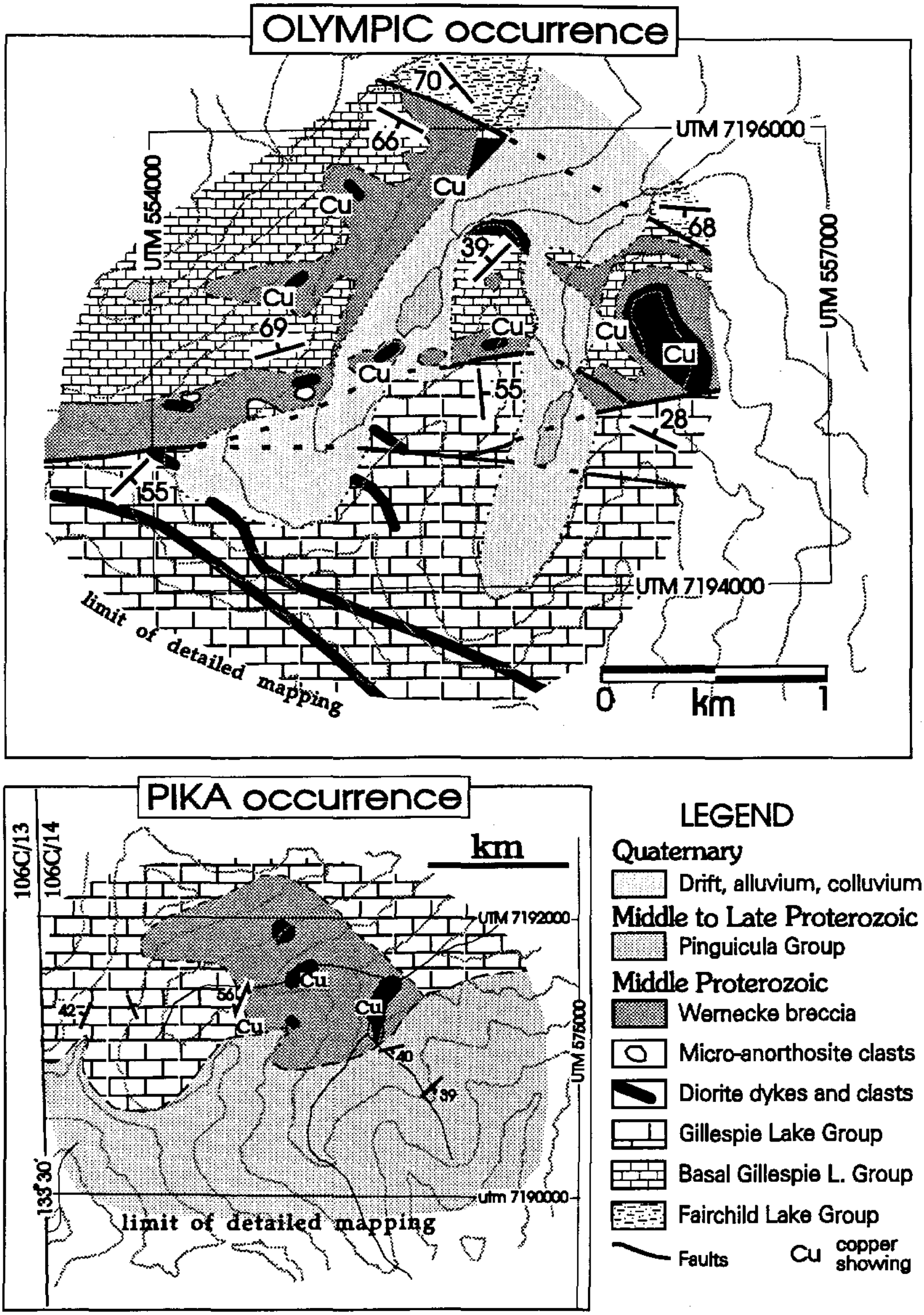

Figure 5: Detailed geological maps of the OLYMPIC and PIKA Minfile occurrences, located on Figs. 1, 2. Legend is common to both maps.

The foregoing observations from SLAB indicate: (1) a volcanic succession at least 250 m thick was deposited subaerially on a substrate of deformed Wernecke Supergroup after Racklan orogeny and before Wernecke breccia generation; (2) parts of the volcanic succession were fragmented and incorporated into Wernecke breccia; and (3) a megaclast of the volcanic strata was downfaulted alongside the breccia.

INTRUSIVE ROCKS

Introduction

Two types of intrusions, igneous dykes and Wernecke breccia, intruded Wernecke Supergroup prior to deposition of Pinguicula Group. Wernecke breccia is the name of breccia zones comprising mainly pebble to cobble size clasts of Wernecke Supergroup (Fig. 8). Dyke emplacement preceded development of Wernecke breccia, a relationship consistent with the work of Laznicka and Edwards (1979), but opposite to that reported previously by us (Thorkelson and Wallace, 1993a). Our former suggestion of post-breccia dyking was based on observations of 3 to 20 m-long bodies of dioritic to basaltic rock within Wernecke breccia. Clasts and brecciated margins of these igneous bodies were not observed, and we assumed that the igneous rock was emplaced into the breccia by dyking. Our more recent work, described in detail below, clearly indicates that dykes in our present study area intruded and cooled within Wernecke Supergroup prior to breccia development. Consequently, the igneous rocks within Wernecke breccia described in our former study are now considered large clasts of dykes dismembered by brecciation. Currently, there is no clear evidence for dykes younger than Wernecke breccia in either our former or present study areas.

Igneous Rocks

Igneous rocks in the study area are of three types: greenish grey weathering diorite, light grey weathering micro-anorthosite, and greenish grey weathering biotitic andesite. Although none are voluminous, all may be important to the geological history of the region, and in particular to genesis of Wernecke breccia.

Diorite is most abundant, forming dykes in Wernecke Supergroup, and discontinuous pods and clasts within Wernecke breccia. It is composed mainly of plagioclase, variably altered to

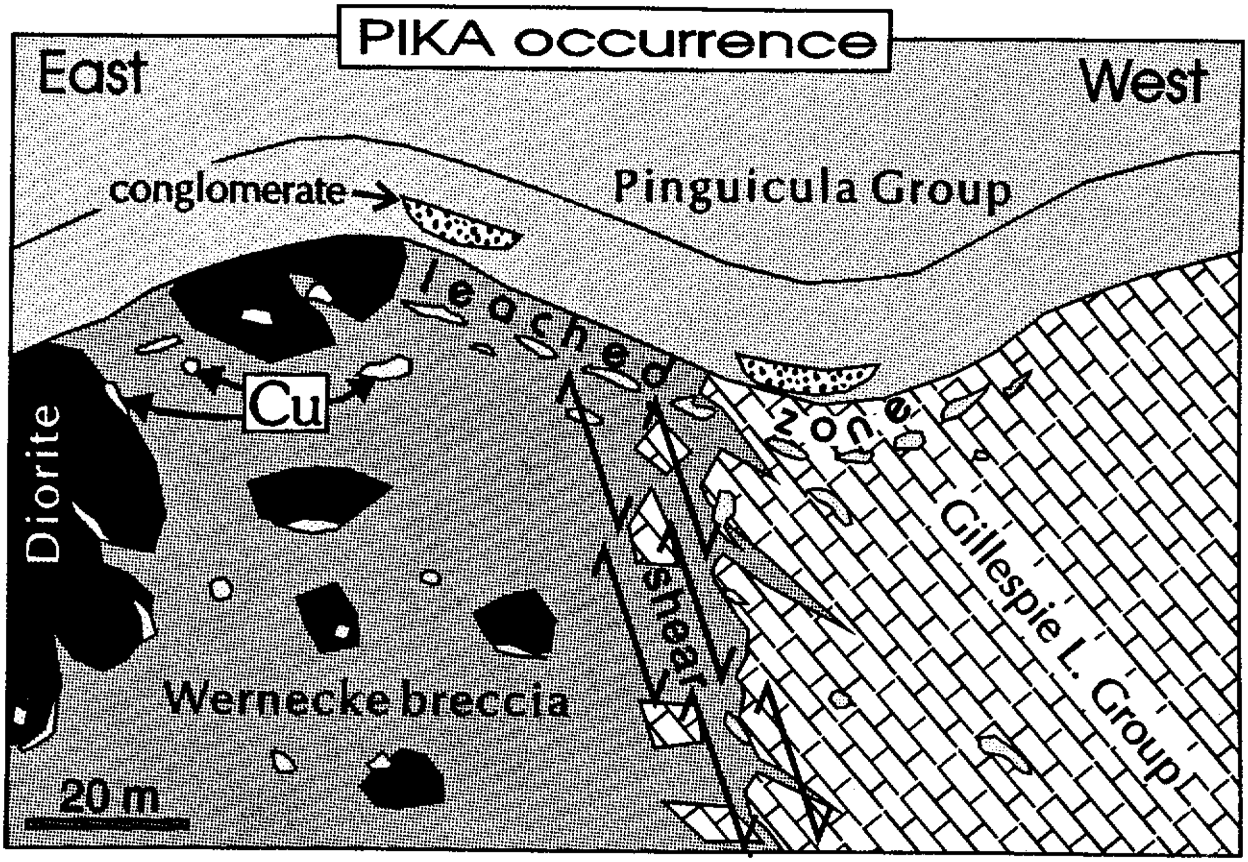

Figure 6: Schematic cross section through the PIKA Minfile occurrence, located in Figs. 1 and 5. Geological history includes: (1) deposition and lithification of Gillespie Lake Group; (2) folding and uplift; (3) intrusion of dioritic dykes; (4) brecciation, metasomatism, and Cu-Ag-Au mineralization; (5) deformation and shear fabric development; (6) subaerial weathering and supergene enrichment; (7) deposition of Pinguicula Group, including basal conglomerate containing clasts derived from Wernecke breccia; (8) folding.

saussurite, and augite, pseudomorphed by chlorite or actinolite. A few prominant dykes of this type are exposed continuously for up to 5 km. They are vertically oriented, and occur in two regions: between the TOW and OLYMPIC Minfile occurrences, west of the Bonnet Plume River; and south of the DOLORES Minfile occurrence, near the eastern boundary of the map area (Fig. 2). The dykes typically display chilled, aphanitic margins which grade into fine to medium grained interiors. Where the dykes intrude Gillespie Lake strata north of the TOW, they are bordered by narrow (0.5–3 m) zones of white limestone produced by contact metamorphism of dolostone (Fig. 9). Several other dykes occur in the study area, notably in the northwestern part where they intrude Fairchild Lake Group.

Numerous bodies of diorite lie within zones of Wernecke breccia, and are particularly common at the OLYMPIC Minfile occurrence (Fig. 5). There, several bodies ranging in length from 20 cm to 0.5 km lie within breccia composed mainly of pebble and cobble size clasts of Wernecke Supergroup. Some of the smaller clasts (<2 m) are well rounded with smooth margins. The discontinuous distribution of diorite in the breccia contrasts with the generally undeformed and continuous diorite dykes immediately to the south. These relationships infer that the diorite bodies in the breccia are clasts produced by fragmentation of dykes during development of Wernecke breccia. Apparently, after the dioritic dykes intruded Wernecke Supergroup, both the dykes and the sedimentary strata were brecciated together (Fig. 3). The roundness of some of the clasts indicates that fragmentation was followed by transport and abrasion.

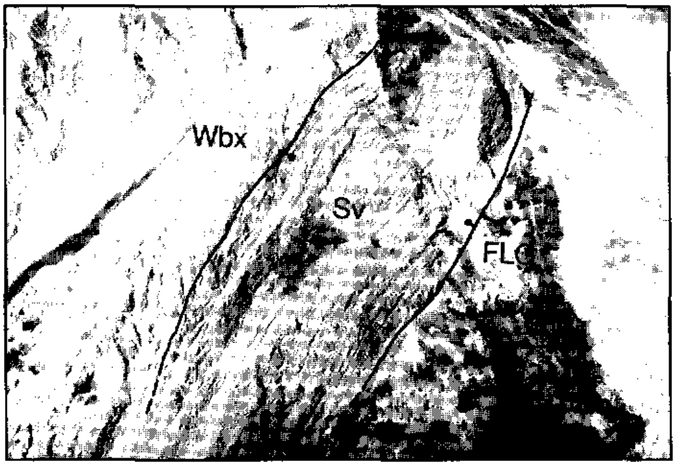

Figure 7: Slab volcanics of the SLAB Minfile occurrence (Fig. 1; Thorkelson and Wallace, 1993). Volcanic succession (Sv) is faulted between Wernecke breccia (Wbx) and cleaved siltstone of Fairchild Lake Group (FLG).

Micro-anorthosite occurs as two bodies about 25 m across in breccia of the OLYMPIC occurrence. Like the diorite, these igneous pods are interpreted as megaclasts engulfed by the breccia. This interpretation is confirmed by the relationship of micro-anorthosite to the breccia along the margins of the igneous bodies. Toward the margins, fractures in the igneous rock are filled by breccia. At the margins, the micro-anorthosite is highly fractured, and surrounded by breccia dominated by angular, pebble to cobble size fragments of the igneous rock (Fig. 10). With increasing distance from the igneous pod, the abundance of igneous clasts within the breccia sharply decreases; at distances of more than 10 m from the pods, clasts of the anorthosite are minor breccia constituents. Grain size is uniform, from the smallest clasts to the interior of the igneous pod. These field relations indicate that the micro-anorthosite was completely solidified prior to brecciation.

The nature and location of the rock unit which originally hosted the intrusion from which the micro-anorthosite mega-clasts were derived remains uncertain. One possibility is that Wernecke Supergroup hosted the intrusion, as it does with the dioritic dykes. However, nowhere has such an intrusion been reported to crosscut Wernecke Supergroup. Another possibility is that the micro-anorthosite enclaves were part of the inferred crystalline basement to

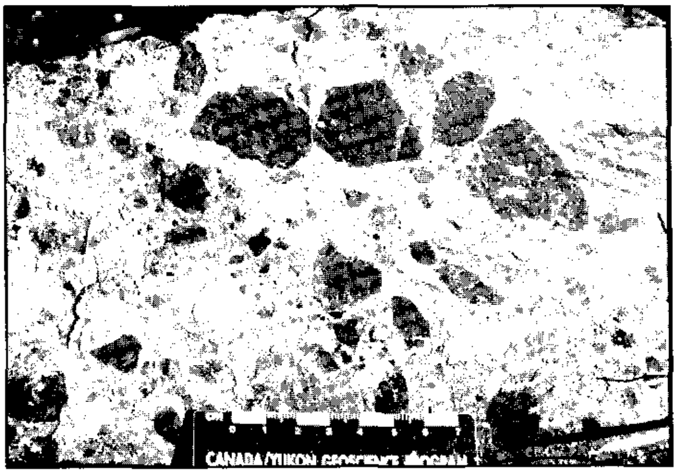

Figure 8: Typical Wernecke breccia from the PIKA occurrence, containing variably metasomatized clasts of siltstone and dolostone.

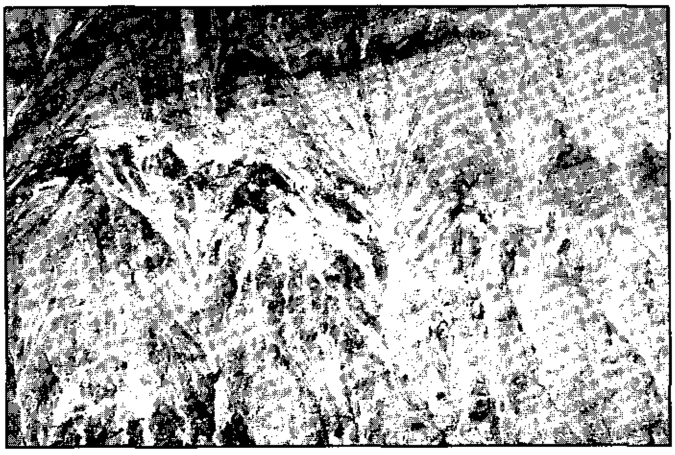

Figure 9: Two parallel vertically dipping dioritic dykes crosscutting tilted dolostone of Gillespie Lake Group, north of TOW Minfile occurrence (Fig. 2). Dykes are bounded by white contact metamorphic aureoles of limestone.

Wernecke Supergroup, and were transported toward the surface by upward flow of the breccia. However, clasts which may have belonged to such a basement have not been identified elsewhere in Wernecke breccia. Until an isotopic age is determined for these unique rocks, their significance will remain enigmatic.

Biotite-phyric andesite occurs as three isolated intrusions in the Fairchild Lake Group. The first intrusion, located at the FAIRCHILD occurrence, is several metres across. It is highly spherulitic and amygdaloidal, indicating emplacement and rapid chilling in a near-surface environment. The second intrusion is a 3 m-wide east-striking vertical dyke on a ridge crest about 3 km northwest of the OLYMPIC occurrence. It is crosscut by 1 mm-wide veins of magnetite. In thin section, a corroded grain of red spinel was observed, suggesting a possible deep magmatic source. The third intrusion was not observed in outcrop, and its existence is inferred from angular talus blocks of biotite-phyric andesite about 3 km northwest of the second intrusion. The magnetite veins imply that the biotitic dykes are older than Wernecke breccia because secondary magnetite and hematite precipitation is generally attributed to hydrothermal activity related to breccia development.

The dioritic and biotitic dykes appear to have intruded the Wernecke Supergroup after Racklan orogenesis. This timing relationship is implied from the near-vertical orientation of several well-exposed dykes which crosscut moderately to steeply dipping Wernecke Supergroup strata. However, not all of the intrusions are exposed well enough to demonstrate this relationship, and the possibility remains that some of the igneous intrusions were emplaced before Racklan deformation.

Possible Correlative Volcanic Strata

None of the intrusive rocks correlate with certainty to volcanic rocks in the region. One possible correlation can be drawn between the dioritic dykes in the study area and the Hart River volcanic succession in the Ogilvie Mountains (Abbott, 1993). However, that succession was erupted as a volcanic interval within the Gillespie Lake Group, i.e., before Racklan orogeny, whereas most of the dykes in the study area appear to have intruded the sedimentary succession after deformation. Another possible volcanic equivalent to some of the intrusions is the Kohse Creek volcanic succession, reported by Eisbacher (1981) to constitute part of unit A of the Pinguicula Group, about 30 km south-southeast of the study area. However, as noted at the PIKA Minfile occurrence, the Pinguicula Group rests nonconformably on dioritic dykes and Wernecke breccia. Since the diorite dykes at the PIKA occurrence probably correlate with most or all of the dioritic dykes elsewhere in the study area, the Kohse Creek volcanics are unlikely volcanic equivalents.

The absence of a compelling correlation between the dioritic dykes and volcanic strata suggests that (1) magma flowing through the dykes did not reach the surface; or (2) a volcanic succession formed but was completely eroded. Such erosion probably occurred prior to deposition of Pinguicula Group, because no volcanic rocks are present between the Wernecke Supergroup and Pinguicula Group.

The biotitic intrusions are tentatively correlated with the Slab volcanics, which are also biotite-bearing. The dykes and the volcanics apparently formed during the same interval of time, i.e., after Racklan orogeny and before development of Wernecke breccia (Fig. 3).

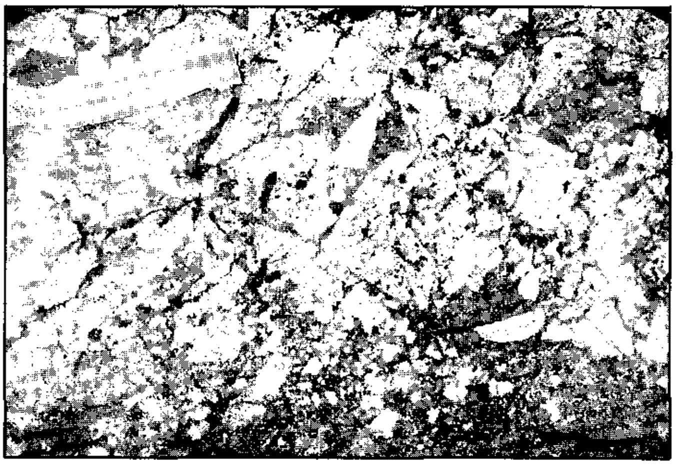

Figure 10: Angular fragments of micro-anorthosite (white) in Wernecke breccia (dark grey) near margin of micro-anorthosite megaclast, OLYMPIC Minfile occurrence.

Wernecke Breccia

Wernecke breccia is a collective term for numerous large breccia zones in the Wernecke Supergroup. Breccia zones generally range from 0.2 to 10 km^2 and crop out in curvilinear arrays over a large area (3 500 km^2) in the Wernecke Mountains. (Bell, 1986a; Wheeler and McFeely, 1991; Thorkelson and Wallace, 1993b). Correlative breccia zones in the Ogilvie Mountains were called Ogilvie Mountain Breccias by Lane (1990). Considerable mineralization of Cu, Co, U, and Au in and around the breccia zones has been a focus of mineral exploration. The origin and significance of Wernecke breccia are controversial.

