

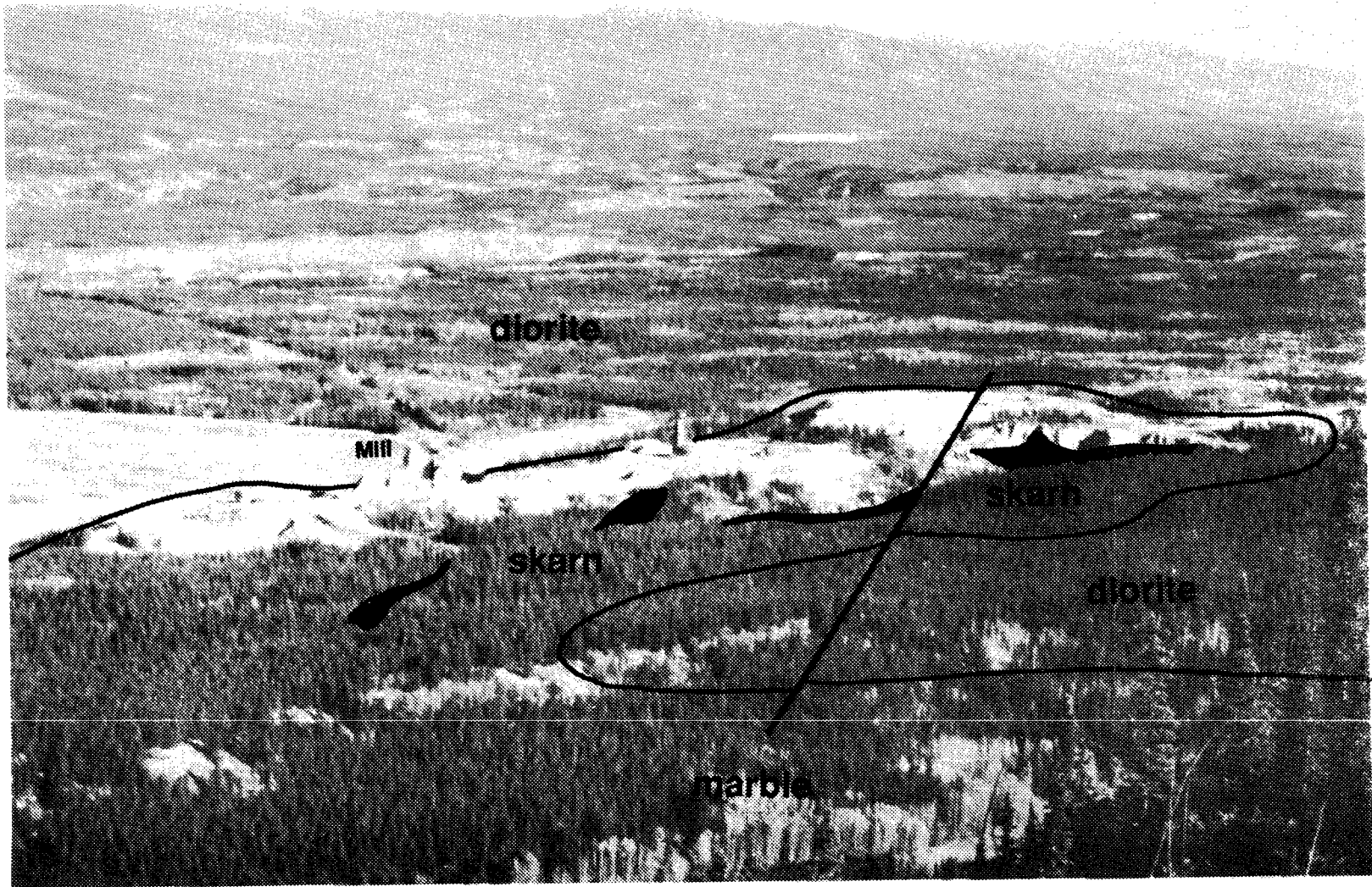
**Indian and Northern Affairs Canada  
Northern Affairs: Yukon Region  
Open File 1989-2**