Wernecke breccia is characterized by clasts of siltstone and dolostone, derived from the Wernecke Supergroup, in matrix composed of smaller rock fragments and a variety of hydrothermally deposited minerals, including ubiquitous disseminated specular hematite (Bell, 1986b; Lane, 1990; Thorkelson and Wallace, 1993a). Clast colours vary from their source rock colours of black, grey, brown and green, to pink, red and maroon, refecting variable degrees of metasomatism. Regionally, metasomatism began before and ended after brecciation, and affected both breccia and adjacent country rock, although specific metasomatic effects and timing vary among breccia zones. Generally, these effects include precipitation of hematite, magnetite, dolomite, siderite, chlorite, quartz and microcline, in both clasts and matrix. Cu, Co, U and Au are concentrated in metasomatic aureoles, although factors controlling metal distribution are poorly understood. Detailed field and geochemical studies, such as those by Laznicka and Gaboury (1988), and Laznicka and Edwards (1979), on breccias beyond our study area, are necessary to provide a comprehensive history of brecciation and mineralization. Our studies are being augmented by joint research projects with James Mortensen of The University of British Columbia, Richard Taylor and Andrew Conly at Carleton University, and Robert Creaser at the University of Alberta.

Igneous clasts are minor but important constituents of the breccias. They are relatively abundant at the OLYMPIC and PIKA occurrences, and are also present at the WHALE, NORANDA, and DOLORES occurrences (Figs. 1, 2, 5, 6). The clasts range in size from a few centimetres to several metres long, and are typically surrounded by breccia dominated by variably altered sedimentary clasts. As with the sedimentary clasts, the igneous clasts in breccia zones are generally metasomatized. Metasomatic effects include replacement of plagioclase by potassium feldspar or scapolite, replacement of augite by chlorite or actinolite, and growth of carbonate, quartz, and hematite or magnetite. In micro-anorthosite of the OLYMPIC occurrence, for example, megaclasts are light grey, and host abundant grains of secondary hematite and carbonate. Smaller clasts of the same protolith, in addition to hosting secondary hematite and carbonate, are variably reddened from potassic alteration. At the DOLORES occurrence, disseminated magnetite has grown in altered diorite.

Clasts of siltstone and dolostone with irregular shapes and marked embayments were observed in Wernecke breccia at several localities, particularly at the OLYMPIC, TOW and PIKA occurrences. Many of these clasts are rimmed with specularite. They are interpreted as clasts which were initially incorporated into the breccia as angular fragments, and were subsequently corroded by hydrothermal fluids during breccia-related metasomatism. The irregular shapes of these clasts, which contrast with the angular to rounded shapes of most other fragments, is suggestive of soft-sediment deformation. However, that notion is rejected in favour of the corrosion interpretation because other evidence indicates that the source of the clasts, Wernecke Supergroup, was fully lithified and deformed by Racklan contractional deformation prior to brecciation. In addition to the evidence for lithification cited by Thorkelson and Wallace (1993a), we note that igneous dykes, which are older than the breccia, intruded Wernecke Supergroup after lithification, dolomitization, and probably after Racklan orogeny.

Previous workers suggested that Wernecke breccia originated as diatremes (Tempelman-Kluit, 1981; Bell and Delaney, 1977), phreatomagmatic explosions (Laznicka and Edwards, 1979), modified evaporite diapirs (Bell, 1989), or mud diapirs (Lane, 1990). As indicated by Thorkelson and Wallace (1993a), the hypothesis of mud diapirism is untenable because Wernecke Supergroup was lithified at the time of brecciation. The hypothesis of evaporate diapirism is also rejected because: (1) brecciation occurred after development of cleavage, kinking in cleavage, and upright to overturned folds, features attributed to Racklan orogeny; and (2) there is no evidence that a formation of evaporite existed beneath the Wernecke Supergroup. Phreatomagmatic explosion as the cause of brecciation is appealing because it recognizes the close spatial relationship between igneous rocks and breccia zones. However, it is rejected because: (1) the igneous dykes intruded fully lithified rock, not sediment as suggested by Laznicka and Edwards (1979); and (2) juvenile fragments of chilled igneous rock representing exploded magma have not been identified in the breccias, despite intensive petrographic studies by the proponents of this hypothesis and by other researchers; the igneous clasts in the breccias are typically fine grained (grains 1–5 mm), indicating that the dykes were completely crystalline at the time of brecciation.

The diatreme model of breccia genesis is consistent with much of the existing data. A diatreme origin can account for: (1) intrusion of breccia into a succession of rock which had previously undergone deformation and igneous intrusion; (2) intense fracturing of country rock; and (3) rounding of clasts by milling within moving breccia (Fig. 11). However, two principal features of the breccias require qualification of this model. Firstly, breccia clasts were derived from the Wernecke Supergroup and the igneous intrusions it hosts. The only known exceptions are: the clasts and megaclasts of volcanic rock at the SLAB occurrence, which were derived from an overlying volcanic sequence; and possibly the micro-anorthosite clasts of uncertain origin, at the OLYMPIC occurrence. Importantly, clasts of lower crustal or mantle affinity, such as gneiss or peridotite, have not been reported from any of the breccias. Consequently, the clastic component of Wernecke breccia appears to have originated entirely within Wernecke Supergroup, although a deeper source for the mineralizing fluids is plausible. Secondly, the breccia zones tend to be elongate, or distributed in curvilinear arrays, and are commonly bounded by steep faults. This pattern of distribution implies a strong supracrustal influence in the location of breccia development. Zones of Wernecke breccia thereby differ from typical diatremes which are generally depicted as downward-tapering conical pipes (Mitchell, 1991).

Our present view is that Wernecke breccia is favourably modelled as a set of explosion-generated breccias whose location was partly determined by crustal features. Brecciation was probably caused by explosive expansion of volatile-rich fluids. Venting of the breccia may have occurred above the Slab volcanics or correlative strata (Fig. 3). An igneous influence is implied by the spatial coincidence of intrusions and breccia zones, and common enrichments of Fe, Cu and Co. Perhaps the fluids were derived from volatile rich residual liquids which accumulated at the top of fractionating tholeiitic magma chambers beneath the Wernecke Supergroup (Thorkelson and Wallace, 1993a). In this depiction, the emplacement of igneous dykes would represent an early magmatic stage, when the source chambers were dominated by mafic magma. Breccia generation would represent a late magmatic stage, when the chambers were largely solidified; fluids enriched in Fe and volatiles escaped toward the surface and boiled explosively. The direct link between mineralizing fluids and crystallizing magma suggested in this model remain to be tested by chemical and isotopic analysis.

Structure

The style of structural deformation in the study area is dominated by open to tight folds, and steep faults. Cleavage and kink bands are present locally, particularly in deformed siltstone of the Fairchild Lake Group. Wernecke Supergroup is demonstrably more deformed than younger rocks. Consequently, much of the deformation is considered a product of Racklan orogeny, which occurred after deposition of Wernecke Supergroup and before emplacement of igneous dykes and Wernecke breccia.

Six phases of deformation are evident, the first four of which are confined to rocks beneath the Pinguicula Group, and are therefore Middle to Late Proterozoic in age. The first phase was contractional, producing folds and slaty cleavage in Wernecke Supergroup. Folding was directed to the southeast, as indicated by a large overturned anticline in the northwestern part of the study area (Fig. 2), consistent with the orientation of Proterozoic folds suggested in our previous report. The second phase was also contractional, producing local kinkbands in phase one cleavage. Development of these fabrics clearly pre-dates emplacement of Wernecke breccia (Thorkelson and Wallace, 1993a). Localized crenulation cleavage in Quartet and Fairchild Lake shale and siltstone probably also developed during this phase. The third phase involved fracturing and possibly faulting during emplacement of Wernecke breccia. In the fourth phase, a foliation consisting of anastamosing fractures, possibly a shear fabric produced by brittle faulting, developed in Wernecke breccia at the PIKA occurrence (Fig. 6). This fabric is truncated at the unconformity with the overlying Pinguicula Group. Similar fabrics in a small breccia zone 5 km east of the FAIRCHILD occurrence may also have developed at this time. Whether these textures are manifestations of a set of regional structures, such as a family of steep faults, is uncertain. Possibly, they relate to steep faults which occur alongside breccia zones, such as those near the NORANDA and OLYMPIC occurrences. The fifth phase was contractional, producing open folds in Pinguicula Group. This phase is likely to have occurred during regional Mesozoic to Paleocene contraction. The sixth phase produced offsets along steep faults such as those in the southeastern part of the study area which involve folded Pinguicula Group.

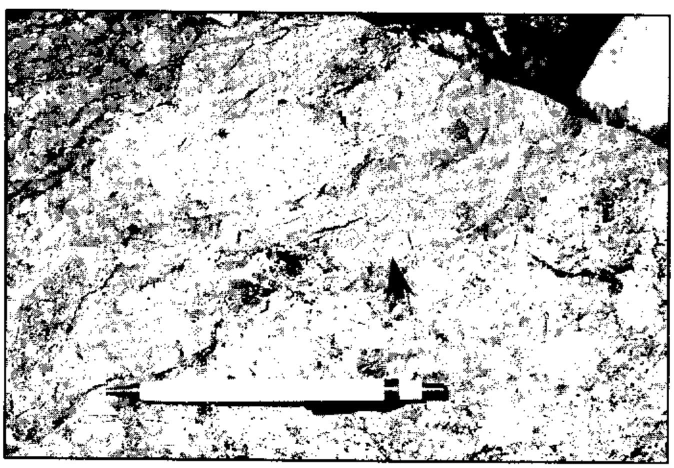

Figure 11: Well-rounded cobble-size clast of altered siltstone in Wernecke breccia, OLYMPIC Minfile occurrence.

The numerous steep faults in the study area are of particular regional and economic interest. Breccia is concentrated along several of the faults, which may have been active at times before, during, or after brecciation. Possibly, motion along these faults produced dilatant zones which served as conduits for rising fluids. Although the sense of displacement on these faults can be defined in terms of normal movement, considerable strike-slip displacement is also possible. Strike-slip displacement has been suggested for other faults in the region, such as the Snake River Fault (Norris, 1975), and faults of the Richardson Fault Array (Norris and Hopkins, 1977).

Strike-slip offset is likely to have occurred along a northwesterly striking fault which juxtaposes Fairchild Lake Group with Wernecke breccia, northeast of the OLYMPIC occurrence. The absence of breccia in deeper level rocks northeast of the fault is difficult to explain if displacement is considered to be entirely dip-slip. However, if a large proportion of strike-slip displacement occurred, then breccia which may have originally continued to the northeast of the present OLYMPIC breccia zone may have been cut off and displaced. No sense or magnitude of displacement has yet been determined. Restoration of crustal blocks along faults with possible strike-slip displacement may be valuable for locating dismembered parts of structurally disrupted breccia zones.

Mineral Occurrences

Mineralization in the study area comprises two sedimentary exhalative occurrences, ten Wernecke breccia-related occurrences, and six vein occurrences, all of which are hosted by Wernecke Supergroup (Fig. 2). The sedimentary exhalative occurrences, which contain Zn, Pb, Cu and Ag, are the only occurrences of this type recognized in Wernecke Supergroup. They are broadly coeval with, and possibly genetically related to, the HART RIVER volcanogenic massive sulphide deposit 150 km to the west-southwest. Vein occurrences hosting Zn, Pb, Cu, U, Ag and Au mineralization are of unknown age, and may be as young as Tertiary. Occurrences related to Wernecke breccia host mineralization of Cu, Co, U, Mo, Ag and Au. Those in the study area are similar to numerous other occurrences in the Wernecke Mountains, such as the PAGISTEEL occurrence, estimated to contain one million tons of 29% Fe (INAC, 1993); and the IGOR, BOND, IRENE, and SLAB occurrences (INAC, 1993).

Sedimentary Exhalative Occurrences

The CORD and GOODFELLOW sedimentary exhalative occurrences were deposited within the Gillespie Lake Group. They contain fine grained pyrite, sphalerite, galena, siderite and chalcopyrite in silty beds within a dominantly dolomitic succession (Campbell and McClintock, 1980; Hardy and Campbell, 1981; Eaton, 1983). Mineralization in the CORD occurrence is confined to a siliceous mudstone and siltsone unit within Gillespie Lake dolostone that generally strikes west and dips 10–15° to the south (Hardy and Campbell 1981). Diamond drilling was carried out in 1981. Four holes totalling 366 m were drilled but only one reached the desired depth. Stratiform mineralization in drill core consists of thin laminated pyrite and/or pyrrhotite with lesser amounts of chalcopyrite, sphalerite, and galena within 0.5–4 m beds of siliceous mudstone. Mineralization also occurs as veinlets and coarsely crystalline "disturbed sulphides" consisting of pyrite, pyrrhotite, with minor chalcopyrite, sphalerite, and galena. The best grades obtained in drill core on were 0.50% Pb, 0.63% Zn, and 0.05% Cu over 2.0 m (Hardy and Campbell, 1981). The GOODFELLOW occurrence is located approximately 8 km east-southeast of the CORD. Mineralization occurs as both stratabound disseminations and veins. The veins are 1–2 m wide and contain coarse grained pyrite, galena, and sphalerite in calcite, dolomite or quartz gangue. Pb isotopic ratios of vein mineralization in the GOODFELLOW are almost identical to those obtained from the CORD occurrence, the HART RIVER deposit (also in the Gillespie Lake Group), and the SULLIVAN mine, a large Pb-Zn deposit in mid-Proterozoic sedimentary strata in southeastern British Columbia (Godwin et al., 1988). An analysis from the GOODFELLOW is given in Table 1.

Wernecke Breccia-related Occurrences

Minfile occurrences of Wernecke breccia type include the PLUME, OTTER, FAIRCHILD, DOLORES, NORANDA, TOW, LEARY, OLYMPIC, WHALE and ATHENS, the last three of which are new and will appear on forthcoming editions of Yukon Minfile. The LEARY has been regarded mainly as a vein occurrence, although it also includes a mineralized breccia occurrence (see section on new prospects). Analyses from the NORANDA and OLYMPIC occurrences, and the PIKA occurrence to the west of the study area (Fig. 1), are listed in Table 1.

Mineralization of Cu, Co and Au in breccia zones and adjacent country rock reflects enrichments far above background levels. Low background levels in Wernecke breccia are established in Fig. 12, which displays elemental compositions of Pb, Zn, Cu, Ni, Co, Cr, Sn, Sb, U, Th, Au and FeO in four hematitic breccia samples from our previous study area (106D/16) normalized to average sedimentary rock. All of the samples contain sedimentary clasts that are highly reddened, probably from potassic alteration. None of the samples have element concentrations greater than ten times the sedimentary normalizing values. In contrast, mineralized parts of the breccias commonly contain enrichments of Cu, Co, U, or Au hundreds or thousands of times the normalizing values (e.g., Table 1). These data indicate that hematization and potassic alteration were not the principal processes controlling distribution of Cu, Co and Au mineralization.

The main factors controlling valuable mineralization remain enigmatic. Apparently, mineralization was produced by some type of hydrothermal activity within and near zones of Wernecke breccia. However, the timing and composition of that activity relative to the more widespread iron-alkali metasomatism has not been determined.

The presence of igneous rock in and near the breccia zones has locally enhanced Cu mineralization. This relationship is established at the OLYMPIC, FAIRCHILD, DOLORES and PIKA occurrences (Fig. 5), where Cu showings commonly occur within or adjacent to dykes or clasts of diorite or biotitic andesite. Apparently, the composition of these igneous bodies was particularly suitable for deposition of Cu from mineralizing fluids. Some of the Cu in these occurrences may represent redistribution of Cu from within the igneous bodies, as suggested by Laznicka and Edwards (1979).

Despite the strong igneous-Cu association in several of the occurrences, much of the Cu is likely to have been derived from mineralizing fluids related to Wernecke breccia, not from local chemical redistribution within the igneous rocks. This contention is supported by strong Cu enrichments in breccia distal from igneous rock. At the TOW occurrence, for example, no igneous rocks are exposed, and chalcopyrite is abundant as disseminated grains within siliceous breccia matrix. The source of Cu in the fluids responsible for this mineralization is unknown. Possibly, Cu was leached from large igneous intrusions at depth; the source of Cu and other elements in Wernecke breccia may be principally of igneous origin or derivation. This possibility is supported by the common spatial association between breccia and igneous intrusions (Laznicka and Gaboury, 1988; Lane, 1990; Thorkelson and Wallace, 1993a,b), which suggests that many of the breccias developed in zones of crustal weakness previously intruded by dykes.

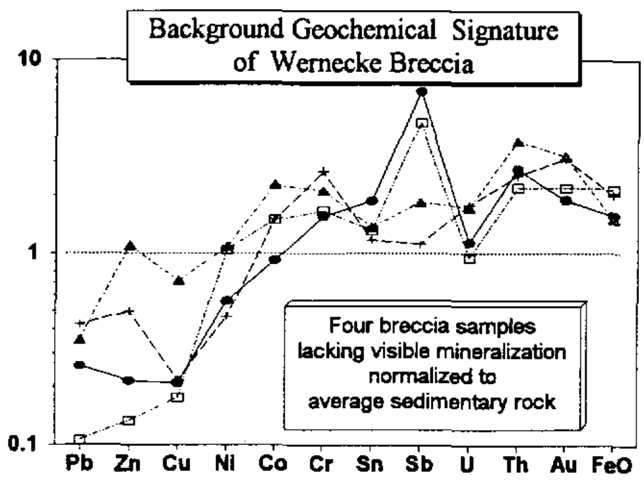

Fig. 12: Samples of metasomatized Wernecke breccia from previous study area (106D/16, Fig. 1) log10-normalized to average (worldwide) composition of sedimentary rock. Except for abundant grains of specular hematite, samples lack visible enrichment of metals. Normalizing values: 12 ppm Pb, 44 ppm Zn, 18 ppm Cu, 30 ppm Ni, 6.5 ppm Co, 45 ppm Cr, 2.3 ppm Sn, 0.58 ppm Sb, 2.1 ppm U, 5.1 ppm Th, 10 ppb Au, 4.0% FeO (total Fe as FeO).

Supergene enrichment of mineralization in Wernecke breccia appears to have occurred at the PIKA minfile occurrence beneath the unconformity separating Pinguicula Group from Gillespie Lake Group (Figs. 5, 6). Cu mineralization occurs in breccia, dolostone and diorite. A thin zone of Cu enrichment was observed beneath the unconformity where underlying Wernecke breccia grades into metasomatized dolostone. Directly beneath the unconformity, and extending downward for about 12 m, the rocks are unusually pale, and devoid of Cu mineralization. At the base of this pale zone is a 1 m-thick horizon of abundant malachite staining, beneath which is breccia and metasomatized dolostone of normal colour and mineralization. The upper, pale zone is interpreted as a leached zone which developed during subaerial weathering of Gillespie Lake Group and Wernecke breccia, prior to deposition of Pinguicula Group. The horizon of abundant malachite staining is interpreted as a thin supergene enriched zone which resulted from downward migration and redeposition of Cu at the base of the leached zone (Table 1). Although the zone of Cu enrichment is thin at this location, thicker zones of enrichment may be present elsewhere in this region of breccia-related mineralization.

Veins

Mineralized vein occurrences include the KIDNEY, BIBBER, LEARY, GEORDIE, GILLESPIE and CAROL, which host enrichments of Zn, Pb, Cu, U, Ag and Au. Although these occurrences appear to be small, some are of considerable grade, notably the GEORDIE and LEARY. Some may represent remobilization of sedimentary exhalative and Wernecke breccia mineralization similar to the vein mineralization in the CORD and GOODFELLOW occurrences.

Mineralization in the GILLESPIE occurs as open space fillings in brecciated dolostone. Samples collected from the GILLESPIE contain up to 3.0% Zn, 0.7% Pb (Dean, 1975). In the nearby and probably related GEORDIE occurrence, pyrite, galena, and sphalerite were found within a 77 m-wide easterly trending fracture zone which grades up to 1.1% Zn and 7.5 ppm Ag (INAC, 1993). The LEARY occurrence consists of stockwork veining hosting pyrite, galena and sphalerite along a 310 m wide zone of fracturing. The best assays from channel samples on the LEARY were 1.74% Zn, 0.24% Pb across 6.2 m (Alsen and Leary, 1975). On the BIBBER, chalcopyrite occurs in quartz veins up to 3.6 m wide within the Quartet Group. The KIDNEY occurrence contains U minerals and chalcopyrite in narrow veinlets crosscutting the Gillespie Lake Group. The CAROL is a new occurrence containing Cu, Ag, and Au.

New Prospects

Our mapping and research has identified zones of Wernecke breccia not shown on previously available maps, including those of Bell (1986a) and Touborg et al. (1979). Two small breccias were found east of Fairchild Lake near the contact between Fairchild Lake and Quartet groups. A third, mineralized breccia was identified on the southwestern part of the LEARY Pb-Zn occurrence. This part of the occurrence was previously identified by Alsen and Leary (1975) as sedimentary conglomerate containing up to 1.34% Cu and 1.2 ppm Ag. Our assay from this site supports the Cu and Ag grades, and indicates enrichment in Bi and Au (Table 1). Two mineralized vein

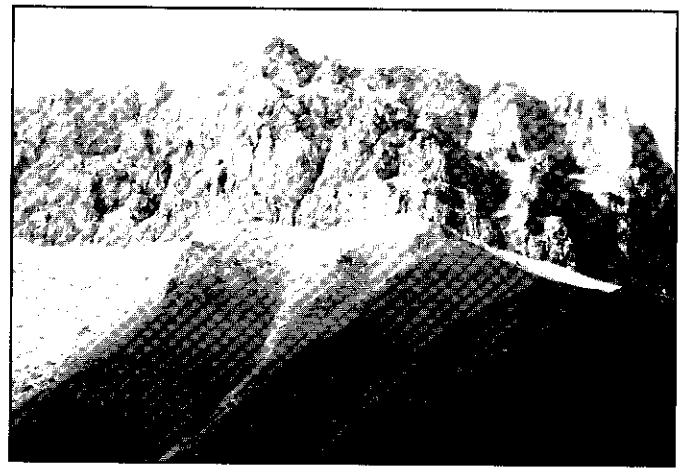

Fig. 13: Resistant dolostone overlying 250 m-thick recessive shale succession within Gillespie Lake Group, northeast of GOODFELLOW occurrence (Fig. 2).

Sample	Minfile Occurrence	Occurrence Type	Location NTS	Location UTM E	Location UTM N	ppb Au	ppm Ag	% Cu	ppm Pb	ppm Zn	ppm Sb	ppm Mo	ppm Bi	ppm Co
G–132	OLYMPIC*	W. breccia	106C/13	555500	7194900	29	0.4	0.6	13	95	bd	3	bd	140
G–133	PIKA	sup. enrich.	106C/14	572500	7191200	40	2.9	0.2	10	22	bd	4	bd	109
G–134	PIKA	W. breccia, di	106C/14	572900	7191600	120	1.5	2	14	72	bd	10	bd	128
G–139	NORANDA	W. breccia	106C/13	549700	7195900	16	0.2	0.6	9	46	bd	124	bd	18
G–141	CAROL*	vein	106C/13	563200	7107600	265	3.3	4.3	12	65	bd	16	bd	95
G–144	LEARY	W. breccia	106C/13	564000	7187000	1463	20	1.1	15	28	bd	16	311	123
G–145	GOODFELLOW	gossanous vein	106C/13	555700	7186600	15	3.3	0.0	357	991	bd	5	2	14
G–200	WALLACE*	vein	106D/16	541400	7190400	59	26	5.1	11	196	2500	2	700	6

*New Name; sup. enrich.=supergene enrichment; W. breccia=Wernecke breccia; di=dioritic; bd=below detection

Table 1: Geochemical Assays

localities not associated with established Minfile occurrences were sampled and analyzed (Table 1). The veins, which are mineralized in Cu and other metals, will be represented on forthcoming Yukon Minfile reports as the CAROL and WALLACE occurrences. A thick succession (250 m) of dark siltstone and shale a few km to the northeast of the GOODFELLOW (Figs. 2, 13) may have potential for strataform Zn-Pb-Ag mineralization.

Conclusions

1. The Fairchild Lake map area is underlain by two main sedimentary successions, Middle Proterozoic Wernecke Supergroup and unconformably overlying Middle to Upper Proterozoic Pinguicula Group. A third unit, herein named the Slab volcanics, is inferred to have been deposited between the Wernecke and Pinguicula successions.
2. Structural deformation includes folding, fabric development and faulting. Some of the faulting may include strike-slip offset.
3. Mineralization is restricted to the Wernecke Supergroup which hosts occurrences of (1) breccias containing Cu, Co, U, Ag, and Au; (2) sedimentary exhalatives containing Zn, Pb, Cu and Ag; and (3) veins, containing Zn, Pb, Cu, Ag, Au and U.
4. Wernecke breccia is the name for a set of intrusive hematitic breccia zones probably caused by underground, explosive expansion of volatile rich fluids. Fluid activity within and around the breccias resulted in the mineralization.
5. Breccia-related Cu mineralization was locally enhanced by supergene enrichment caused by Proterozoic weathering prior to deposition of Pinguicula Group.
6. Wernecke breccia developed after intrusion of igneous dykes and before deposition of Pinguicula Group.
7. Igneous rocks include three types: diorite, biotitic andesite and micro-anorthosite. They are concentrated in places subsequently intruded by Wernecke breccia. They signal a possible igneous source for the mineralizing fluids.
8. Encouraging new Cu and Au assays, and identification of previously unmapped breccia zones, may provide new exploration targets.
9. The geological history of the map area between deposition of Wernecke Supergroup and deposition of Pinguicula Group is summarized:
    a) Middle Proterozoic deposition of Wernecke Supergroup, including sedimentary exhalative Zn-Pb in Gillespie Lake Group;
    b) folding, cleavage development, and kink banding related to Racklan orogeny; uplift and emergence;
    c) emplacement of igneous dykes; subaerial deposition of the Slab volcanics and perhaps other volcanic rocks related to the dioritic and anorthositic intrusions; d) probable beginning of erosion of Slab volcanics and other possible volcanic successions; erosion may have continued through to stage (g);
    e) explosive generation of Wernecke breccia, possibly accompanied by faulting; mineralization in and around breccia zones from breccia-related fluids; downfaulting of the Slab volcanic succession;
    f) faulting and local development of shear fabrics;
    g) weathering, erosion, and local supergene enrichment of breccia mineralization;
    h) marine transgression and Middle to Late Proterozoic deposition of Pinguicula Group.

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Geology of the Aishihik Lake and Hopkins Lake Map Areas (115 H/6,7), Southwestern Yukon

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JOHNSTON, S.T., and TIMMERMAN, J.R., 1994. Geology of the Aishihik Lake and Hopkins Lake areas (115 H/6,7), southwest Yukon. In: Yukon Exploration and Geology, 1993. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 93–110.

Abstract

Paleozoic and older metamorphic rocks in the Aishihik Lake and Hopkins Lake map areas (115 H/6 and 7) comprise the Aishihik Metamorphic Suite (AMS) and form a north-northwest-trending panel of rock that dips regionally to the east. The suite is divisible into a lower feldspathic quartz micaschist and marble package with a minor component of metaigneous rock and an upper package that includes black and brown quartzite, marble, metabasite and orthogneiss. Igneous rocks of three plutonic suites and one volcanic suite are present in the study area. Foliated hornblende granodiorite of the Aishihik Batholith, part of the Aishihik Plutonic Suite (APS), intruded in the Early Jurassic resulting in upper amphibolite grade metamorphism of the AMS. Relatively mafic APS plutonism evolved rapidly into more leucocratic quartz monzonite of the Early to Middle Jurassic Long Lake Plutonic Suite (LLPS). The Ruby Range Plutonic Suite (RRPS), including the Ruby Range Batholith and isolated stocks and tear-shaped plugs north of the batholith, intruded in the Late Cretaceous to Early Tertiary resulting in contact metamorphism and potassic metasomatism of the AMS. Sub-volcanic dykes and plugs that intrude the AMS are spatially associated with, and are thought to be genetically related to, Eocene strata of the Mount Creedon Volcanic Suite (MCVS). MCVS strata unconformably overlie all other rocks in the study area.

Potential exploration targets include: massive sulphide deposits associated with black quartzite of the AMS; Cu skarn and porphyry deposits related to isolated stocks and tear shaped plutons of the RRPS; Cu-Au porphyry deposits associated with sub-volcanic plugs related to the MCVS; and mineralized east-trending quartz veins which may be related to a buried intrusion, possibly of the RRPS.

Introduction

The Aishihik Lake area is significant from tectonic and metallogenic perspectives. Regional tectonic syntheses of the Canadian Cordillera (Wheeler et al., 1991; Monger and Berg, 1987) have suggested that two major terrane boundaries, including the Stikine - Nisling and the Nisling - Insular terrane boundaries, are present in the Aishihik Lake area. The area straddles and lies along the roof of the Coast Plutonic Complex, a zone which has long been recognized as being favourable for mineralization (Cockfield, 1927).

There remains, however, considerable disagreement over the location and significance of terrane boundaries inferred to cross the Aishihik Lake area (Johnston et al., 1993; Johnston and Erdmer, in press). Although the potential for mineral deposits is high, no economic deposits have been identified. In addition, the distribution, age and tectonic setting of rock units associated with mineralization remains poorly documented.

To address questions regarding the metallogeny and tectonic development of the Aishihik Lake region, we conducted 1:50 000 scale mapping along an east-west transect (map sheets 115 H/6 and 7) in south-central Aishihik Lake region (Fig. 1). This paper reports on these studies and is meant to accompany the associated 1:50 000-scale geologic maps (Johnston and Timmerman, 1994a; 1994b).

Metamorphic strata of the Aishihik Metamorphic Suite (AMS) comprise the oldest rocks in the study area. These strata were intruded in the Early Jurassic by hornblende granodiorite of the Aishihik Plutonic Suite (APS); in the Early to Middle Jurassic by leucocratic quartz monzonite of the Long Lake Plutonic Suite (LLPS); in the Late Cretaceous to Tertiary by the heterogeneous Ruby Range Plutonic Suite (RRPS); and in the Eocene, by dykes and plugs genetically related to volcanic strata of the Mount Creedon Volcanic Suite (MCVS) that unconformably overlie the area. Exploration targets include massive sulphides in the AMS; Cu skarns and porphyry deposits associated with the RRPS; Cu-Au porphyry deposits associated with the MCVS; and mineralized east-trending quartz veins.

Physiography and Access

The Aishihik Lake region lies along the southern margin of the Yukon Plateau (Bostock, 1946; Tempelman-Kluit, 1980; Fig. 1) and consists of an uplifted and incised plateau. North flowing glaciers of the St. Elias and Cordilleran ice sheets carved out deep, north-trending valleys now occupied by Sekulmun, Aishihik, Hopkins and Long lakes. The base level is 3 000' a.s.l., the surface elevation of Aishihik Lake. Mount Creedon (6 990' a.s.l.) is the highest topographic feature; tree line is at approximately 4 000' a.s.l. Outcrop is plentiful in the heavily glaciated southwest part of the study area. Elsewhere, outcrop is rare and is restricted to isolated ridge top tors. Extensive fields of felsenmeer are present east of Aishihik Lake in the vicinity of Long Lake. Access to the study area is by the Aishihik Lake Road (Fig. 1). The road, which extends 125 km (75 miles) north from the Alaska Highway along the east side of Aishihik Lake to the village of Aishihik at the north end of the lake, is not maintained past kilometre 42 (mile 27). A campground with a boat launch is located at the south end of Aishihik Lake. Fixed wing aircraft can operate on the Seklumun, Aishihik and Long lakes. The central part of the study area is approximately 35 minutes by helicopter from Haines Junction. Class A (surface and subsurface rights) and Class B (surface rights) land selections made by the Champagne-Aishihik Band are shown in Fig. 2.

Previous Work

Previous work in the Aishihik Lake area (Fig. 3) includes: 1) a reconnaissance report by Cockfield (1927) on the southern part of the Aishihik Lake region; 2) 1:250 000-scale geological mapping of the Aishihik Lake map sheet by Tempelman- Kluit (1974). Tempelman-Kluit and Currie (1977) reported on the geochemistry of rocks collected during this study. A B.Sc. thesis on rocks cropping out along part of the west side of Aishihik Lake was completed at that time (Gordey, 1973); 3) 1:25 000-scale geological mapping by Morin (1981) in parts of map sheets 115 H/2, 3, 6, and 7 aimed at better understanding copper skarns in the vicinity of Hopkins Lake and Giltana Lake; and 4) 1:50 000-scale mapping of parts of map sheets 115 H/2, 3, 6, 7, 9, 10, 11, 14, and 15 aimed at documenting the nature of the margin of the Aishihik Batholith (Johnston, 1988; 1993; Johnston and Erdmer; in press). The geology exposed adjacent to the Aishihik Lake Road between the Alaska Highway to Lac Lacelle (kilometre 70; mile 44) is described in a field guide to the geology of southern Yukon (Johnston et al., 1993). Results of a regional stream sediment and water geochemical reconnaissance study of the Aishihik

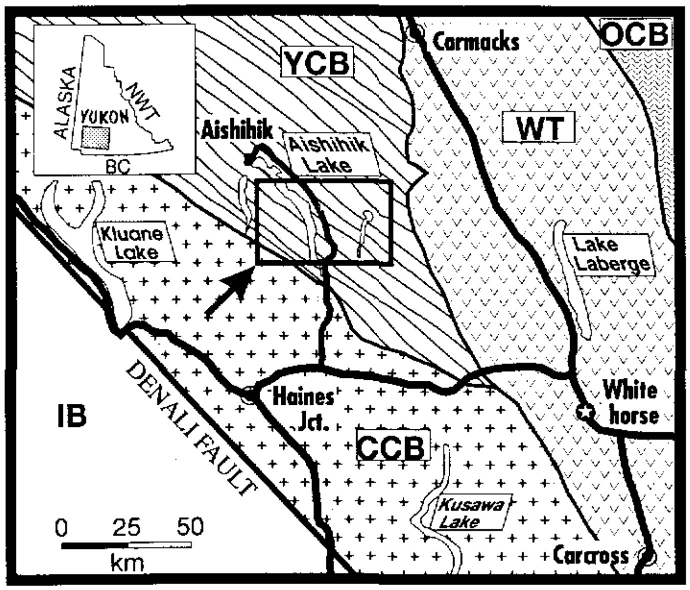


Figure 1: Location map showing the location of the study area (indicated by the arrow). Morphotectonic provinces of southwestern Yukon are indicated and include the: OCB (wavy pattern)—Omineca Crystalline Belt; WT ("v" stipple)—Whitehorse Trough; YCB (lined stipple)—Yukon Crystalline Belt; CCB ("+" stipple)—Coast Crystalline Belt; and IB—Insular Belt. The YCB roughly corresponds with the Yukon Plateau and underlies much of the study area; the southwest part of the study area is underlain by rocks of the CCB.

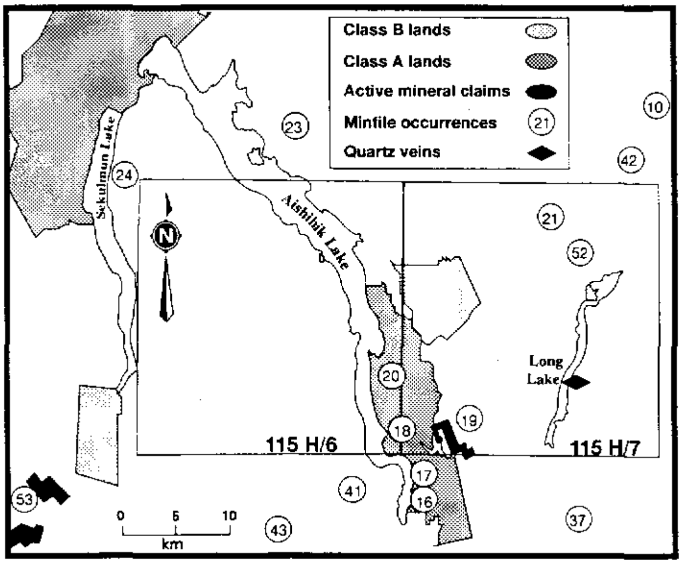


Figure 2: The location of Class A and B lands in the Aishihik Lake area. Also indicated are: Yukon Minfile occurrences (INAC, 1992): active claims as of June, 1993; the study area (map sheets 115 H/6 and 7); and the location of mineralized quartz veins mapped during this study. The quartz veins are described in the text. Assay results for these and other veins sampled during this study are included in Appendix 1.

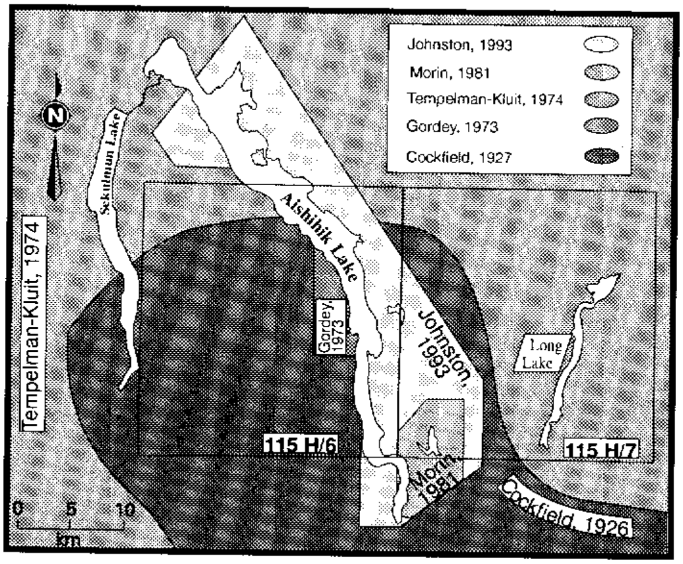


Figure 3: Previous geological studies in the Aishihik Lake area. The extent of the area investigated by Cockfield (1926) is taken from Tempelman-Kluit (1974). The location of the 1:50 000 scale map sheets mapped during this study (115 H/6 and 7) are indicated.

lake map area (115 H) were published as GSC Open File 1219 (Geological Survey of Canada, 1985). Hughes (1967, 1968, and 1990) and Geurts and Dewez (1993) have reported on the surficial geology and geomorphology of the Aishihik Lake region.

Regional Geology

The study area is divisible into four northwest to north-trending geologic belts, described below from southwest to northeast. A fifth 'belt' consists of younger, widely distributed volcanic rocks (Fig. 4).

1) **Ruby Range Plutonic Suite.** The Cretaceous-Tertiary RRPS includes the Ruby Range Batholith (Tempelman-Kluit, 1974) and isolated plugs and tear-shaped plutons which lie north of the batholith. It is included as part of the Coast Plutonic Complex (Roddick and Hutchison, 1974; Brew and Morrell, 1983; Woodsworth et al., 1991). Initial $^{87}Sr/^{86}Sr$ reported RRPS samples (LeCouteur and Tempelman Kluit, 1976) ranges from 0.705 to 0.706 for samples of the batholith. The RRPS intrudes along and obscures the boundary between the Nisling Terrane to the northeast from metamorphic rocks of the Insular Terrane to the southwest (Wheeler et al., 1991; Erdmer, 1990; 1991). The suite is inferred to have developed in response to the closure of a basin that separated the Insular Terrane from more inboard terranes in the Cretaceous (Way, 1977).

2) **Aishihik Metamorphic Suite** (Erdmer, 1991). The AMS consists of penetratively deformed and metamorphosed sedimentary and igneous rocks. It was previously included in the Cambrian and older Nisling Assemblage (Wheeler et al., 1991; Johnston, 1993; Johnston and Erdmer, in press) and is considered part of the Nisling Terrane. The Nisling Terrane is interpreted as an allochthonous continental margin assemblage which may or may not have originated as part of North America (Wheeler et al., 1991).

3) **Aishihik Plutonic Suite** (Johnston and Erdmer, in press). The Early Jurassic APS, which in the study area consists entirely of the Aishihik Batholith (Tempelman-Kluit, 1974), was formerly included in the Klotassin Plutonic Suite (Tempelman-Kluit, 1976; 1979) and has been interpreted as the allochthonous plutonic root of Stikinia (Johnston, 1988), a Triassic-Jurassic magmatic arc terrane (Wheeler et al., 1991). More recent research (Mortensen, 1992; Johnston, 1993; Johnston and Erdmer, in press) has shown that elements of the APS intrude the Aishihik and correlative metamorphic suites. This plutonic suite may, therefore, provide a record of the development of a magmatic arc on the Nisling Terrane, not Stikinia, in the Early Jurassic (Johnston and Erdmer, in press).

4) **Long Lake Plutonic Suite** (Woodsworth et al., 1991). The Early to Middle Jurassic LLPS consists largely of leucocratic pink quartz monzonite (Tempelman-Kluit, 1974). Plutons of the LLPS intrude and cut the Aishihik Batholith. Locally, however, the Aishihik Batholith and pink quartz monzonite have an agmatitic relationship (Tempelman-Kluit, 1974; Johnston, 1993). Plutons of the LLPS also intrude the Nisling Terrane and Late Triassic volcanic rocks of Stikinia (Tempelman-Kluit, 1974; Johnston, 1993 and unpublished data) and constitute a stitching assemblage that link these disparate terranes by the early Middle Jurassic (Johnston and Erdmer, in press).

5) **Mount Creedon Volcanic Suite** Volcanic rocks of the MCVS overlie and obscure the above described geological belts. Volcanic rocks west of Aishihik Lake and on a peak on the west side of Long Lake were formerly included in the Mount Nansen Group; those cropping out east and north of Long Lake were called Varicoloured Acid Tuff and were correlated with the Carmacks Group. All the volcanic strata were assumed to be Eocene or younger (Tempelman-Kluit, 1974).