**GEOLOGY OF  
WHITEHORSE (105D/11) MAP AREA**

by

**C.J.R.Hart and K.S.Pelletier  
Aurum Geological Consultants Inc.**

**This report is available from:  
Exploration and Geological Services Division,  
200 Range Road, Whitehorse, Yukon Y1A 3V1**



**Frontispiece:** View looking southeast across Yukon River valley. Little Chief open pit and Big Chief shaft and mill complex sit on a carbonate peninsula surrounded by diorite of the Whitehorse Pluton. Black patches represent surface exposures of ore. Total production from the Whitehorse Copper Belt exceeds 123 000 tonnes copper, 90 tonnes silver and 7 tonnes gold.

## **PREFACE**

The City of Whitehorse owes its existence to the rocks found there.

Miles Canyon basalt formed the Whitehorse Rapids and thus prevented further upstream travel of steamships and created a need for a transportation terminus. These cataracts have since provided local residents with efficient hydro electricity. Copper mineralization found in the hills west of the Yukon River provided incentive for miners on their way to the Klondike to remain in the area. The deposits have since provided considerable employment and economic benefits to the region.

This report describes geology and mineralization of the of the Whitehorse area. The project was funded under the Minerals Sub-Agreement of the Canada-Yukon Economic Development Agreement, Contract YEDA 01/87.

This report accompanies the Geological Map of Whitehorse Map Area (105D/11)  
by C.J.R. Hart, K.S. Pelletier, J. Hunt and M. Finland.

## ABSTRACT

Geology of the Whitehorse (105D/11) map area was mapped at 1:50 000 scale during the 1988 field season. The map area is in the Teslin Plateau physiographic region.

The map area is underlain by rocks of the Mesozoic Whitehorse Trough which have been intruded by Triassic to Eocene granitic rocks of the Coast Plutonic Complex. Mapping has allowed the development of a new understanding of the facies relationships in the upper portion of the Lewes River Group. Contacts between the Lewes River and Laberge Groups are facies controlled and difficult to map.

The Tantalus Formation was deposited in fluvial braidplains transgressed by marine modified clastic rocks.

Previously unrecognized Eocene volcanics and coeval alaskite are mapped on Ibex Mountain. A small plug of Oligocene(?) felsite represents the first such occurrence east of the Shakwak Fault.

Whitehorse Trough strata were folded about north, northwest-trending axes during middle Early Cretaceous time. The western margin of the Fish Lake Syncline is cut by the Ibex Faults which include a westward verging contemporaneous thrust fault and steep, westerly dipping reverse faults. Northeast-trending faults representing primarily normal displacement cut units as young as Eocene.

Skarns of the Whitehorse Copper Belt containing significant precious metal values are associated with sulphide-rich, bornite-bearing, magnetite skarns emplaced in dolomitic protoliths which have undergone retrograde metamorphism.

## TABLE OF CONTENTS

	page
Preface	i
Abstract	ii
Table of Contents	iii
List of Figures	v
List of Tables	v
<b>INTRODUCTION</b>	
Purpose and Scope of Study	1
Location and Access	1
Glaciation and Glacial Deposits	3
Previous Work	4
Geological Setting	4
Acknowledgements	6
<b>LITHOLOGIC UNITS OF THE WHITEHORSE MAP AREA</b>	
Foliated Granodiorite/Diorite:P <sub>gdn</sub>	8
Whitehorse Trough	
Lewes River Group	8
Povoas Formation:Tr <sub>P</sub>	8
Aksala Formation	10
Annie Member:uTr <sub>A</sub> :	10
Hancock Member:uTr <sub>H</sub> :	11
Mandanna Member:uTr <sub>M</sub>	11
Laberge Group	13
Conglomerate Unit:J <sub>Lcg</sub>	13
Sandstone Unit:J <sub>Ls</sub>	14
Argillite Unit:J <sub>La</sub>	14
Tantalus Formation:K <sub>Tcg</sub>	18
Eocene Volcanic Rocks:E <sub>va</sub>	21
Oligiocene Subvolcanic Rocks:O <sub>f</sub>	21
Miles Canyon Basalt:PP <sub>MC</sub>	21
Coast Plutonic Complex	24
Ibex Granodiorite:Tr <sub>gd</sub>	24
Cretaceous Granodiorite:K <sub>gd</sub>	25
Whitehorse Pluton: <sub>M</sub> K <sub>W</sub>	25
Mount McIntyre Pluton: <sub>M</sub> K <sub>M</sub>	26
Ibex Alaskite:E <sub>al</sub>	27
Jackson Creek Granite:E <sub>gr</sub>	27