General Geology

Layered rocks

The Aishihik Metamorphic Suite

The AMS underlies the central portion of the study area and is bound to the southwest by the Ruby Range Batholith and to the northeast by the Aishihik Batholith (Figs. 4 and 5). The suite is broadly divisible into a lower package of feldspathic quartz micaschist and marble, and an upper package of black quartzite, marble and metaigneous rocks.

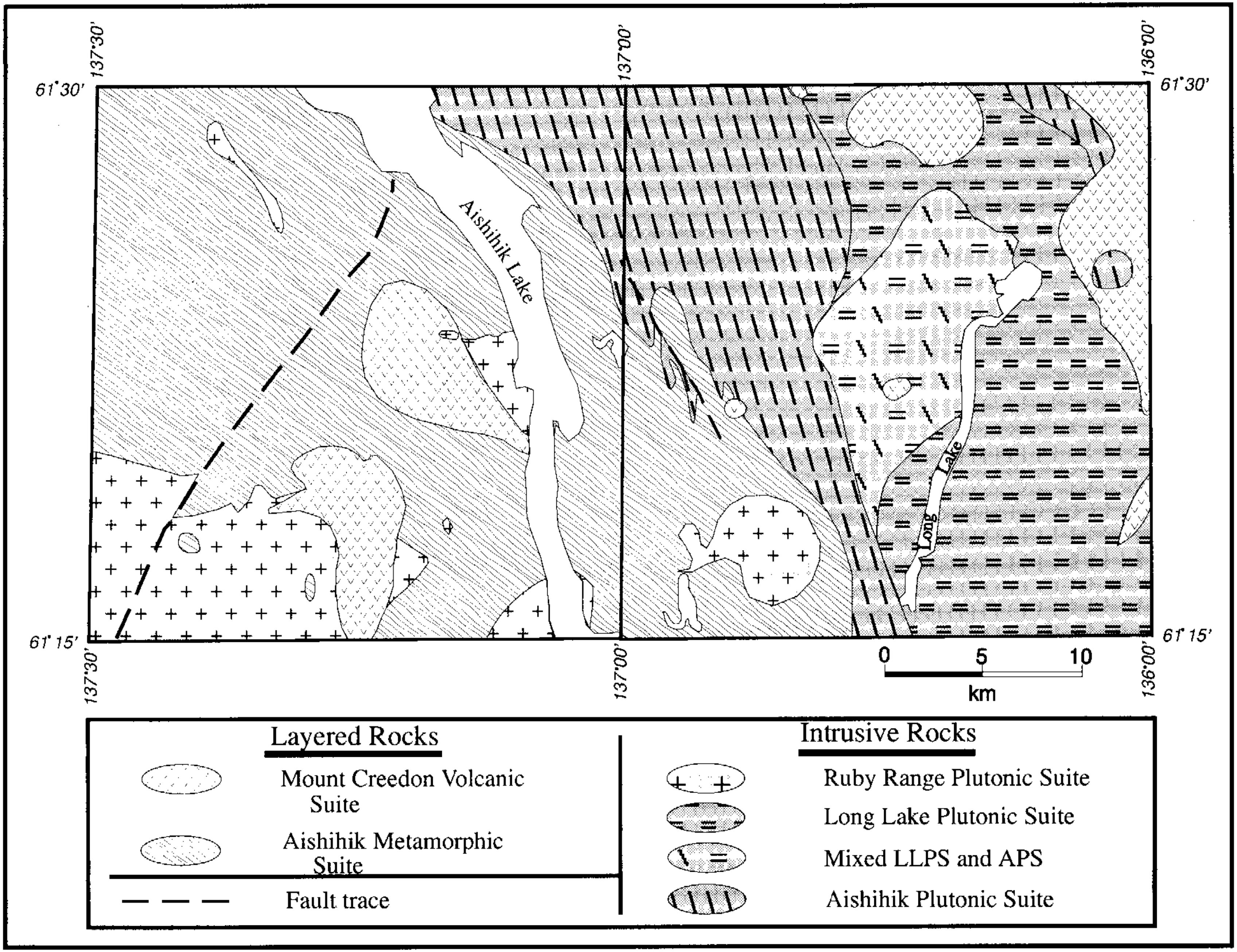


Figure 4: Simplified geological map of, from west to east, the Aishihik Lake (115 H/6) and Hopkins Lake (115 H/7) map areas (Johnston and Timmerman, 1994a and b).

Quartzofeldspathic micaschist crops out east and west of Aishihik Lake and appears to occupy the structurally lowest levels of the AMS. Feldspathic micaschist weathers a pink purple to dark grey colour, is dark grey to medium grey brown on fresh surfaces (Fig. 6a), and occurs as continuous horizons tens of metres thick and as thin and discontinuous lenses several cm-long surrounded by quartzite. Major mineral constituents includes biotite, muscovite, quartz, andesine plagioclase, and potassium feldspar. Metamorphic porphyroblasts include garnet, staurolite, and kyanite. Fibrolitic sillimanite is also present. Accessory minerals include apatite, tourmaline, rutile, titanite, zircon, pyrite, magnetite, graphite, and ilmenite. Migmatite is common, and consists of lenses of quartz-feldspar leucosome 2 to 100 cm-long. Common alteration products include chlorite, sericite, and cryptocrystalline talc. Interfoliated quartz paragneiss and quartzite weathers light grey, is grey on fresh surfaces, and is commonly micaceous (Fig. 6a). A strongly developed banding, defined by alternating recessive selvages and resistant quartzite, is common.

Marble is common in the quartzofeldspathic lower package and consists of bleached white-weathering, white to grey banded marble that when scratched, emits a strong fetid odour. Well-developed flow banding, defined by graphitic horizons, thin continuous chert bands (Fig. 6b), and by horizons of tremolite rosettes, is typically present. Marble is coarsely crystalline and consists of 80% to 100% calcite, with minor amounts of quartz, diopside, garnet, epidote, phlogopite, and graphite. Tremolite occurs along cross-cutting veins and as rosettes that overgrow and replace diopside. Chert defines thin and discontinuous laminae, weathers brown and is dark grey to black on fresh surfaces. Marble horizons vary from discontinuous lenses less than 10 m across up to 50 m thick horizons continuous for hundreds of metres. Marble also occurs as discontinuous pods in the hinge zones of macroscopic folds. The pods can be 10 to 50 m-thick and up to 100 m-long.

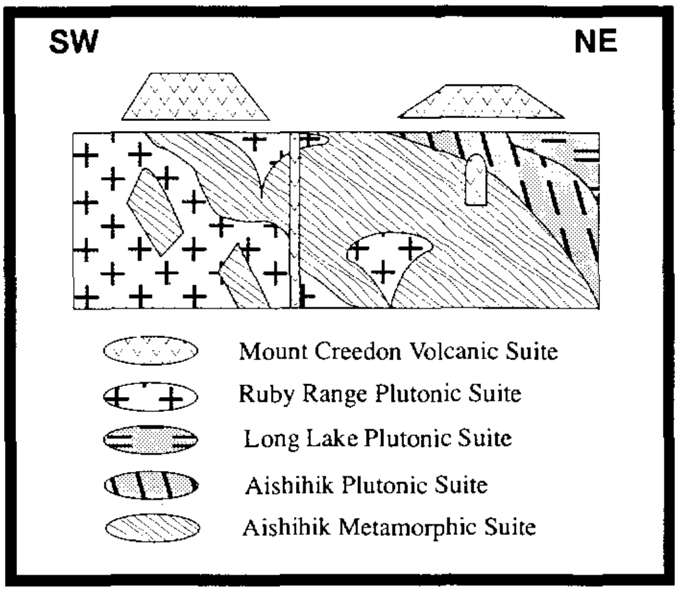


Figure 5: A schematic cross-section, not drawn to scale, showing the relationship of rock types mapped in the study area. See the text for discussion.

Metaigneous rocks are rare in the quartzofeldspathic lower package of the AMS. Green to black metabasite, composed primarily of hornblende and plagioclase, occurs as 1 to 20-cm thick horizons interfoliated with micaschist and, more commonly, with marble. A mega-boudin 30 m-long and 15 m-wide of rust orange weathering, dark green to black, gneissic metagabbro interfoliated with micaschist and marble was observed.

A thick and relatively continuous marble horizon that overlies and is interfoliated with thick, but discontinuous metabasitic horizons marks the base of the upper package of the AMS. The marble is similar to that described above and forms horizons greater 200 m-thick and several kilometres in length. Associated metabasitic rocks (Fig. 6c) are commonly recessive and heavily fractured and jointed. They typically weather black to dark green, appear dark green on freshly exposed surfaces, and consist of 50% to 100% hornblende, 0% to 35% labradorite plagioclase, and minor amounts (less than 10%) of diopside, tremolite (after diopside and amphibole), quartz, potassium feldspar, biotite, garnet, and epidote. Biotite amphibolite schist, with 10 to 25% biotite, is locally interfoliated with hornblende amphibolite and varies from discontinuous lenses several centimetres wide to continuous horizons several metres thick. Pistachio green, fine to coarsely crystalline, calc-silicate gneiss is common where metabasite is in contact with marble. Calc-silicate gneiss consists of variable amounts of hornblende, diopside, calcite, epidote, and quartz. Tremolite is common and replaces diopside. Accessory minerals include titanite, zircon, apatite and allanite. Alteration products include chlorite, biotite, epidote, calcite, sericite and pyrophyllite. Chloritization of hornblende is common, as is sericitization of feldspar. Deformation and recrystallization have produced a schistose to gneissic foliation. Metabasite typically occurs beneath the marble horizon, but also occurs interfoliated with marble, and is locally over 300 m-thick. The marble-metabasite couplet appears to sit structurally above quartzofeldspathic micaschist of the lower package of the AMS.

Structurally above the marble-metabasite couplet is tan to brown to black quartzite (Fig. 6d). Brown quartzite crops out along the plateau-top east of Hopkins Lake and north and west of the feldspathic micaschist west of Aishihik Lake. Black quartzite was not observed east of Aishihik Lake but is associated with brown quartzite west of the lake. Brown quartzite exhibits well developed banding, defined by colour variations and by dark grey, graphitic laminations and appears to grade into black quartzite. Black quartzite is commonly a homogeneous black to dark grey colour and has a lustrous, greasy sheen. Grain size in quartzite varies from finely crystalline in clean quartzite, to coarsely crystalline in more feldspathic and micaceous quartzite. Quartz is the major mineral constituent, with minor to trace amounts of feldspar and mica. Accessory minerals include garnet, sillimanite, apatite, zircon, rutile, pyrite, and graphite. Discontinuous lenses of marble, calc-silicate and metabasite are locally present.

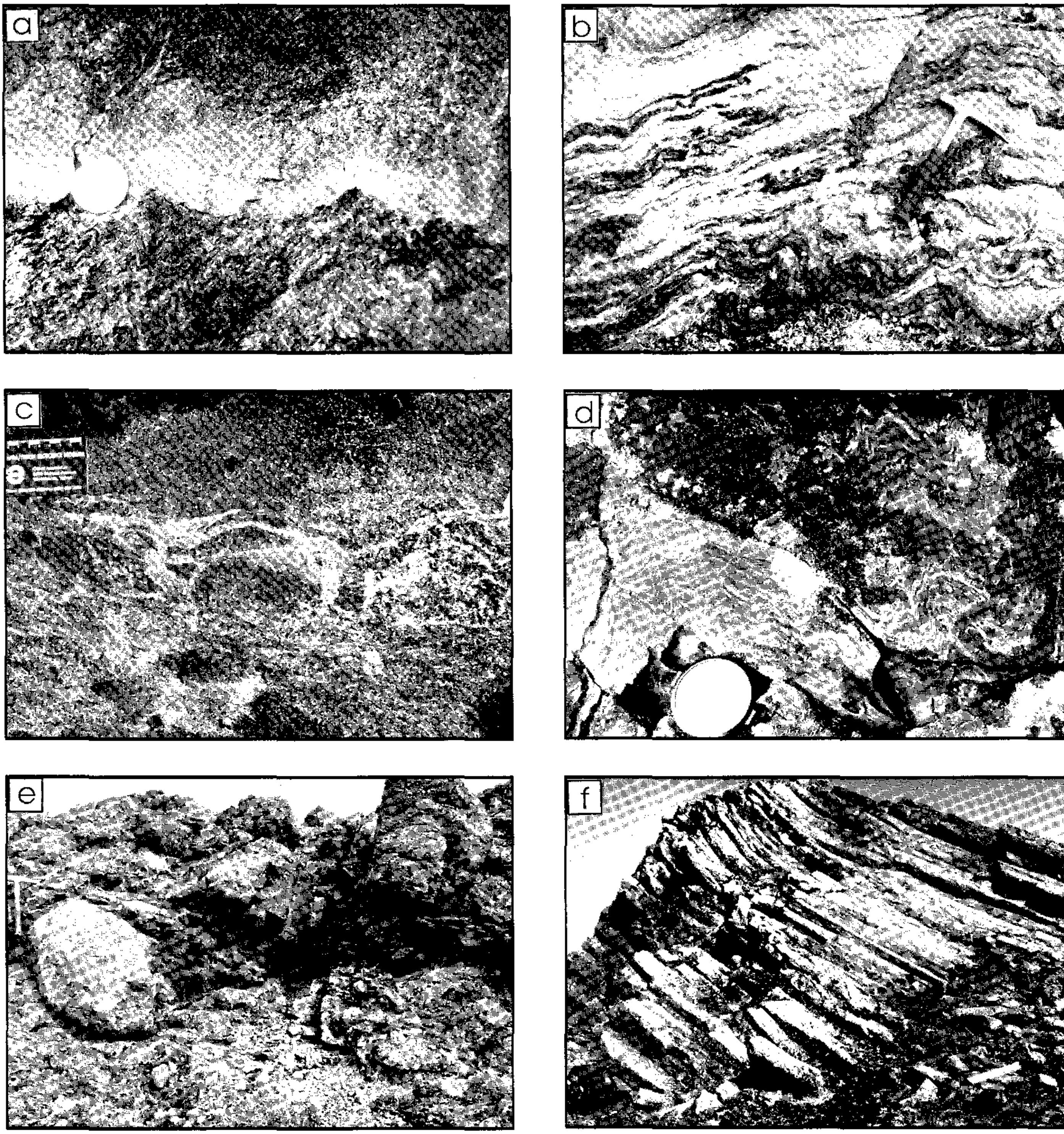


Figure 6: a) Interfoliated grey quartzite (above) and muscovite-biotite schist (below) of the lower package of the AMS. Note that compositional banding and schistosity are crenulated; b) coarsely crystalline grey marble, included in the AMS. Dark laminae consist of black chert; c) dark green hornblende amphibolite with interfoliated light weathering aplite, included in the AMS; d) black quartzite of the upper package of the AMS; e) autoclastic breccia and boulder volcanoglomerate of the MCVS. Rounded clasts up to 1 m in diameter and matrix consist of feldspar-porphyritic intermediate volcanic rock; f) columnar jointing in glassy aphanitic intermediate volcanic rock.

Additional metaigneous rocks common in the upper package include: 1) metafelsite; 2) two-mica granitic gneiss and schist; and 3) hornblende diorite gneiss. Metafelsite is rare and occurs as thin sill-like horizons 10 cm-thick within quartzite and micaschist. It has only been observed west of Aishihik Lake. These horizons are typically buff-weathering and white on a fresh surface. They are finely crystalline to aphanitic and appear to consist primarily of feldspar with minor, but variable amounts of quartz. Feldspar occurs as aphanitic milky white streaky lenses and continuous horizons; quartz as clear grey eyes which lie parallel with the enclosing fabric. Two-mica granitic gneiss and hornblende diorite gneiss are interfoliated with brown quartzite and micaschist east of Aishihik Lake; they have not been observed west of the lake. Granitic gneiss and schist weathers light brown to brown grey. Fresh surfaces are white to light grey. These rocks vary from homogeneous coarsely crystalline granite to quartz monzonite gneiss to heterogeneous felsic schist with interfoliated marble, micaschist and metabasite. Major mineral constituents include quartz, potassium feldspar and albitic plagioclase. Significant amounts of muscovite are commonly present, and minor to trace amounts of biotite. Accessory minerals include zircon, apatite, tourmaline and pyrite. Gneissic banding is commonly defined by colour and compositional banding and by well developed and pink potassium feldspar augen. Muscovite locally occurs as large continuous sheets that parallel the gneissic banding and which define a schistosity.

Hornblende quartz diorite gneiss weathers light grey. Fresh surfaces are dark grey. The gneiss is fine- to medium-grained and ranges in composition from mafic hornblende diorite to hornblende biotite granodiorite. Major mineral constituents are hornblende, andesine plagioclase, and quartz. Minor amounts of biotite and potassium feldspar are common. Accessory minerals include zircon, apatite, titanite, and magnetite.

The AMS is intruded by the Aishihik Batholith and by plutons of the RRPS, including the Ruby Range Batholith (Fig. 5). Constraints on the age of the metamorphic uite are few. Rocks of the AMS were previously included entirely in the Nisling Assemblage, which is thought to consist of a Cambrian and Precambrian continental slope and margin sequence (Wheeler et al., 1991). The feldspathic micaschist and associated marble horizons included in the lower package of the AMS are lithologicially similar to, and are inferred to be correlative with, the Nisling Assemblage. The lower package may, therefore, Cambrian or older. However, black quartzite and thick sections of marble and metaigneous rocks included in the upper package of the AMS are more typical of, and are inferred to be correlative with, the Nasina Assemblage - a Devono-Mississippian marginal basin sequence which locally includes a significant igneous component (Wheeler et al., 1991; Mortensen, 1992). The presence of rocks correlative with the Nisling and Nasina assemblages, both of which are included in the Nisling Terrane, implies that the AMS includes rocks of probable Precambrian to Mississippian age.

The Mount Creedon Volcanic Suite

Isolated exposures of rocks included in the MCVS occur throughout the study area. This diverse suite includes a variety of volcanic and related sedimentary rocks. Volcanic rocks west of and adjacent to Aishihik Lake consist of brown-, orange- and green-weathering, green and maroon, feldspar porphyritic to aphanitic vesicular and non-vesicular, auto-brecciated and massive, intermediate volcanic rock. White to yellow 3 to 7-mm long euhedral feldspar grains commonly constitute 10 to 20% of the porphyritic rocks. Anhedral grey quartz phenocrysts are rare as are hornblende and pyroxene phenocrysts. Hornblende locally occurs as cigar-shaped phenocrysts characterized by distinct red cores. The matrix varies from an aphanitic dark green glass, to finely crystalline felted plagioclase, to fine-grained breccia. Rare vesicles are locally rimmed with chalcedony and chalcedony-calcite. Breccia is typically evident only on weathered faces and consists largely of rounded autoclastic fragments (Fig. 6e). Angular to rounded clasts of basement rock, including metamorphic rocks and granitic clasts thought to have been derived from intrusions of the RRPS, are rare.

The top of a mountain just west of Long Lake is capped with vesicular tan brown to dark brown feldspar and quartz porphyritic, finely laminated felsic (dacitic?) volcanic rock. Abundant vesicles locally impart a pumaceous texture; elsewhere the volcanic rocks are finely laminated with welded lapilli which lie along and enhance the planar fabric.

Volcanic sequences cropping out east and north of Long Lake consist of volcaniclastic rocks and autobreccia deposits. The brecciated and volcaniclastic rocks are typically poorly lithified, light green- to brown-weathering, and pastel green, grey and maroon on fresh surfaces. The matrix and clasts commonly consist of aphyric to feldspar porphyritic tuffaceous rocks. Glomeroporphyritic hornblende is locally abundant. Clasts range from 5 to 300 cm in diameter. Graded feldspathic sandstones that have locally incorporated plant debris are interbedded with the breccia deposits.

The alignment of feldspar phenocrysts, chilled horizons, and planar partings define a subhorizontal fabric thought to be primary flow-parallel bedding. Finely laminated rocks, and the presence of water escape (tee pee) structures, imply deposition of at least part of the sequence in water. Glassy rocks locally exhibit columnar jointing; columns are non-linear and curve towards vertical going up-section (Fig. 6f). These textures, together with the abundance of autoclastic breccia imply that the volcanic rocks were deposited as a series of flows and lahars. The presence of fossiliferous clastic strata indicates reworking of the volcanic strata by water.

The MCVS unconformably overlies all other units in the study area (Fig. 5). Clasts derived from each of the AMS, the APS, the LLPS and the RRPS were observed within the volcanic strata. Along the east shore of Aishihik Lake the contact of the volcanic package with the underlying metamorphic basement is exposed and is marked by a clast-supported conglomerate. Well-rounded cobble- and boulder-sized clasts of volcanic, metamorphic, and granitoid rocks sit unconformably on brecciated metamorphic rocks. The matrix consists of dirty feldspathic sand. The conglomerate is massive; no bedding or grading was observed.

Tempelman-Kluit (1974) inferred that volcanic rocks cropping out west of Aishihik Lake were genetically related to alaskite intrusions west of Sekulmun Lake and assigned an Eocene age to the volcanic rocks based on K-Ar age determinations on the alaskite and on rocks intruded by the alaskite. Tempelman-Kluit (1974) correlated, on the basis of lithology, these volcanic rocks with the Mount Nansen Group. More recent geochronological studies (Hunt and Roddick, 1991; Hart et al., in prep.) indicate that the Mount Nansen Group was deposited in the middle Cretaceous. Because the volcanic rocks west of Aishihik Lake lie unconformably on and include clasts of the RRPS they are inferred to be younger than 90 Ma (the maximum possibly age of the suite—Johnston, 1993) and probably younger than 60 Ma. Volcanic rocks cropping out east and north of Long Lake were assigned an Eocene or younger age and were correlated with the Carmacks Group (Tempelman-Kluit, 1974). More recent geochronological studies (Grond et al., 1984; Lowey et al., 1986; Hart et al., in prep., Johnston and Mortensen, unpublished data) indicate, however, that the Carmacks Group was deposited in the Late Cretaceous. The MCVS may therefore include volcanic rocks as old as Late Cretaceous and as young as Eocene.

Intrusive Rocks

The Aishihik Batholith

The Aishihik Batholith crops out east of the AMS and underlies the topographically subdued plateau east of the Aishihik Lake. Good outcrops are present along the margins of the batholith. In the unglaciated central eastern parts of the study area, exposure is limited to felsenmeer and to isolated outcrops of weathered rock.

Rocks of the Aishihik Batholith are characteristically foliated, coarsely crystalline and equigranular. A porphyritic texture defined by potassium feldspar megacrysts 2 to 4 cm-long, is present locally (Fig. 7a). Granodiorite is the most common rock type; quartz diorite and quartz monzonite are less common (Tempelman-Kluit, 1974). Variation in rock type is gradational and results from minor changes in mineral abundances. Major mineral phases include andesine, potassium feldspar, quartz, and hornblende. Minor to trace amounts of biotite commonly are present. Accessory minerals include apatite, titanite, zircon, magnetite, allanite and epidote. Alteration products include sericite, pyrophyllite, epidote, hematite and chlorite. The rock is tenacious.

Andesine occurs as euhedral laths. Potassium feldspar occurs both as anhedral grains interstitial to plagioclase and locally as poikilitic megacrysts containing hornblende grains. Potassium feldspar megacrysts are spatially associated with potassium feldspar microveins, indicating that, at least in part, the megacrysts may have a late, possibly post magmatic, origin. Myrmekitic intergrowths of feldspar and quartz commonly mantle the megacrysts. Quartz occurs interstitially and as subhedral to anhedral eyes 0.5 cm across. Mafic minerals account for 5 to 20% of the rock. Hornblende is the dominant mafic mineral and occurs as euhedral black to dark green prisms. Biotite is only locally abundant. Euhedral epidote grains cored by allanite are common. They are intergrown with biotite, appear to have developed at the expense of hornblende and plagioclase, and are inferred to be primary magmatic grains. Microdiorite enclaves up to one metre-long are common and are composed of abundant fine-grained hornblende and minor biotite and plagioclase. Migmatite, consisting of networks of aplite veins and discontinuous pods of leucosome mantled by thin mafic selvages, occurs in the batholith near its west margin. Rare aplite veins occur in non-migmatitic parts of the batholith. Two types of veins are common including grey potassium feldspar veins 1 mm- to 3-mm thick, and coarsely crystalline, pink and white pegmatite veins up to 1 m-wide. Potassium feldspar and quartz, which commonly occur as graphic intergrowths, oligoclase and chloritized mica compose the pegmatite veins. The pegmatite veins only occur in the batholith and are thought to represent late magmatic fluids. They are therefore assumed to be close in age to, albeit somewhat younger than, the surrounding granodiorite.

Granodioritic rocks of the Aishihik Batholith are characterized by a planar fabric (Fig. 7a) defined by the parallel orientation of mineral grains including: euhedral, poikilitic, potassium feldspar megacrysts; subhedral to euhedral elongate lathes plagioclase; subhedral to euhedral elongate hornblende prisms; quartz eyes; and biotite booklets. Undeformed veins of leucocratic aplite lie along the plane of foliation. Because this fabric is defined by the alignment of undeformed primary igneous grains it is interpreted as a magmatic fabric which probably developed in response to flow during intrusion.

A second planar fabric parallels the magmatic fabric and is defined by: 1) thin (1 to 5 m), streaky, finely crystalline to nearly aphanitic, annealed mylonite bands; and 2) gneissic banding in which coarse-grained foliated granodiorite is interleaved with finely crystalline bands of recrystallized quartz, biotite and rounded, subhedral to euhedral, fractured feldspar augen that lack internal structure. Because this fabric is defined by mylonite, and sheared and gneissic rock, it is interpreted as a solid-state fabric that developed either in response to magmatic ballooning during intrusion, or syn-tectonic intrusion.

Micaschist of the AMS dips regionally to the east-northeast beneath the western margin of the Aishihik Batholith (Fig. 5). The contact is concordant with foliation in the overlying granodiorite and with schistosity in the underlying micaschist. The contact is commonly characterized by a discrete plane. Locally granodiorite grades into feldspathic schist over a 1 to 3 m-wide interval and no distinct contact can be discerned.

The batholith appears to have intruded at moderate to deep crustal levels. This interpretation is consistent with the coarsely crystalline, equigranular nature of the granodiorite. The development in granodiorite of magmatic epidote at the expense of hornblende, an equilibria indicative of pressures of at least 8 kbar (Naney, 1983; Zen, 1985; 1989; Zen and Hammerstrom, 1984; 1986), suggests crystallization of the batholith at depths of greater than 25 km.

U-Pb zircon geochronology of a sample of the batholith yielded a concordant age of 187.0 + 9.7/-1.0 Ma (Johnston, 1993). Because the batholith is texturally and compositionally homogeneous, this age is interpreted as the crystallization age of the entire batholith. More age determinations are, however, required to test this interpretation.

The Long Lake Plutonic Suite

Plutons of the LLPS underlie much of the eastern part of the study area (Fig. 4). Good, in situ exposures are rare; exposures typically consist of felsenmeer and isolated ridge and hilltop tors. Intrusive rocks of the LLPS are characteristically pink-orange-weathering and pink to white on fresh surfaces. They are, texturally heterogeneous and range from equigranular finely crystalline massive rock to megacrystic foliated packed porphyry. Pegmatitic and aplitic textures are also common.

Leucocratic, biotite hornblende pink quartz monzonite (Fig. 7b) and granite are the most common phases. The major mineral constituents include albitic plagioclase, quartz, and potassium feldspar. Biotite and hornblende occur in trace amounts. Accessory mineral include zircon, apatite and pyrite. Alteration products include sericite, calcite, epidote and hematite.

Albitic plagioclase occurs as coarsely crystalline laths and as fine grained, acicular crystals. Plagioclase grains are commonly characterized by normal zonation with slightly more calcic cores. Spectacular pink-orange potassium feldspar poikilitic megacrysts impart the distinct pink-orange colour that characterizes rocks of the LLPS. Quartz occurs as fine- to coarse-grained eyes and as anhedral grains interstitial to feldspar. Biotite and hornblende are equally common; biotite occurs as medium-grained euhedral booklets and hornblende as disseminated euhedral grains.

Foliation is common in coarse-grained rocks and is defined primarily by alignment of potassium feldspar megacrysts. Quartz eyes, plagioclase lathes and mica grains parallel and enhance the planar fabric. Finer grained and pegmatitic rocks are commonly massive.

Pink quartz monzonite is spatially associated with hornblende granodiorite of the Aishihik Batholith; in the study area pink quartz monzonite occurs entirely within the Aishihik Batholith (Fig 5). This relationship is also evident on a regional scale; plutons of the LLPS are commonly spatially related to more mafic intrusions of the Aishihik Plutonic Suite. Examples include the association of intrusions in the vicinity of Long Lake and the Carmacks Batholith, all included in the LLPS, with the Aishihik Batholith; and the association of the Big Creek Syenite, part of the LLPS, with the Granite Mountain Batholith, part of the APS, in the Carmacks map area (Tempelman-Kluit, 1984; Carlson, 1987). This spatial relationship suggests a genetic link between the LLPS and the APS.

Field relations indicate that pink quartz monzonite of the LLPS is, at least in part, younger than the Aishihik Batholith. Dykes of massive finely crystalline pink quartz monzonite intrude and truncate foliated hornblende granodiorite of the Aishihik Batholith. A rounded xenolith of hornblende granodiorite similar to that of the Aishihik Batholith was observed within pink quartz monzonite (Fig. 7b). North of the study area, plutons of massive pink quartz monzonite intrude foliated hornblende granodiorite of the Aishihik Batholith and truncate the contact of the batholith with adjacent metamorphic rocks (Johnston, 1993). Elsewhere however, coarsely crystalline foliated pink quartz monzonite appears to grade into hornblende granodiorite of the Aishihik Batholith. The transition from monzonite to granodiorite results from a loss of the spectacular pink potassium feldspar megacrysts, an increase in the number and size of hornblende grains, and the development of a more equigranular and less megacrystic texture. Potassium feldspar megacrysts in the Aishihik Batholith are less common than in the LLPS and lack the spectacular pink-orange colour. Foliation in the monzonite parallels foliation in the granodiorite. These relationships imply that the pink quartz monzonite is, in part, the same age or only slightly younger than the Aishihik Batholith.

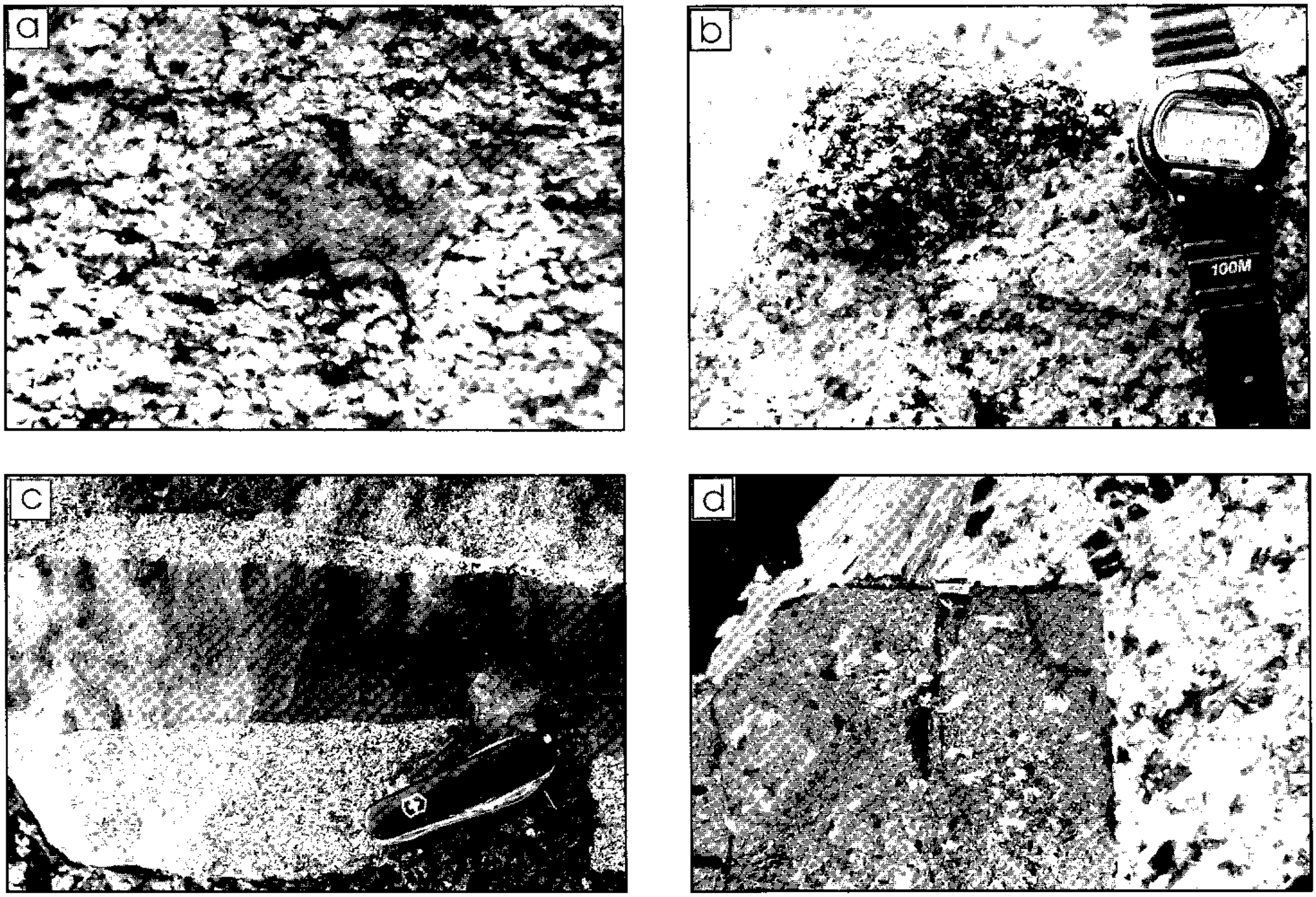
A concordant U-Pb titanite age determination (189.7 +/- 3.3 Ma) indicates that at least part of the suite cooled through the 600°C isotherm - the blocking temperature of Pb in titanite (Heamon and Parrish, 1991) - by 186.4 Ma (Johnston, 1993; Johnston and Mortensen, unpub. data) thus providing a minimum age constraint on part of the LLPS.

The Ruby Range Plutonic Suite

The RRPS includes the Ruby Range Batholith and isolated plugs and tear shaped plutons north of the batholith (Figs. 4 and 5). Inclusion of the isolated intrusions in the RRPS is based on their lithological and textural similarity to the granitoid rocks that comprise the Ruby Range Batholith. In addition, the isolated plugs, like the batholith, are discordant and cut and metamorphose rocks of the AMS. The batholith underlies the glaciated Ruby Range along the southern part of the study area and stands in high relief relative to the adjacent metamorphic rocks of the AMS.

Weathered surfaces range in colour from grey to light brown; fresh surfaces from dark to light grey. Locally bright orange and green colours were observed. Grain size and texture are variable. The most common rock type is medium- to coarse-grained, biotite hornblende granodiorite (Fig. 7c); diorite and monzonite are less common. Potassium feldspar megacrysts impart a coarse porphyritic texture. Proximal to the north margin of the batholith a porphyritic texture, characterized by a fine grained to aphanitic matrix and by tabular feldspar phenocrysts or by acicular hornblende grains, is common. Major mineral phases includes plagioclase, potassium feldspar, quartz, biotite and hornblende. Accessory minerals include titanite, apatite, zircon and magnetite. Chlorite, sericite, pyrophyllite, calcite, and epidote alteration is present.

Plagioclase is albitic to labradoritic, euhedral, and exhibits normal and reverse compositional zoning. Potassium feldspar locally exhibits cross-hatch twinning and occurs as anhedral grains which mantle and are interstitial to other grains and as subhedral phenocrysts. It also commonly occurs as euhedral, poikilitic phenocrysts and megacrysts which include 1 mm-long hornblende grains. Quartz occurs as clear to smoky grey eyes, 2 to 5 mm-long and as equant anhedral grains interstitial to other minerals. Hornblende and biotite occur as coarse-



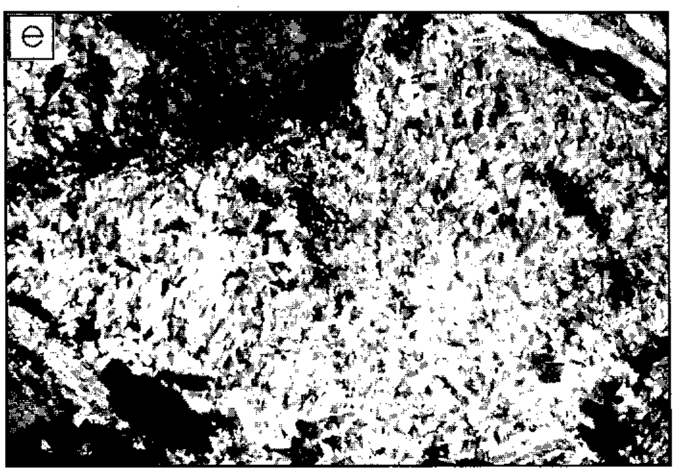


Figure 7: a) foliated potassium feldspar megacrystic hornblende granodiorite of the Aishihik Batholith. The field of view is 5 cm. Foliation parallels the top of the photograph. A poikilitic potassium feldspar megacryst is present at center; b) leucocratic hornblende quartz monzonite of the LLPS. Immediately left of the watch-face is a rounded xenolith of mafic hornblende quartz diorite inferred to have been derived from the Aishihik Batholith; c) coarse grained, equigranular hornblende granodiorite of the RRPS. The granodiorite is intruded at center by an aphanitic dyke inferred to be related to the MCVS; d) a photomicrograph, taken under plain polarized light, of a euhedral porphyroblast of andalusite (the square grain) which truncates older mica of the AMS at the top left. The field of view is 1 mm; e) a photomicrograph, taken under plain polarized light, of sericite which has overgrown and replaced micaschist; f) a 1.5 m-wide, east-trending mineralized quartz vein intruding pink quartz monzonite of the LLPS. See text for discussion.

grained glomeroporphyritic clots. Locally biotite occurs as coarse, 5 to 10 mm-wide mica booklets.

Fine-grained leucocratic to mafic microgranitoid enclaves are common and range in composition from granite to gabbro. Enclaves are typically massive and equigranular. Mafic enclaves consist largely of plagioclase and hornblende; more granitic enclaves include quartz and potassium feldspar. Enclaves range from spheroidal bodies 10 cm in diameter up to irregularly shaped masses more than 100 m-across.

A mild foliation is commonly present and varies from a subtle, nebulitic banding, which appears to highlight relict migmatitic textures, to a weak planar fabric defined by the alignment of hornblende, potassium feldspar megacrysts and plagioclase laths. Finer grained rocks, including porphyritic rocks and microgranitiod enclaves, are generally massive.

Rocks of the RRPS are generally fresh with little or no alteration. Mild sericitization of plagioclase is rare as is chlorite and pyrophyillite replacement of biotite. Zones of friable and highly weathered rock are developed adjacent to calcite, ankerite and quartz veins, and within and adjacent to brittle shear zones and faults.

The RRPS intrudes metamorphic rocks of the AMS. Discordant plugs and tear-shaped plutons of the RRPS cut across and truncate fabrics in the AMS. Large roof pendants of metamorphic rock of the AMS were observed along the roof of the Ruby Range Batholith (Figs. 4 and 5). Where RRPS stocks are in contact with marble, the marble is commonly skarned and altered (Morin, 1981). At the south end of Aishihik Lake, contact metamorphism (Fig. 7d) and potassic metasomatism (Fig. 7e) of the AMS occurred during the emplacement of the plutons of the RRPS (Johnston, 1993).

U-Pb zircon age determinations for samples of the Ruby Range Batholith collected along a north-trending transect imply that the batholith, and the RRPS as a whole, is the product of episodic plutonism, including magmatic pulses at about 70 Ma and 58 Ma (Johnston, 1993). Widespread sillimanite-grade metamorphism in southwest Yukon in the Eocene (Mortensen and Erdmer, 1992; Erdmer and Mortensen, 1993) may be related to the emplacement of part of the suite at 58 Ma. The U-Pb zircon data are not, however, unequivocal; emplacement of parts of the suite may have occurred as early as about 90 Ma; magmatism may have been continuous, rather than episodic. Further detailed U-Pb isotopic studies and geological mapping are required to resolve these questions.

Dykes and Shallow Level Intrusions

Orange- to grey-weathering, grey, equigranular to porphyritic, medium-grained quartz diorite dykes are abundant adjacent to the Ruby Range Batholith. Acicular plagioclase and hornblende grains are common. Matrix minerals consist of feldspar with minor quartz. The dykes intrude metamorphic rocks of the AMS, but were not observed intruding volcanic rocks of the MCVS. Based on the lithological and textural similarity of the dyke rocks with granitoid rocks of the RRPS and on the spatial association of the dykes and the Ruby Range Batholith; and because the dykes cut the AMS but do not appear to intrude the MCVS, they are inferred to be genetically related to the RRPS.

A diverse array of light grey- to dark orange-brown-weathering, dark green to buff, intermediate to felsic subvolcanic dykes and plugs are commonly spatially associated with, and locally intrude into, volcanic rocks of the MCVS. Dykes commonly trend north and vary from 10 cm to 25 m in width. Feldspar and feldspar-hornblende porphyry dykes are most common; aphanitic dykes are less common (Fig. 7c). Pink-weathering, buff to white, finely laminated felsic dykes with abundant disseminated pyrite are rare and commonly intrude along foliation in the metamorphic rocks. Small intrusive stocks include a buff-weathering pink feldspar porphyritic monzonite that intrudes the Aishihik Batholith-AMS contact. Feldspar phenocrysts up to 2 cm across and characterized by distinct compositional zoning comprise 15 to 25% of the rock. An additional plug located north of Long Lake consists of light grey-weathering, blue-grey, fine grained equigranular hornblende diorite. These intrusive rocks are inferred to be cogenetic with the MCVS based on their spatial association with volcanic rocks, their subvolcanic porphyritic texture, and because they locally intrude into the associated volcanic rocks.