<b>STRUCTURAL GEOLOGY</b>	
Folds	29
Faults	29
Ibex Faults	29
Younger Faults	32
<b>ECONOMIC GEOLOGY</b>	
History	33
Setting and Description of Deposits	33
Gold in Whitehorse Skarns	37
Summary	38
Exploration Methods	38
Notes to Prospectors	39
<b>REFERENCES</b>	41
<b>APPENDIX A: Assay and Geochemical Analyses</b>	45
<b>APPENDIX B: Whole Rock Geochemistry</b>	49

## LIST OF FIGURES

	page
Figure 1. Whitehorse map sheet (105 D).	2
Figure 2. Tectonic elements of the southern Yukon and northern British Columbia.	5
Figure 3. Schematic stratigraphic section of the Lewes River Group.	9
Figure 4. Laberge Group conglomerate.	15
Figure 5. Laberge Group argillite unit.	17
Figure 6. Lewes River Group-Laberge Group contact.	17
Figure 7. Ibex Thrust Fault.	30
Figure 8. Models for the formation of the Ibex Faults.	31
Figure 9. Skarn zonation in the Whitehorse Copper Belt.	36

## LIST OF TABLES

Table 1. Table of Formations	7
Table 2. Deposits of the Whitehorse Copper Belt	35

## INTRODUCTION

### Purpose and Scope of Study

Geological mapping of the Whitehorse map area (105D/11) represents the second of a two year 1:50 000 scale mapping program in the western half of the Whitehorse map sheet (105D). The Whitehorse Geological Mapping Project was undertaken by Aurum Geological Consultants, Inc. through a contract funded through the Canada-Yukon Economic Development Agreement (Contract YEDA 01/87).

The project area (Figure 1) includes four 1:50 000 scale map sheets including Alligator Lake (105D/6) and Fenwick Creek (105D/3) map areas (Doherty and Hart 1988), the Carcross (105D/3) and part of the Robinson (105D/7) map areas (Hart and Pelletier 1989) and the Whitehorse map area which were mapped concurrently during the summer of 1988.

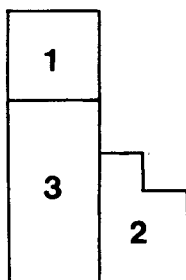
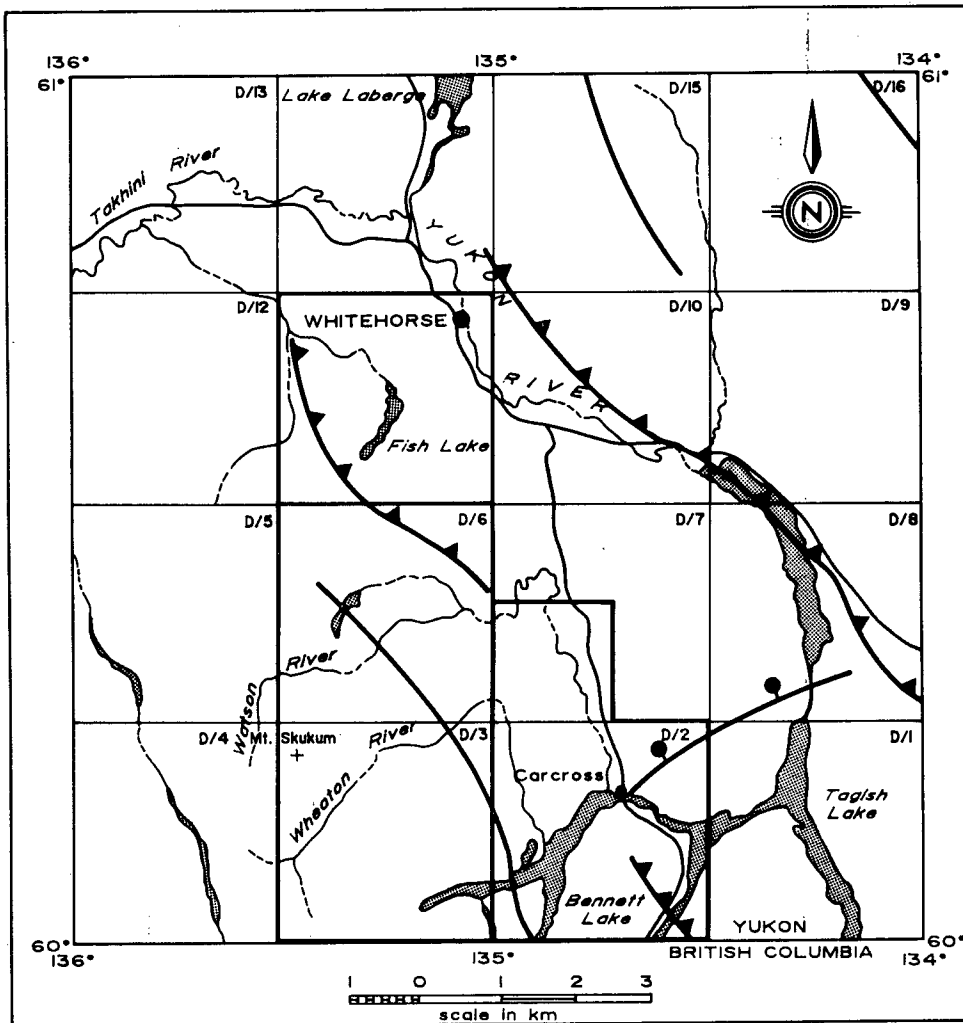
The Whitehorse map area includes numerous copper skarn deposits. The project was initiated to provide 1:50 000 scale geological maps, documentation and correlation of map units, structural analysis, and geological controls and genetic models for mineralization.

Radiometric age dating of volcanic and intrusive rock units collected from the project area are currently being undertaken by Dr. R. L. Armstrong at the University of British Columbia. A few preliminary age dates are cited in this report but supporting data was unavailable at press time. These and other age dates are scheduled for release during the summer of 1989.

### Location and Access

The Whitehorse (105D/11) map area encompasses approximately 800 square kilometers between the Ibex and Yukon Rivers. The City of Whitehorse is located in the northwest portion of the map area.

Good road access is provided by the Alaska Highway, Fish Lake road and Copper Haulage roads. Secondary 4x4 roads allow access to the Whitehorse Coal deposit, Jackson Hill, Firetower Hill and Mount McIntyre areas. Helicopter access was required to map the southwestern quarter of the map area.



1. This report
2. Hart and Pelletier (1989)
3. Doherty and Hart (1988)

**Figure 1.** Whitehorse map sheet (105 D) divided into sixteen 1:50 000 map areas. Bordered area defines project area of the Whitehorse Geological Mapping Project. Dark lines represent major faults: thrust faults have teeth on upper plate; normal faults have dot on downthrown side; other faults, displacement is uncertain.

## Glaciation and Glacial Deposits

The effects of glaciation are responsible for the physical expression of the environment around the City of Whitehorse. Deposits of sand and gravel left by the retreating glaciers have allowed the aggregate industry to prosper and supply the growing needs of Whitehorse.

Several glacial advances covered the Whitehorse area during the Pleistocene epoch. The most recent or McConnell advance, took place approximately 30,000 years ago and moved in a west-northwesterly direction across the map area (Wheeler 1961) and probably originated from the Cassiar lobe.