Structural Geology

Planar fabric elements in the AMS include: 1) compositional and colour banding (Figs. 6a and b); and 2) a schistosity, which is defined by the parallel alignment of mica in schistose rocks (Fig. 6a) and by hornblende in metabasite. Banding is apparent from hand sample to map scale and is assumed to represent a transposed primary depositional fabric. Tight to isoclinal folds of compositional banding are characterized by schistosity-parallel axial surfaces. Where compositional banding is not folded, compositional banding and schistosity are generally parallel (Fig. 6a). A rodding or elongation lineation that lies within the plane defined by compositional banding, is common in quartzose rocks. Rare asymmetric fabric elements (C and S planes), evident on surfaces that contain the rodding lineation and are perpendicular to compositional banding, consistent with both top-to-the-north and top-to-the-south sense of shear are present. Top-to-the-north shear indicators are, however, dominant. Extensional shears which offset and merge with compositional banding and which are indicative of top-to-the-north shear sense have also been observed.

A weakly developed crenulation cleavage, defined a planar parting and rarely by mica, overprints compositional banding and schistosity. A crenulation lineation lies in the plane defined by the crenulation cleavage, is evident in schistose rocks and is defined by microfolds of schistosity (Fig. 6a). The hinge lines of open, moderately inclined, subhorizontal to gently north-plunging kink, or chevron-shaped folds, parallel the crenulation lineation. Crenulation folds are symmetric to asymmetric with vertical to steeply east-dipping axial surfaces, and verge east and, more commonly, west. They affect schistosity and compositional banding in the AMS, and the margin of, and foliation within, the Aishihik Batholith.

Late, steep to vertical faults that truncate older structures and fabrics affect all units with the possible exception of the MCVS (Fig. 4). Faults are poorly exposed and are rarely observed. They are commonly recognized as linear topographic lows, by the development of shear fabrics, including C and S fabrics and fault gouge, adjacent to lineaments, and by the offset of contacts. Faults displacing the AMS - Ruby Range Batholith contact, the AMS - Aishihik Batholith contact, and structural levels in each of the AMS, the Aishihik Batholith, the LLPS, and the Ruby Range Batholith, were observed. Offsets across faults are generally less than 200 m, but are locally up to 2 km. Normal and lateral offsets were observed.

The timing and tectonic significance of the steep faults is not known. They may have developed prior to the deposition of strata of the MCVS. However, the limited areal extent of the MCVS makes this difficult to ascertain. No faults that are truncated and uncomformably overlain by strata of the MCVS were observed and it remains possible that faulting was synchronous with or post-dates deposition of the MCVS.

METAMORPHIC GEOLOGY

Rocks of the AMS are metamorphosed to upper amphibolite facies, as indicated by a coarse schistosity, by regionally developed migmatitic fabrics, and by the presence of coexisting staurolite, kyanite and sillimanite (Gordey, 1973; Tempelman-Kluit, 1974; Erdmer, 1990; 1991; Johnston, 1993). Metamorphic zones, including staurolite, staurolite-kyanite, kyanite, kyanite-sillimanite, and sillimanite, parallel schistosity and the margin of the Aishihik Batholith and define an increase in grade towards the batholith. Geothermobarometry data (garnet -biotite - aluminosilicate - plagioclase) indicate that metamorphism occurred at pressures of at least 8 kbar and at temperatures, in the sillimanite zone adjacent to the batholith, in excess of 700°C (Johnston, 1993). A concordant U-Pb titanite cooling age of 184 +/- 2 Ma from micaschist of the AMS places a minimum age constraint on regional metamorphism (Johnston and Mortensen, unpub. data). Because metamorphic grade increases towards the batholith and because isotopic age determinations indicate that metamorphism is approximately the same age of the batholith, it is inferred that regional upper amphibolite grade metamorphism resulted from the intrusion of the Aishihik Batholith.

Low-pressure, high-temperature contact metamorphic aureoles overprint the regional metamorphic paragenesis adjacent to intrusions of the RRPS, including the Ruby Range Batholith. Andalusite (Fig. 7d) and cordierite are developed immediately adjacent to RRPS intrusions. Sillimanite is more widespread and post-dates the andalusite cordierite aureoles: fine-grained sillimanite and fibrolitic sillimanite replaces, nucleates on, and mantles andalusite and staurolite. Potassic metasomatism, characterized by sericitization (Fig. 7e) and by the development of large anhedral poikilitic potassium feldspar clots, increases towards and is locally pervasive adjacent to some intrusions of the RRPS. These observations indicate that thermal metamorphism is related to the intrusion of the RRPS.

METALLOGENY

Mineral Occurrences

The locations of known mineral occurrences in and adjacent to the study area are shown in Fig. 2; mineral occurrences in the study area are summarized in Table 1. Tempelman-Kluit (1974) recognized three classes of mineral showings in the Aishihik Lake area including: 1) magnetite skarns with chalcopyrite + scheelite ± molybdenite; 2) magnetite skarns with chalcopyrite; and 3) disseminated chalcopyrite ± molybdenite. Some skarning of marble in the AMS was thought to be related to unspecified Mesozoic granitic rocks, while others to younger igneous rocks. Felsic volcanic rocks of the MCVS host the disseminated chalcopyrite and molybdenite mineralization (Tempelman-Kluit, 1974).

Morin (1981) examined mineral showings in the Hopkins Lake and Giltana Lake areas and on the northeast shore of Sekulmun Lake in order to establish metal contents and the source of mineralization. Near Hopkins Lake, mineralization consists of coarse-grained patchy chalcopyrite and pyrrhotite disseminated and along fractures in magnetite-rich skarn. Examples include Minfile occurrences 18, 19 and 20 (INAC, 1992; Fig. 2). Massive magnetite forms horizons 10 to 100 cm-thick. Magnetite and calc-silicate with disseminated and banded chalcopyrite defines pods 10 to 70 cm-thick and up to several metres long. Skarns occur adjacent to feldspar porphyry dykes of the MCVS and locally adjacent to contacts with a granodiorite stock included in the RRPS. Minor pyrite and chalcopyrite occur disseminated in feldspar porphyry.

At Giltana Lake, south of the study area, Morin (1981) observed the intermittent development of calc-silicate skarn along the north margin of a northwest-trending RRPS plug that intrudes the AMS (Minfile occurrence 16, INAC, 1992; Fig. 2). Mineralization in the AMS is spatially associated with feldspar porphyry dykes of the MCVS and consists of minor pyrite, rare molybdenite, and anomalous W values. Quartz veins, several centimetres-thick and carrying minor chalcopyrite and pyrite are localized along fractures in metamorphic rocks of the AMS. Granodiorite of the RRPS is similarly mineralized. Skarns at the Sekulmun Lake showing (Minfile occurrence 24; INAC, 1992; Fig. 2) are developed where marble is intruded by quartz feldspar biotite porphyry. It remains unkown whether the intrusion is correlative with the RRPS or the MCVS.

Skarns are characterized by 0.3 to 8 m-thick lenses of magnetite and massive black sphalerite. Brown sphalerite post-dates skarn mineralization and occurs in fractures. The rocks are also anomalous in Au, Sn, and W (Morin, 1981).

The source of the skarn mineralization remains enigmatic. It has been assumed that the feldspar porphyry dykes, which are spatially associated with all known skarn occurrences, were the source of skarning and mineralization (Morin, 1981; J. Morin, pers. comm., 1993). However, the dykes rarely exceed 2 or 3 m in width and no contact metamorphic effects have been observed where the dykes intrude schist of the AMS. It seems unlikely therefore that there was enough thermal energy associated with the dykes to develop the thick and laterally extensive skarns associated with the mineral occurrences.

Granitic stocks of the RRPS are spatially associated with some, but not all, of the skarn-associated mineral occurrences. This plutonic suite may be a better candidate for the source of most of the mineralization. Andalusite, cordierite, and sillimanite define high-temperature, low-pressure metamorphic aureoles developed in schist of the AMS adjacent to some RRPS stocks indicating that a significant amount of heat was transferred to the crust during the intrusion. Potassic metasomatic alteration of schist is consistent with the development of a hydrothermal alteration halo during intrusion. Together, these observations imply that porphyry-type mineralization may have developed during the intrusion of stocks of the RRPS. This model predicts that: 1) the bulk of skarns and skarn associated mineralization is related to the RRPS, not the feldspar porphyry dykes; 2) mineralization spatially associated with younger feldspar porphyry dykes probably resulted from minor remobilization of skarn and porphyry mineralization during the intrusion of the dykes; and 3) the skarn deposits, which have been the main exploration focus in the study area, may be developed on the peripheries of more extensive (but possibly overlooked) porphyry deposits.

Disseminated chalcopyrite and molybdenite are developed in and adjacent to a sub-volcanic stock in the northeast part of the study area (Minfile 21, INAC, 1992; Fig. 2). The stock intrudes into, and is thought to be genetically related to, volcanic strata of the MCVS. Mineralization of the stock and the wall rock volcanic strata is thought to be part of a porphyry alteration halo that developed during the intrusion of the stock.

Cu-Au mineralization mapped during this study is associated with east-trending quartz veins (Fig. 2). The veins crop out east of Long Lake, consist of milky-white bull quartz, and are commonly 0.5 to 2 m wide and up to 60 m-long (Fig. 7f). Malachite and azurite are evident on weathered surfaces; disseminated sulphides are locally apparent on fresh surfaces. The mineralized veins are anomalously enriched in Cu, Au, Sb, As, Pb, Zn, and Cd. Assay results for these and other veins sampled in the study area are given in Appendix 1.

The source of the vein-related mineralization is unknown. The veins are not spatially associated with volcanic rocks of the MCVS. The high Cu values and the size and continuity of the veins is consistent with a hot, moderately deep level magmatic source. It seems unlikely, therefore, that the veins are part of an epithermal system related to volcanic rocks of the MCVS. A buried pluton, possibly of the RRPS may be the source of mineralization.

Suggestions for Exploration

Metamorphic strata of the AMS includes black quartzite and metaigneous rocks thought to be correlative with the Devono-Mississippian Nasina Assemblage, an assemblage that has proved prospective for massive sulphide deposits elsewhere in Yukon and southern Alaska. Examples include chalcopyrite-bearing black quartzite at Lucky Joe Creek, Yukon (McClintock and Sinclair,1983), and volcanogenic massive sulphide in metavolcanic strata in the Bonnifield, Trident Glacier and Delta districts of south-central Alaska (Lange et al., 1993). The Minto-Def -Williams Creek Cu deposits occur within schist and gneiss which may be correlative with the Nasina Assemblage (Tempelman-Kluit, 1974; McClintock and Sinclair, 1983). Rocks of the upper package of the AMS, including black quartzite and metaigneous rocks are, therefore, prospective for massive sulphide.

Numerous Early Jurassic hornblende granodiorite intrusions similar to the Aishihik Batholith are present along the entire length of the Canadian Cordillera. These intrusions are commonly associated with porphyry Cu and Cu-Au deposits (Anderson, 1988). It is not, therefore, unreasonable to expect that the Aishihik Batholith has the potential to host similar mineralization. However, because the batholith was emplaced at deep crustal levels deep crustal levels it seems unlikely that porphyry mineralization would have resulted. The Aishihik Batholith probably has little potential for Cu porphyry mineralization.

Skarn-related Cu-rich mineral occurrences have been the focus of much of the exploration in the Aishihik Lake area. Feldspar porphyry dykes of the MCVS spatially associated with the skarns were assumed to have been the source of skarning and mineralization. Mineralization may, however, have occurred during the intrusion of stocks and tear-shaped plugs of the RRPS and may not be restricted to the skarns. RRPS intrusions were emplaced at shallow crustal levels, as indicated by their discordant nature and by the development of andalusite and cordierite contact metamorphic halos. Potassic alteration spatially associated with the RRPS stocks is consistent with hydrothermal alteration during intrusion. These observations suggest that, in addition to skarn-related mineral occurrences, there is potential for porphyry mineralization associated with isolated stocks of the RRPS.

Additional exploration targets include subvolcanic plugs of the MCVS and east-trending quartz veins. Porphyry mineralization associated with a sub-volcanic plug that intrudes volcanic strata of the MCVS implies that similar sub-volcanic stocks may make favourable exploration targets. East-trending, mineralized quartz veins identified during this study may be related to a buried intrusion, possibly of the RRPS. Further study is required to determine the extent of the veining and the source of the mineralization.

Summary and Conclusions

1. The AMS comprises the oldest rocks in the study area. It includes black quartzite, marble, orthogneiss, and metabasite correlative with the Devono-Mississippian Nasina Assemblage, and feldspathic quartz micaschist and marble correlative with the Cambrian and older Nisling Assemblage.
2. The AMS was intruded by foliated hornblende granodiorite of the Aishihik Batholith, part of the APS, in the Early Jurassic. Intrusion occurred at crustal depths of approximately 30 km and resulted in upper amphibolite facies metamorphism of the AMS.
3. APS plutonism evolved rapidly into more leucocratic rock of the LLPS. Coarse-grained, foliated pink quartz monzonite occupies the core of the Aishihik Batholith and grades out into hornblende granodiorite; elsewhere fine-grained dykes of massive pink quartz monzonite intrude and truncate hornblende granodiorite.

4. In the Late Cretaceous - Early Tertiary, the AMS was intruded by granitic rocks of the RRPS including the Ruby Range Batholith and isolated stocks and tear shaped plutons north of the batholith. Low pressure-high temperature contact metamorphic aureoles, characterized by cordierite, andalusite and sillimanite are locally developed adjacent to RRPS intrusions. Intrusion also resulted in potassic metasomatism of schist of the AMS.
5. Potential exploration targets include: massive sulphide associated with black quartzite and/or metaigneous rocks of the AMS; Cu skarn and porphyry deposits related to isolated stocks and tear-shaped plutons of the RRPS; Cu-Au porphyry mineralization associated with sub-volcanic plugs related to the MCVS; and mineralization associated with east-trending quartz veins.

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Table 1. Location and Description of Known Mineral Occurrences

Minfile No.	Name	UTM Zone 8v	Host Rock	Description
Skarn				
115H018	Janisiw	E392936 N6794851	AMS	Skarn mineralization consists of magnetite and chalcopyrite with minor moybdenite, scheelite and precious metals. The lensoid skarns rarely exceed one metre in width and are found in limy sections of quartz-biotite schist near or along contacts with dykes and stocks of variable composition.
115H019	Hopkins	E397312 N6796701	AMS	Five magnetite-pyrrhotite-chalcopyrite stratigraphically controlled horizons in marble occur over a strike length of 1.2 km averaging 2% Cu with grades as high as 11.36% Cu.
Porphyry				
115H021	Sato	E408062 N6816865	MCVS	Disseminated pyrite, magnetite, chalcopyrite and minor molybdenite occur in a weakly altered and brecciated part of a diorite stock of Tertiary age. Stock intrudes coeval andesitic tuff and is cut by quartz porphyry dykes.
Unknown				
115H020	Dericon	E390949 N6799959	AMS	Claims are underlain by metasedimentary rocks of the Aishihik Metamorphic Suite. Soil samples from a gossan returned anomalous copper values but no further work was completed.
115H022	Brass	E437566 N6781237	AMS	Claims are underlain by metasedimentary rocks of the Aishihik Metamorphic Suite.
115H052	Lascas	E411483 N6812845	LLPS	Claims are underlain by Early Jurassic quartz monzonite and were staked to cover a deposit of pure industrial grade quartz that forms a vein that intrudes the quartz monzonite.

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Appendix 1: Selected Geochemical Analyses (Au by fire assay; all other elements by ICP. All analyses by IPL, Vancouver, B.C.)

SAMPLE	LOCATION (UTM GRID ZONE 8V)	DESCRIPTION	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	As (ppm)	Sb (ppm)	Hg (ppm)	Mo (ppm)	Bi (ppm)	Cd (ppm)	Ba (ppm)
STJ-93-6	E369600 N6800080	calcite-quartz-diopside vein in highly altered granite of the Ruby Range. Veining and alteration are associated with brittle shear zone. Alteration consists of chloritization and limonitization.	14	2.1	5	115	34	35	< 2					
STJ-93-13	E367760 N6808000	rusty weathering quartz vein; vein occurs along a subhorizontal brittle shear in black quartzite	59	3.6	35	200	12	<10	2					
STJ-93-32	E372915 N6817250	quartz-ankerite veining; veins are 1 to 3 cm wide and continuous for >10 m and occur in altered granodiorite of the Ruby Range Plutonic Suite; alteration consists of almost complete chloritization and sericitization.	81	1.4	38	51	42	<10	< 2					
JRT-93-10a	E370940 N6803010	green feldspar porphyry dyke with disseminated pyrite. Dyke intrudes marble.	8	0.2	19	25	96	<10	< 2					
JRT-93-127	E410190 N6800890	East trending, 1 - 2 m wide vein consisting of vuggy mineralized bull quartz which intrudes megacrystic pink quartz monzonite. Vugs are lined by euhedral, vug-filling quartz crystals up to 1 cm long. Malachite and azurite occur in vugs and along fractured surfaces. Disseminated sulphide is present in bull quartz.	688	200*	2.3%	789	3452	1389	1.4%	8	7	8	100*	52
JRT-93-151	E410220 N6800890	collected along strike from JRT-93-127 on the same east trending quartz vein	97	73.3	2489	2428	653	83	385	-	17	-	8.4	314
JRT-93-152	E410560 N6801080	east trending quartz vein similar to that described for sample JRT-93-151	317	88.4	6198	2162	738	313	2831	-	4	4	34.4	757

Note: *blank cells indicate no analysis; "-" indicates concentrations less than the analytical detection limit.*
*Cu and Sb given in percent; * indicates an estimate (Ag and Cd); anomalous in W (19 ppm)*

Geological Framework of West Lake Map Area (NTS 105N/9), Hess Mountains, East-Central Yukon

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ROOTS, C. and BRENT, D., 1994. Geological framework of West Lake map area (NTS105N/9), Hess Mountains, east-central Yukon, In: Yukon Exploration and Geology, 1993, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 111–121.

Abstract

West Lake map area (105N/9) is underlain by three fault-bounded structural blocks containing tectonically thickened (Late Proterozoic to Mississippian) Selwyn Basin strata. Northeast of the West Lake Fault tightly folded Hyland Group is structurally overlain by Road River Group. Between the West Lake and Wilson Range faults Hyland Group is thrust over Earn Group. In this block the variety of rocks preserved beneath the sub-Earn Group unconformity is greater than surrounding areas. Southwest of the Wilson Range Fault is a tectonically thickened, homoclinal succession of Road River and Earn groups. Silver-bearing quartz veins above and below a thrust fault were mined at the Plata occurrence. Anomalously high Ag, Zn and Pb concentrations in stream sediments result from black shale of the Earn Group exposed in three belts across the map area.

Introduction

The present work forms part of a regional bedrock mapping project jointly funded by the Geological Survey of Canada and the Canada-Yukon Economic Development Agreement which will yield updated geological maps for the Lansing 1:250 000 scale map area. Recently produced maps for the surrounding areas (Gordey and Irwin, 1987; Roots and Murphy, 1992; Cecile and Abbott, 1993; see Fig. 1) incorporate advances in regional geology and provide the regional context for this work. Furthermore, comprehensive descriptions of regionally widespread stratigraphic units of the Selwyn Basin have recently become available (Gordey and Anderson, 1993). The new information from surrounding areas and the relatively poorly known geology of Lansing map area indicate a timely opportunity to improve the work of Blusson (1974). Up-to-date regional maps showing the distribution of prospective units, as well as facies changes, unconformities and structures that influence metal deposition can increase the efficiency of exploration for sediment-hosted mineral deposits such as at Macmillan Pass. The Hess Mountains, 180 km east of Mayo and 180 km north of Ross River, provide excellent exposure of Selwyn Basin strata. The West Lake map area (1:50 000 scale) surrounding the Plata mine is an example of the structural style and stratigraphic units that underlie the northern half of the larger Lansing (1:250 000 scale) map area (105N).

This report accompanies open file map 1994–5 (Roots and Brent, 1994a) and notes on stratigraphy of the surrounding Lansing area (Roots and Brent, 1994b). These interim reports will be augmented by continuing laboratory studies and field mapping in 1994 and 1995.