The slow retreat of the last continental ice sheet approximately 10,000 years ago left remnant ice masses north of Whitehorse, along the east side of the Yukon valley between Whitehorse and Chadburn Lake, in the upper Ibex River valley, near Louise Lake and at the south end of Fish Lake. All these localities are represented by hummocky and pitted terrane, pothole lakes and in some areas extensive esker and kame development.

The stagnant ice masses acted as dams and resulted in the formation of proglacial lakes which are easily recognized by accumulations of lacustrine silt and local numerous raised beaches. A deep lake filled the upper Yukon River valley and southern lakes. Similar lakes formed at other sites in the map area occupied by stagnant ice masses. Silt accumulated to thicknesses of 70 m near Whitehorse. Strand lines in the Ibex Valley have been observed as high as 4600' (1400 m) but are best developed at 4200' (1320 m). Paleo-shorelines above Fish Lake are all below 4000' (1240 m).

During melting of the stagnant ice masses, sands and gravels were deposited in eskers and kames. Outwash channels formed in response to melting of proglacial dams. Lowering lake levels allowed water to flow, and cross-bedded sands and gravels were deposited on top of the glacial-lacustrine silts. Continued lowering of lake levels caused the Yukon River and smaller feeder systems to cut channels into the silt deposits. Short-lived fluvial channels between Mt. McIntyre and Whitehorse emptied into the Yukon River and cut ravines in the silt deposits north of the present location of the Whitehorse airport.

Younger alpine glaciers formed on north and east facing slopes above 5500' (1670 m) were responsible for rejuvenating and carving out cirques and depositing morainal debris. Cirques are developed on Ibex Mountain and Mt. Granger.

## Previous Work

Initial geological investigations of the Whitehorse area began in 1907 when R.G. McConnell (1909) examined the copper deposits west of Whitehorse. Reconnaissance scale mapping of the Whitehorse map area was undertaken between 1922 and 1924 by Cockfield and Bell (1926, 1944). Systematic 1:250 000 geological mapping of the Whitehorse map sheet was begun in 1946 by Fyles (1950), continued by J.R. Johnston in 1947 and completed by J.O. Wheeler during the 1948 to 1951 field seasons (Wheeler 1952, 1961).

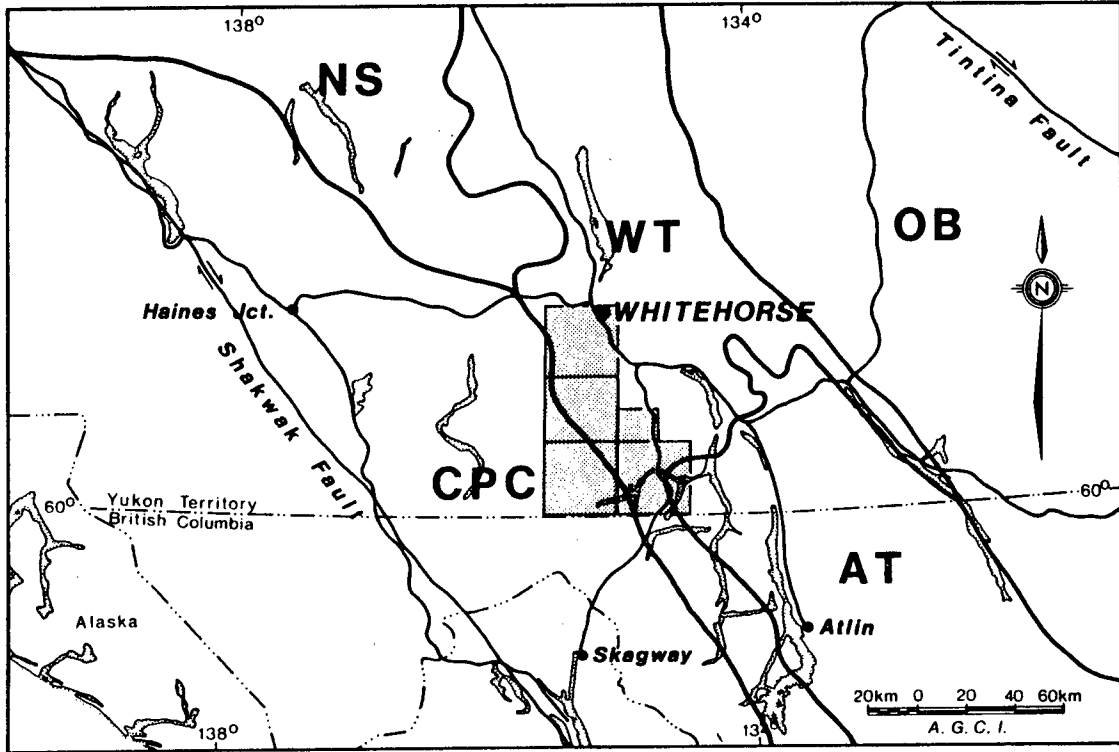
Morrison et al. (1979) obtained radiometric age dates of intrusive rocks of the area and Morrison (1979) compiled information on the metallogeny of the Whitehorse map sheet. Numerous investigations of the deposits of the Whitehorse Copper Belt have been undertaken since 1909 and are referenced later in this report.