Regional Geology

This area lies within the Selwyn Basin, a 250 km wide belt of Late Proterozoic through Triassic deep-water sediments (Abbott et al., 1986) that lies southwest of the Ogilvie-Mackenzie Platform and is truncated to the southwest by Tintina Fault. In the western half of the Basin, extending from Niddery Lake map area on the east (Fig. 1), westward through Lansing toward Dawson, these strata have been metamorphosed (greenschist grade predominates) and structurally deformed, leaving few fossil localities upon which to determine age and define stratigraphic units. The southern third of Lansing map area is occupied by the Robert Service Thrust sheet and is characterized by the highly strained Hyland Group rocks as described further west (e.g. Murphy et al., 1993; Murphy and Heon, this volume). In northern Lansing area the same Selwyn Basin strata are folded and imbricated but less metamorphosed than further south. West Lake map area lies 40 km south of the eastern end of the Dawson Fault that bounds the Selwyn Basin westward to the Yukon-Alaska border. Although rocks of the West Lake area have been shortened, it is unlikely that this region has moved significantly northward.

Cretaceous granitic stocks and plugs intrude two northwest-trending belts across Lansing map area. Their affinity with either the Tombstone suite to the west (90–96 Ma; J.K. Mortensen, pers. comm. 1993) or the slightly older Selwyn Suite to the east (Woodsworth et al., 1992) awaits systematic isotopic dating.

Geology of the West Lake Map Area

Seven stratigraphic units are present in West Lake map area. The Hyland Group (PC_H: Latest Proterozoic to Middle Cambrian) is exposed in the northeast (Fig. 2) It is overlain by volcanic mudstone (Cg; may be equivalent to the Cambrian Gull Lake Formation of Gordey and Anderson, 1993) and limy siltstone and nodular limestone (COr) correlated with the Rabbitkettle Formation (Late Cambrian to Ordovician). Along the northern and eastern sides of the map area the Hyland Group is unconformably overlain by dark-coloured clastic sediments and chert of the Road River Group (OS_R; Ordovician and Silurian) and Earn Group (DM_E; Devono-Mississippian) respectively. Two provisional units are also included. They are unnamed because age and stratigraphic control are insufficient to determine whether they belong to either Road River Group or lower Earn Group. Unit ODb includes brown-weathering siltstone and brown shale in a northwest-trending belt, and unit ODs contains dark siltstone and sandstone, with bands of chert, limestone and light-coloured sandstone in the southeast third of the map area. Generally Earn Group rocks overlie an erosional unconformity that intersects all these stratigraphic units at different places in the map area.

The rocks of the map area lie in three structural blocks separated by the northwest-trending West Lake and Wilson Range faults (Fig. 2).

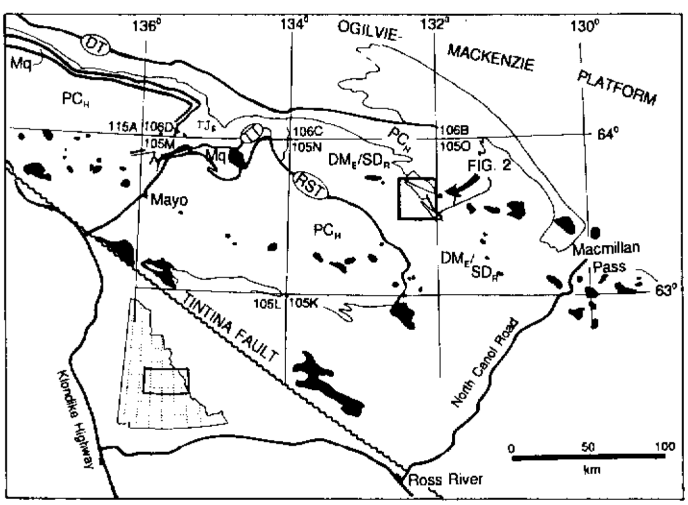
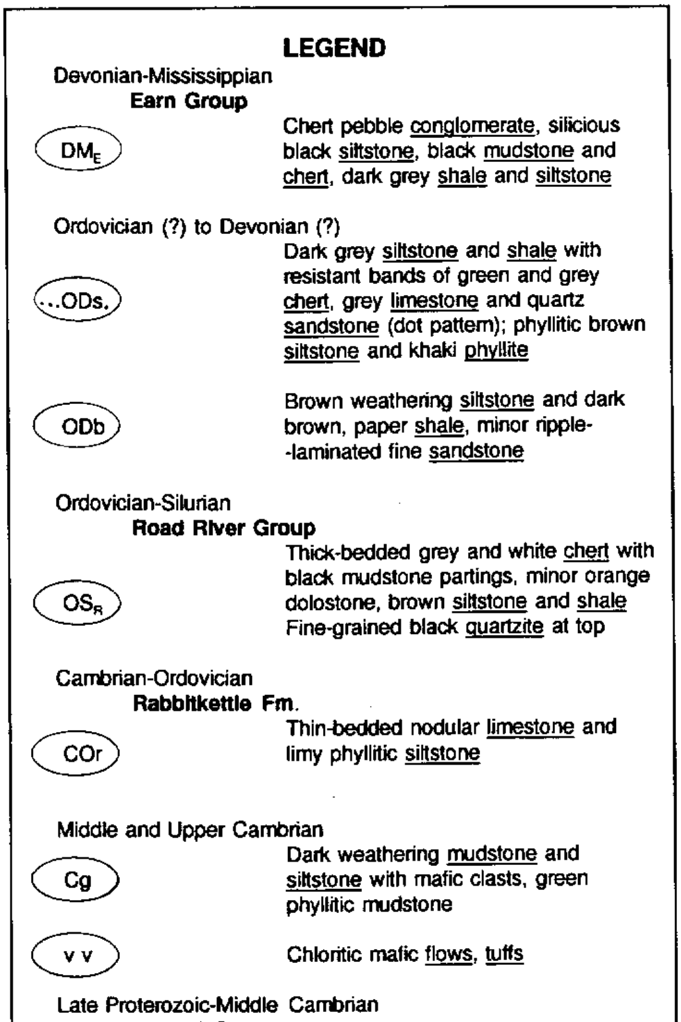


Figure 1: Tectonic setting and location of West Lake map area. DT-Dawson Thrust, TT-Tombstone Thrust, RST-Robert Service Thrust; Mq-Keno Hill quartzite, TJs-Lower schist and related rocks; DM_E/OS_R-Earn and Road River strata, PC_H-Hyland Group. Solid areas are Cretaceous granitic intrusions. Letters denote map areas, as follows: 105I: Nahanni (Gordey and Anderson, 1993); 105J: Sheldon Lake, and 105K: Tay River (Gordey and Irwin, 1987); 105M: Mayo (Roots and Murphy, 1992); 105N: Lansing (Blusson, 1974); 105O: Niddery Lake (Cecile and Abbott, 1992); 106C: Nadaleen River (Blusson, 1974); 106D: Nash Creek and 115A: Larsen Creek (Green, 1972).



Legend for Figure 2.

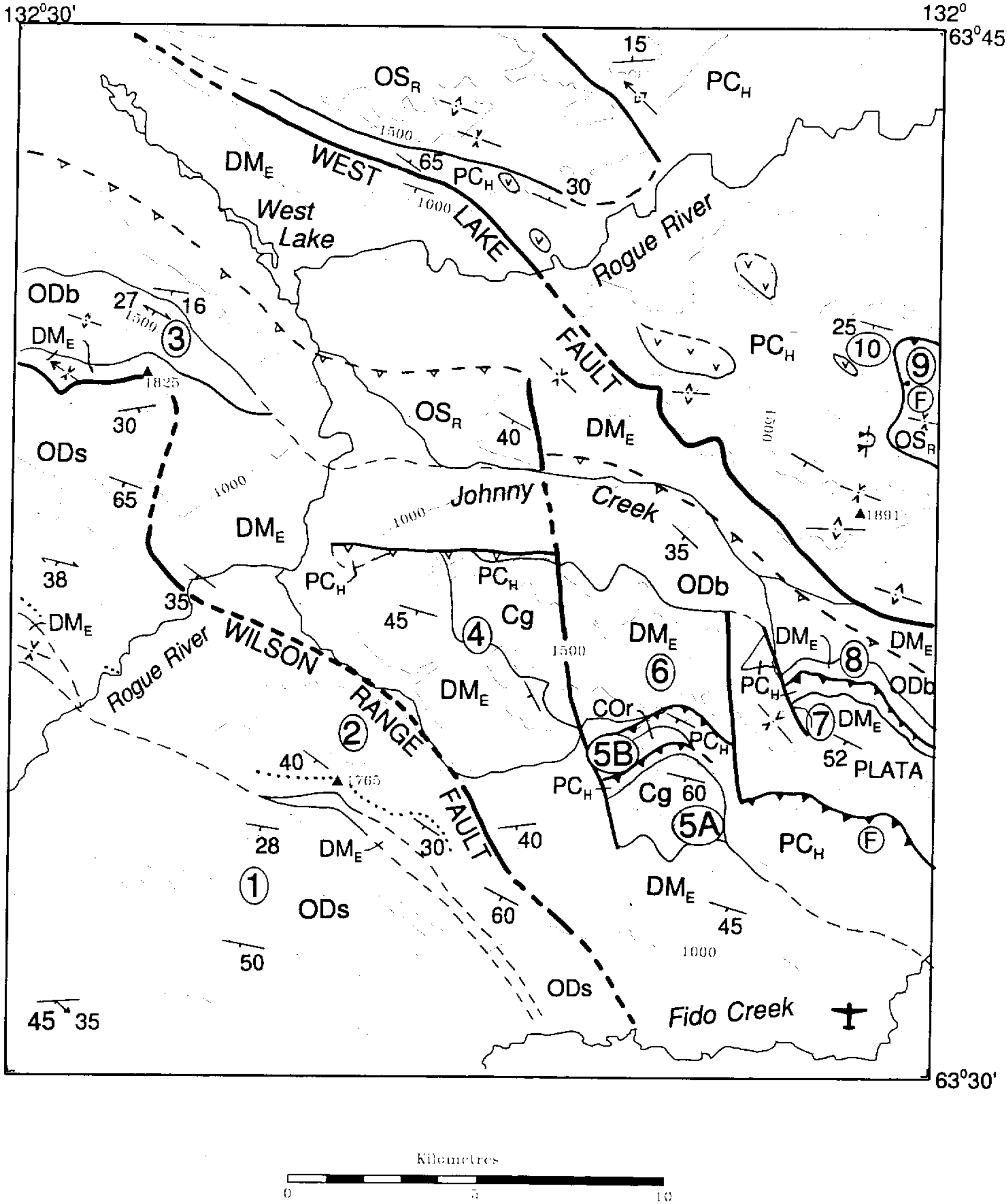


Figure 2: Simplified geological map of West Lake map area (105N/9). Numbers show the location of stratigraphic columns in Figure 3.

Each fault clearly separates contrasting stratigraphic successions and truncates folds and thrust faults in the adjacent northeastern block, although their senses of displacement are unknown. The West Lake Fault dips 40° southwest along the northeast side of Johnny Creek, but is steep or vertical north of the Rogue River and north of the Plata mine. Along its length black chert and siliceous siltstone of the Earn Group on the southwest side overlap folded Hyland Group shale and sandstone on the northeast side. The Wilson Range Fault occupies southeast-trending valleys east of the Rogue River. This fault separates thrust-faulted Proterozoic to Mississippian stratigraphy on the northeast from a laterally continuous, although tectonically thickened Road River and Earn succession. The northern boundary of the southern block is a fault that dips 75° south (near the 1 825 m peak; Fig. 2).

On a regional scale the northwest and west-trending straight faults with vertical displacement (Cecile and Abbott, 1992) in a general way mark the boundary between exposed Hyland Group and younger rocks (cf. Wheeler and McFeely, 1991). The locations of these relatively late-stage discontinuities are critical when attempting to trace specific rock units and unconformities that may contain stratiform mineral deposits. In West Lake map area the West Lake Fault and Wilson Range Fault are more than simple offsets because the block between them has different stratigraphic characteristics. The faults may be re-activation of syndepositional structures, or the boundaries of far-travelled slices of disparate Selwyn basin paleogeography.

This section is a summary of the rock units and structures in each of the three structural blocks of West Lake map area. These stratigraphic relationships are diagrammatically shown in Figure 3.

1. Northeast of the West Lake Fault

The northeast third of the map area contains folded Hyland Group, with mafic volcanics and intrusions near its top. Road River Group strata overlie the Hyland Group in synclinal keels.

Stratigraphy

The oldest sediments in the map area are part of the lower Hyland Group. A strip of white quartz grit lies north of West Lake, and thin-bedded quartz sandstone, typically with calcareous cement is found south of the Rogue River. The latter rocks, which match the Yusezyu Formation of Gordey and Anderson (1993), are the base of a succession that at the east edge of the map area (column 10 on Fig. 3) consists of limy siltstone with minor maroon and buff shale, overlain by white weathering grey limestone and capped by a greater thickness of maroon argillite (Narchilla Formation, Ibid.). Cores of west-plunging anticlines expose interbedded thin sandstone, siltstone and buff, greenish or maroon shale less than two hundred metres thick

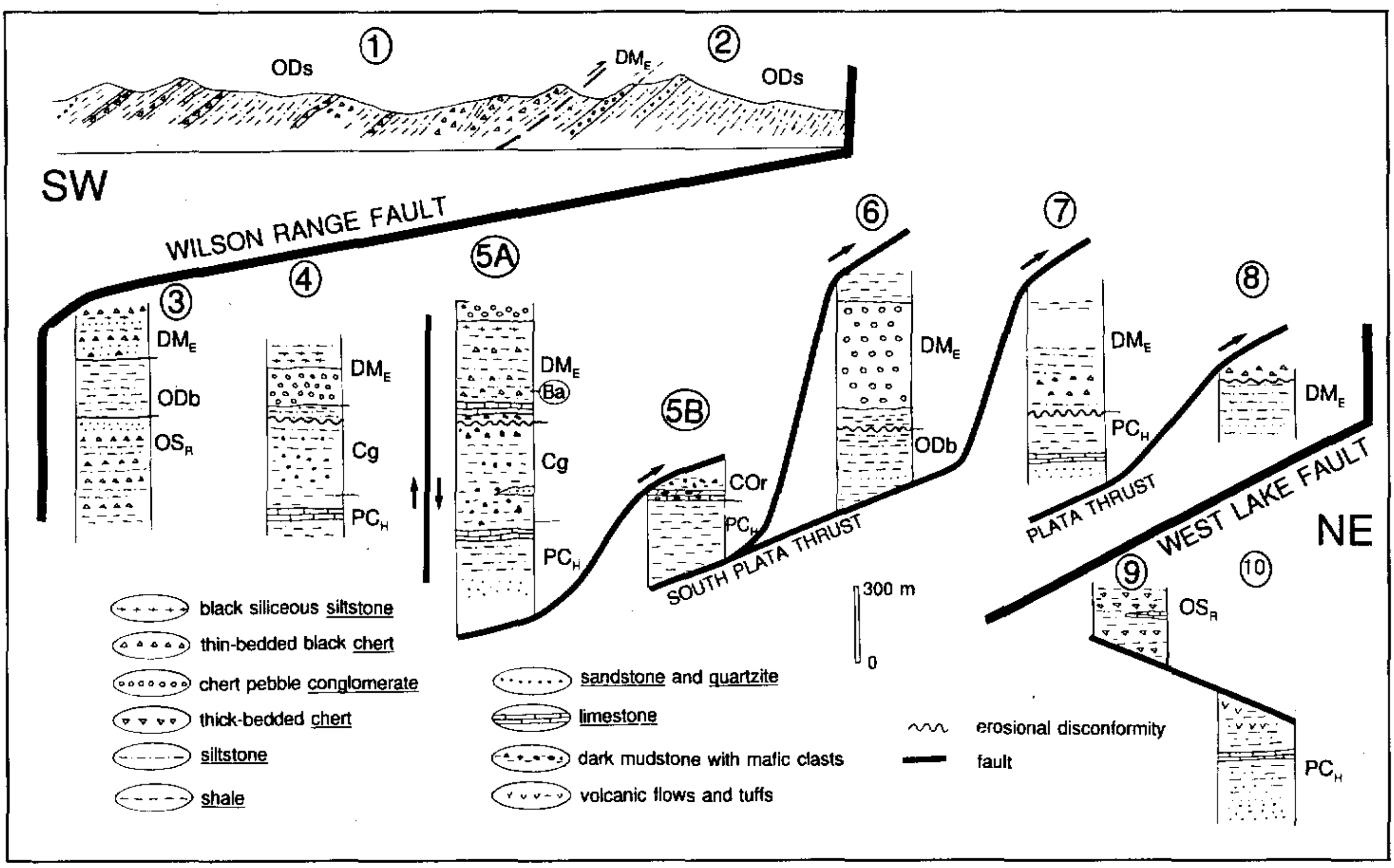


Figure 3: Generalized stratigraphic columns showing the main stratigraphic relationships in West lake map area.

(Fig. 4) beneath the white limestone. This sequence, apparently not present where the Hyland Group was described by Gordey and Anderson (1993) is probably unit Hma in adjacent Niddery Lake map area (Cecile and Abbott, 1992) which will be given formation status (M.P. Cecile, pers. comm., 1993). Chloritic volcanic flows and tuffs overlie, and sills are intercalated with, the uppermost maroon mudstone throughout the area.

Thick-bedded brown weathering chert, which varies from white to grey and rarely black or green on fresh surface, occupies synclines at the west edge and the north edge of the map area. Within the chert are black shale and argillite interbeds that contain Monograptus fauna, indicating that these are Ordovician strata of the Road River Group. In the northern syncline the chert is overlain by brown weathering siltstone and mudstone that characteristically crumbles into pea-size gravel. Rare chert beds define tight chevron folds of this unit.

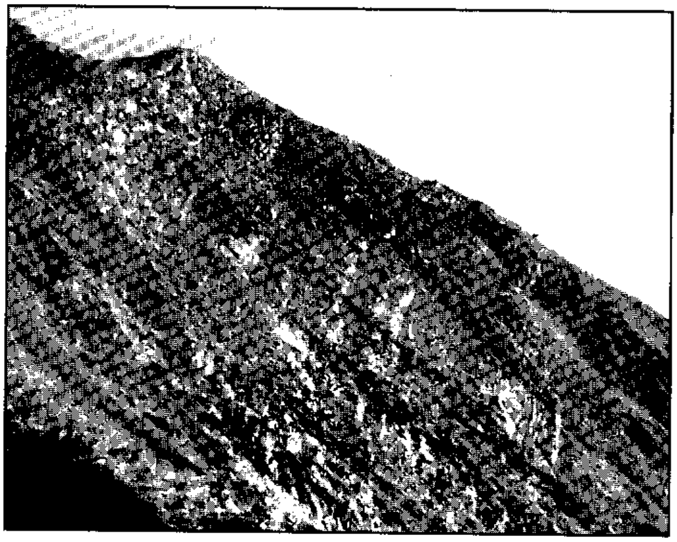


Figure 4: Thin sandstone and siltstone (resistant layers) interbedded with recessive maroon argillite in the Hyland Group below the limestone unit. UTM 64345E, 706210N, about 8 km NW of Plata.

Structure

In this block, tight folding reflects relatively incompetent lithology: the maroon shale and upper Road River rocks are crumpled in upright folds with west and northwest-trending axes. Underlying these folds, however, are gentle south-plunging folds within the Hyland Group. The best visible example is 2 km north of 1 891 m peak where an overturned fold with an amplitude of several tens of metres occurs in an inlier of Yusezyu sandstone. The map-scale folds, however, appear to result from northeastward contraction. Road River strata are downfaulted into the Hyland Group on the northeast side of the syncline north of Rogue River. South of Rogue River the north side of the syncline is bounded by a south-dipping fault contact, including wedges of Road River chert enclosed in footwall maroon argillite (Fig. 5). North-verging folds, repetition of chert beds and slickensides at the Hyland Group contact indicate slippage of the Road River rocks, perhaps as they were caught in the core during formation of the syncline.

2. Between West Lake and Wilson Range Faults

This structural block is a 10 km wide strip trending northwest into a broad valley occupied by West Lake. This block contains the only exposed lower Paleozoic units (COg and COr) as well as several thrust slices offset by north-trending shear shears, not found in adjacent structural blocks.