## Geological Setting

Whitehorse map area lies at the western edge of the Mesozoic Whitehorse Trough, the northernmost extension of the Intermontane Belt of the Canadian Cordillera (Figure 2). The Trough is underlain by volcanic rocks of the Lewes River Arc, which forms part of Stikinia. It is overlain by a forearc basin onlap assemblage, which forms the fill for the Whitehorse Trough. This is disconformably overlain by a terrestrial siliciclastic unit (Wheeler and McFeely 1987).

The oldest unit exposed in the map area are isolated occurrences of foliated granodiorite associated with Paleozoic Nisling Terrane (Doherty and Hart 1988). Metamorphic rocks of the Nisling Terrane are bounded between the Coast Plutonic Complex and western Whitehorse Trough.

Strata of the Whitehorse Trough and the underlying Lewes River Arc dominate the bedrock geology of the map sheet. Basic to intermediate volcanic rocks overlain by volcanoclastic, carbonate shelf and clastic beach deposits of the upper Triassic Lewes River Group form the arc assemblage. The arc sequence was deposited near the eastern edge of Stikinia, in an island arc basin above a west dipping subduction zone (Tempelman-Kluit 1979, 1981; Reid and Tempelman-Kluit 1987). Fore-arc basin fan-delta conglomerate with associated pro-delta sandstone and siltstone of the Lower and Middle Jurassic Laberge Group onlap the arc assemblage. Fluvial chert pebble conglomerate and associated flood plain and lagoonal facies rocks of the Early Cretaceous Tantalus Formation were unconformably deposited in an intra-suture successor basin during Mesozoic deformation of the Whitehorse Trough (Lowey and Hills 1988).



**Figure 2.** Tectonic elements of the southern Yukon and northern British Columbia. Project area is defined by shaded area. NS-Nisling terrane; WT-Whitehorse Trough; AT-Atlin Terrane; OB-Omineca Belt.

The Whitehorse Trough and Lewes River Arc strata are folded about broad, northwest-trending axes, and thrust faulted in the western part of the map area. Deformation is related to accretion of Stikinia to ancient North America in Middle Jurassic time (Tempelman-Kluit 1979).

Inboard plutons of the Coast Plutonic Complex range in age from mid-Cretaceous to Eocene and include two distinct intrusive suites. Middle to Late Cretaceous biotite and hornblende-bearing granodiorite and quartz monzonite are related to relaxation of regional compressive stress after arc-continent collision (Tempelman-Kluit 1979). Eocene stocks are alkali-enriched biotite granite and alaskite, and often intrude coeval volcanic rocks. Eocene magmatism occurred primarily along the eastern margin of the Coast Plutonic Complex, in response to regional crustal extension.