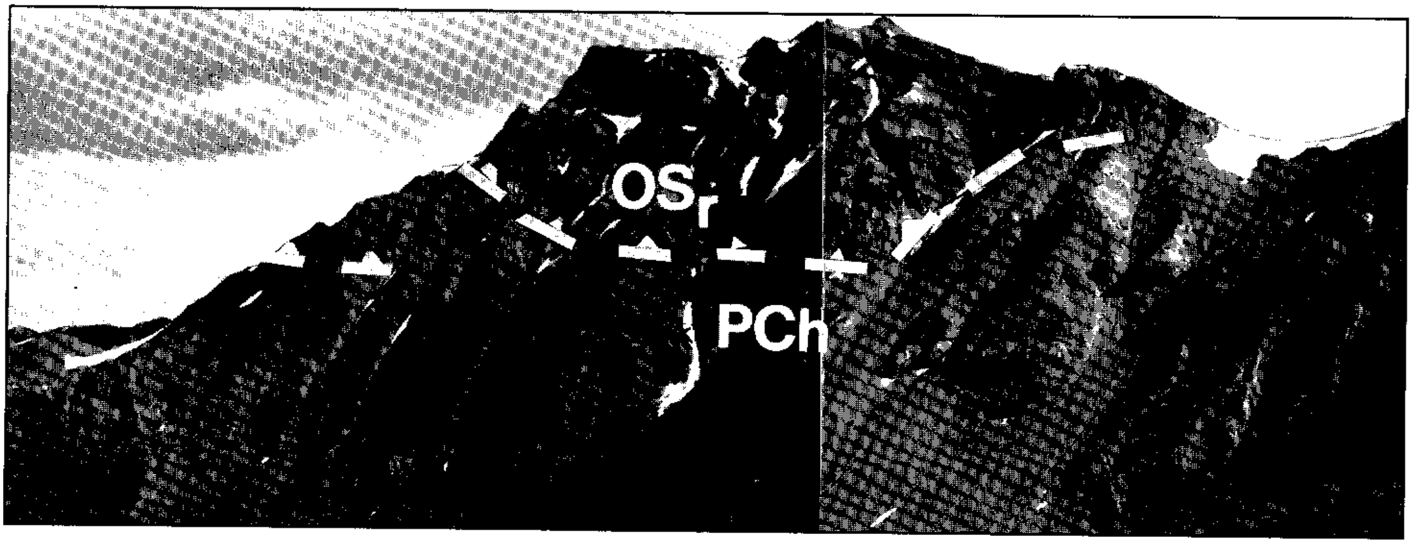


Figure 5: View southeast of Hyland Group limestone (outlined bands) and maroon argillite (PCh) overlain and truncated by black chert of Road River Formation (OSr). UTM 64730E, 706440N, 10.5 km N or Plata.

Stratigraphy

Fine-grained sandstone and maroon argillite, successively overlain by medium-bedded grey limestone and maroon argillite with lesser buff and green shale and siltstone comprise the Hyland Group succession near the PLATA (column 7.) About 5 km southwest of the PLATA the Hyland Group is overlain by two different stratigraphic units in adjacent thrust slices (columns 5a and 5b). Unit Cg comprises massive dark grey and brown mudstone containing mafic and mudstone granules and cobbles, associated with indigo-weathering dark grey-khaki mudstone. Its stratigraphic position and latter rock type resemble that of the Gull Lake Formation (Gordey and Anderson, 1993). The next thrust panel to the north consists of Hyland Group maroon argillite with black shale and thin sandstone (possibly structurally interleaved slices of overthrust Earn Group) overlain by phyllitic siltstone that is increasingly calcareous upward and capped by about 25 m of thin, nodular bedded beige-weathering limestone (Fig. 6). This limestone is diagnostic of the Rabbitkettle Formation (S.P. Gordey, pers. comm., 1993) and is here designated unit COr. In this area thin-bedded black chert (locally including baritic limestone horizons) and siliceous black siltstone of Group unconformably overlie both Hyland Group and unit Cg, and Unit COr is overthrust by Hyland Group.

Figure 6: Thin bedded and nodular grey limestone with dark mudstone partings of the Rabbitkettle Formation. UTM 64170 E, 705330N, about 6 km E of Plata

South of West Lake a different succession underlies the Earn Group (column 3). A cliff-forming exposure that can be traced 8 km contains more than 400 m of black shale and chert, and grades upward to fine-grained black sandstone and white-weathering black quartzite in the uppermost 40 m. This succession is interpreted as Road River Group because it changes to thick-bedded black chert along strike about 8 km to the west. The uppermost quartzite beds contain tight chevron folds but are generally conformable with those of the overlying unit, here called unit ODb. It consists of strongly tectonized brown-weathering siltstone and phyllitic shale several hundred metres thick. No characteristic features distinguish unit ODb, except for common single beds of grey or dark brown sandstone less than 5 cm thick. This succession is disconformably overlain by chert and siliceous black shale of the Earn Group. The age of ODb is uncertain, although south of Johnny Creek the disconformity beneath Earn siliceous black siltstone cuts downward through this unit, suggesting that this unit could be an upper Road River correlative.

Chert pebble conglomerate appears to occur at several stratigraphic levels within the extensive Earn Group of this structural block. Six kilometres west of PLATA it overlies black siliceous siltstone and appears to be more than 400 m thick (column 6). About 10 kilometres west of PLATA it overlies 50 m of dark, indurated siltstone, is about 150 m thick and is overlain by several hundred metres of black siliceous siltstone and shale.

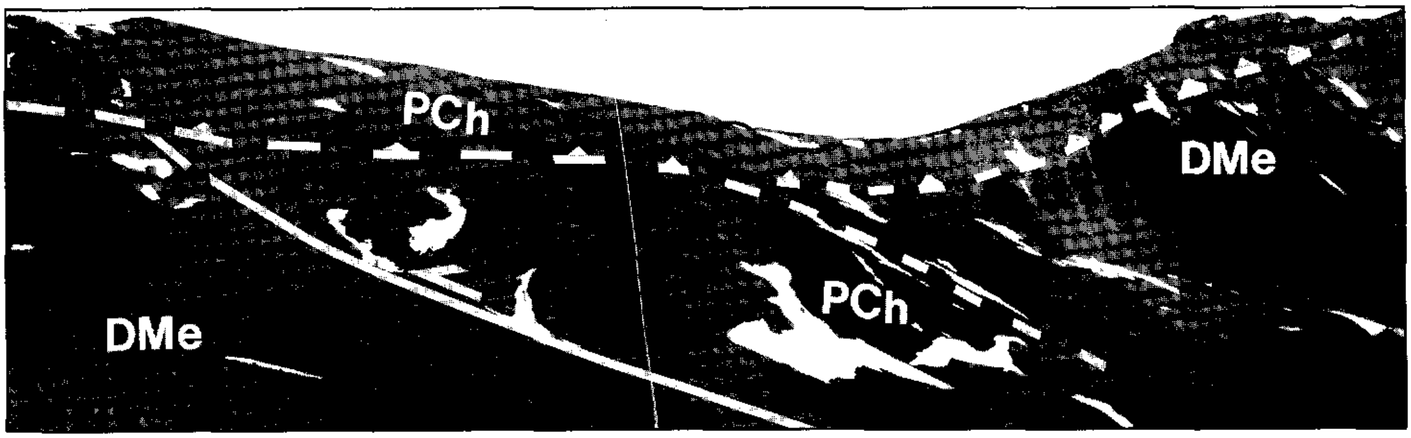


Figure 7: View south at Plata Thrust. Foreground Earn siltstone (DMe) is overthrust by folded Hyland limestone and maroon argillite (PCh). UTM 64635E, 705500N, 200 m SW of Plata #6 vein.

Structure

Almost all strata in this structural block dip moderately southwest, but are juxtaposed by thrust faults and north-trending shears. The Plata thrust (Abbott, 1986) and South Plata thrust (named here) bring Hyland Group rocks over Unit ODb and Earn Group respectively. Both thrusts are parallel to underlying bedding. Limestone in the hanging wall of the Plata thrust is exposed in an overturned fold verging northeast (Fig. 7). Upright folding in the thrust panels produced steep axial planar cleavage in the hanging wall Hyland argillite (Abbott, 1986). At some places in the footwall of the Plata thrust bedding is isoclinally folded and transposed in foliation planes (Fig. 8). Bedding-parallel foliation is common in the belt of Unit ODb, and particularly well developed above quartzite (Road River Formation?) at the west edge of the area (column 3). Several zones of pencil cleavage in the 600 m thick exposure below the Earn Group chert suggest that this unit has been isoclinally folded, although no markers or smaller folds were found.

North-trending faults that offset thrusts and stratigraphic contacts appear vertical with a dextral sense of motion. To the south the faults end abruptly, suggesting that they were transforms or tears that accommodated differential movement of the thrust panels.

Discussion

This block contains rock units stratigraphically overlying the Hyland Group, and also contains extensive Earn Group above a profound regional unconformity. Although not enough information exists to palinspastically restore the area, it appears that the Earn group was deposited upon an uneven surface, or that the older units had been deformed before Devonian erosion. The apparent lack of Road River sediments in this area suggests that this area was a source of chert clastics in the Earn Group conglomerate (Gordey and Anderson, 1993, p. 67), and the tremendous thickness of conglomerate preserved in the centre implies that this are was topographically depressed during Earn deposition.

Figure 8: Foliation (S1) in brown siltstone is axial planar to recumbent north-verging fold of sandstone interbed (outlined) transposed along horizontal foliation. View westward in unit ODb at UTM 64635E, 705570N, 300 m north of Plata #6 vein.

3. South of the Wilson Range Fault

Marker beds in the dark-weathering strata in the southwest third of the map area that can be traced for more than 10 km along strike. The succession, here referred to as unit ODs, is divided near the middle by a conformable strip of Earn Group black siltstone and chert pebble conglomerate.

Stratigraphy

Earn conglomerate is exposed in a tight synclinal ridge at the west edge of the map area, where it is both over- and under-lain by siliceous black siltstone. Along strike 10 km southeast is a lens of similar conglomerate, about 5 km thick, near the ROGUE occurrence, which is in overlying black siltstone and chert. These are the only exposures

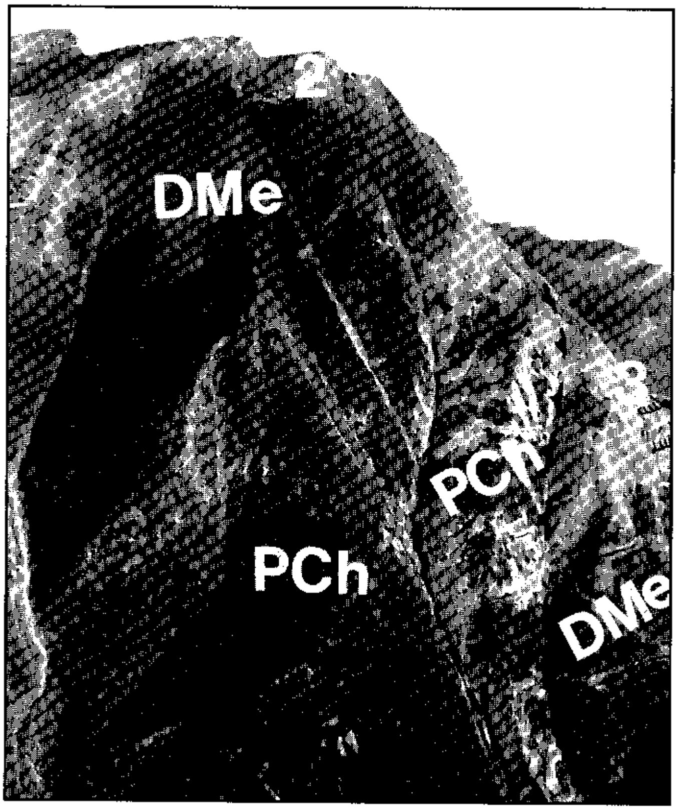


Figure 9: Aerial view looking northwest at the PLATA property. Numbers denote silver-lead veins that were mined between 1976 and 1985. Hyland Group (PCh) sandstone (foreground), limestone (near adit) and maroon argillite (middle right) are thrust over Earn Group (DMe) on right, and unconformably overlain by DMe (left). The normal fault in centre has about 100m south-side down displacement.

of known Earn Group in this structural block, although it may be present further southeast along strike.

The siltstone and phyllitic mudstone succession at underlies DM_E to the north (unit ODs; column 2) contains a prominent brown sandstone-quartzite section about 10 m thick (at Peak 1765 m). This sandstone is a prominent marker which outcrops at the Rogue River and 3 km west, at the same stratigraphic distance below the Earn Group. Below the sandstone the succession is lithologically non-descript, but increases in degree of induration to the Wilson Range Fault.

The succession south of the Earn Group consists of recessive brown siltstone and shale punctuated by rare cliff-forming beds of dark grey or green chert 2–5 m thick (column 1). Less common are thinner beds of light-weathering, dark grey limestone of astonishing continuity, and a single brown quartzite, about 7 m thick in the southwest corner of the map area. No clues to the age of this succession were found, but on the basis of similar lithology, and possible correlation of the brown sandstone with the quartzite markers, it is here included in unit ODs.

Structure

All strata in this structural block are uniformly south dipping: a succession potentially 7 km thick. A ridge spur 2 km west of the 1765 m peak demonstrates that the succession to the south cross-cuts underlying Earn Group strata, and a thrust fault contact is inferred. Thus unit ODs is repeated, with a thin strip of Earn Group at the top of the footwall.

In the northern rocks west of Rogue River a phyllitic foliation is formed by mica growth parallel to bedding planes, and minor structures typically plunge southwest. This part of the block contains complex structures that extend westward and are best exposed in the adjacent map area.

Discussion

The age of unit ODs is critical to resolution of the structure in this region, and numerous limestone and chert beds were sampled to search for recognizable microfossils. It is most likely, however, that this unit is upper Road River Group. The apparent conformity of Earn rocks above strata containing the brown sandstone implies that the Devonian unconformity may be lacking in this area. Perhaps this structural block originated in the basin beyond the extent of erosion that gave rise to the Earn Group.

Igneous Rocks

Chloritic mafic flows and tuffs are intercalated with and overlie Narchilla Formation northeast of West Lake fault. Accumulations as much as 250 m thick underlie resistant knobs in a northwest trend. Flows are massive and some vaguely pillowed; most rocks are green-grey and amygdaloidal. Fine-laminated sand and siltstone beds interpreted as tuffaceous are intercalated with the flows. Metadiorite sills and dykes containing glomeroporphyritic plagioclase outcrop in the maroon shale west of the 1891 m peak. Similar rocks are exposed in adjacent Niddery Lake map area (Unit Ca) where a single archaeocyathid was collected from volcanic breccia (Cecile and Abbott, 1992).

Six biotite latite dykes were located in the headwaters of Johnny Creek. All trend 300° and are vertical or steeply south-dipping. Their white-weathering, kaolinized matrix contains biotite (1–5%), feldspar (0–15%) and quartz (2–10%) phenocrysts. The localized distribution and composition suggests these dykes are related to unexposed granitic intrusions. A less likely alternative possibility is an Early Tertiary age, as the volcanics in southwestern Lansing map area are thought to be (Blusson, 1974).

Mineral Occurrences

The map area hosts the former Plata Ag-Pb-Zn mine, numerous silver, lead, zinc and copper stream geochemical anomalies, and some places are underlain by Cambrian through Devonian rock units whose equivalent formations enclose the stratiform zinc-lead deposits at Macmillan Pass and in the Anvil Range. PLATA (Minfile occurrence 105N #3; Fig. 9) yielded some 2 800 tonnes of hand-sorted ore in 1976, 1983, 1984 and 1985. Abbott (1986) described the geology of this occurrence. Numerous quartz veins occupy open spaces in a 2 x 1 km area underlain by concretionary black siltstone and chert, overthrust by maroon shale unconformably overlain by black shale. One vein crosscuts the unconformity, but is barren in underlying sandstone where intersected by an exploratory adit. A biotite porphyry dyke is adjacent in two vein exposures less than 50 m below the Plata Thrust (Abbott, 1986).

PLATA and nearby INCA (105O #15) are notable because the quartz veins contain galena with high silver content, as well as other silver-bearing minerals. In this respect they recall the Keno Hill district. Although the source of the silver at Keno Hill is unclear, metal zoning of the veins suggests the hydrothermal system was driven by the Roop Lakes pluton, 20 km distant (Lynch, 1986). The PLATA and INCA occurrences are respectively located 8 km southwest and 5 km south of a small granitic plug at Mount Etzel (64°40'N, 131°56'W). Small mineralized veins and hydrothermal alteration are known within the plug (FANGO, 105O #41). Were silver mineralization thought related to this intrusion, favourable structures and open spaces should be investigated within a ten km radius. In the PLATA area more than 20 km of bulldozer trail around ridges was used to locate vein float from slopes above. In this area of abundant talus and friable rocks, this may be an effective exploration method.

Other occurrences in West Lake map area are FLATASA (105N #17) and ROGUE (105N #4). Current claims at FLATASA cover valleys underlain by soft black shale north of the thick conglomerate of the Earn group. Streams draining this shale are anomalous in silver and lead. Near the headwaters, bright green "zinc moss" grows on the banks, and the stream bottom is coated with a white precipitate which probably includes hydrozincite. At least four streams draining this black shale succession (exposed over 4 km across north-facing slopes) have bright orange bottoms coated with iron hydroxide.

The ROGUE claims cover the strip of Earn Group southwest of the Wilson Range fault. Original interest was drawn to three gossanous patches on a spruce forest slope, which probably formed from iron hydroxide seeps. Silt from the adjacent stream is high in zinc (Minfile, 1992, 105N #4), and it is likely that most streams draining the recessive black Earn group shale are similarly anomalous. Diagenetic pyrite cubes, readily found in the black siltstone and chert, were the only mineralization observed.

Stream and Sediment Geochemistry

A lightweight water tester was carried to assess the conductivity and other parameters of streams encountered during geological mapping. We intended to use this simple indication as a rough guide to streams with anomalous metal content, thus improving the efficiency of collecting silt samples. Although drainages in claim groups have been well sampled, the Regional Geochemical Survey of this area (Friske et al., 1991) provided an average of one sample per 10 km^2. Use of the water tester was a pilot project, to determine whether some fill-in sampling could be done during future geological mapping in the Lansing area.

Table 1 shows results from the water tester, and assays for silt samples collected from streams yielding high conductivity readings. In general, water giving a reading higher than 300 contained at least one high metal concentration, although in some cases this was arsenic or cadmium. Conductivity readings are best used in conjunction with pH readings, because acidic waters are likely to contain more dissolved metals. Our water tester (Cole-Parmer model 05556-00) calculates pH through a porous glass-coated electrode; this needed periodic drying which was difficult during wet weather. Nonetheless, conductivity reading remained reliable as indicated by checking the tester with a standard solution at the end of the season. A more thorough test would involve collecting silt at every stream tested to check insoluble metal content in streams with low conductivity.

Conclusions

1. Three distinct stratigraphic sequences, each thickened by folding and repeated by faults, are separated by two regional-scale faults.
2. In the northeast part of the map area Road River chert overlies a Hyland Group succession. Cambrian volcanic rocks are present, but other lower Paleozoic units are missing.
3. In the southwest a thick succession interpreted as upper Road River Group is conformably overlain by Earn Group.
4. Between these faults Hyland Group is overlain by lower Paleozoic units and overlain by Earn Group resting with profound unconformity on all older units. This area contains thrust faults offset by north-trending shears.
5. Silver-bearing quartz veins of the Plata occurrence are probably genetically related to a nearby granitic stock.
6. The black shale near the base of the Earn Group is the likely source of high zinc, silver and lead geochemical anomalies.

Acknowledgements

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#	UTM-East 8V 6-	UTM-North 70-	Cond µS/cm	pH	Ag ppm	Pb ppm	Zn ppm	Cd ppm	Cu ppm	As ppm	Au ppb	Remarks
37	4460	6080	195	7.7								
38	4640	6060	162	-								
40	4595	6000	086	-								
41	4645	5880	277	7.2								
42	4640	5880	157	6.5								
43	4720	5850	060	-								
44	4795	5820	232	-								
45	4680	5610	360	-	15.9	>1%	296	4.9	29	166	10	rusty seepage in trench
46	4680	5615	270	-	2.6	145	51	0.2	34	39	10	Fe-hydrox, swampy
47	4655	5585	350	-	48.8	2460	373	3.8	87	426	50	North drainage from PLATA
48	4650	5540	109	-								seep from trench, #6 vein
49	4585	5345	129	-	1.1	81	199	0.4	108	45	14	SW drainage from ridge below #2
50	4610	5350	642	-	26.1	51	552	1.6	212	57	5	white precipitate in creek, 1365 m
51	4697	5305	460	-								
52	4687	5439	1110	-	2.0	232	> 1%	93.0	24	1087	10	adit drainage below #2 vein
53	4350	5075	213	-								
54	4352	5072	070	-								
55	4310	5480	235	-	0.4	15	156	1.2	62	, 10	18	
56	4315	5500	470	-	1.2	22	97	0.1	45	33	23	rusty seepage
57	4370	5540	370	-								
85	3135	4740	257	4.1	0.7	26	436	3.6	96	21	15	
86	3155	5160	207	6.0	0.1	3	344	<0.1	10	505	8	drainage from gossan
87	3150	5130	238	4.0								
88	3101	5158	315	6.0								
89	3665	4950	174	8.0								
90	3840	5225	274	-	0.2	19	386	1.2	50	11	11	
91	3910	5560	604	7.1								
92	3955	5556	1103	-	0.2	30	34	<0.1	15	2750	6	black shale, "zinc moss", white ppt
93	4150	5655	1245	-	<0.1	3	13	<0.1	5	15	7	yellow ppt, Fe-hydroxide

Table 1: Results of water testing and stream sediment analysis, West Lake map area. Conductivity measured in S/cm using Cole-Parmer Water Test 05557-00; *Atomic Absorbtion analyses by Northern Analytical Laboratories, Whitehorse.*

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