Plio-Pleistocene Miles Canyon basalt is overlain by glacial deposits throughout the map area, and is locally represented by spatter cones and dyke swarms.

Lithologic units of the map area are summarized in Table 1.

Age dating in progress has resulted in revisions of age determinations for volcanic and plutonic rocks across the project area. Interpretations are subject to re-evaluation as dates become available.

### **Acknowledgements**

The authors would like to acknowledge the assistance of Julie Hunt and Mark Finland who contributed far beyond their Field Assistant status and endured the wettest summer on record. Discussions with John Dickie of Dalhousie University regarding the depositional environment of the Laberge Group were most helpful. Grant Lowey provided useful information about the Tantalus Formation.

Conversations with Al Doherty, who also administered the contract and Roger Hulstein of Aurum Geological Consultants, Inc. are appreciated. Nicole Hulstein drafted the maps and figures and patiently incorporated numerous last minute changes.

Whitehorse Coal Corporation are thanked for road access to the Whitehorse Coal deposit.

Grant Abbott, Minerals Geologist of Exploration and Geological Services, DIAND, contributed his time, advice and ideas throughout the project and his efforts are sincerely appreciated.

### Table of Formations

ERA	PERIOD or EPOCH	FORMATION	UNIT	LITHOLOGY	
CENOZOIC	Pleistocene to Pliocene		<b>Q</b>	Glacial drift, alluvium, volcanic ash	
		Miles Canyon Basalt	<b>PPMC</b>	Basalt flows, minor scoria and interflow sediments	
	U n c o n f o r m i t y				
	Oligocene		<b>O<sub>f</sub></b>	Felsite and subvolcanic dacite	
	Eocene	Jackson Creek Granite	<b>E<sub>gr</sub></b>	Biotite granite	
		Ibex Alaskite	<b>E<sub>al</sub></b>	Alaskite and quartz rich-granite	
		I n t r u s i v e C o n t a c t			
		<b>E<sub>va</sub></b>	Dacite and andesite flows		
MESOZOIC	U n c o n f o r m i t y				
	Cretaceous	Mount McIntyre Pluton	<b>M<sub>KM</sub></b>	Monzonite; granodiorite and qtz-syenite	
		Whitehorse Pluton	<b>M<sub>Kw</sub></b>	Biotite hornblende granodiorite	
			<b>K<sub>gd</sub></b>	Biotite hornblende granodiorite	
		I n t r u s i v e C o n t a c t			
		Tantalus Formation	<b>K<sub>Tcg</sub></b>	Chert pebble conglomerate, sandstone, shale and minor coal	
	U n c o n f o r m i t y				
	Jurassic	Laberge Group		<b>J<sub>Lcg</sub></b>	Granite and volcanic cobble conglomerate
				<b>J<sub>Ls</sub></b>	Feldspathic greywacke and arkose
				<b>J<sub>La</sub></b>	Siltstone, mudstone and minor sandstone
	Triassic	Lewes River Group	Aksala Formation	<b>u<sub>TKM</sub></b>	Volcaniclastic greywacke and arenite
				<b>u<sub>TKH</sub></b>	Limestone and marble
				<b>u<sub>TKA</sub></b>	Andesite and breccia, epiclastic rocks
			Povoas Formation	<b>T<sub>p</sub></b>	Basalt and basaltic andesite flows
R e l a t i o n s U n c e r t a i n					
			<b>T<sub>gd</sub></b>	Hornblende granodiorite	
I n t r u s i v e C o n t a c t					
PALEOZOIC			<b>P<sub>gdn</sub></b>	Foliated hornblende granodiorite, diorite and quartz diorite	

Table 1.

## LITHOLOGICAL UNITS OF THE WHITEHORSE MAP AREA

### FOLIATED DIORITE ( $P_{\text{gdn}}$ )

Foliated diorite occurs in low lying exposures east of Ibex Mountain where it is intruded by Eocene alaskite plugs. Outcrops are massive, grey to white, and spheroidal to blocky weathering. It is a medium grained, well foliated to gneissic, equigranular diorite to granodiorite. The rock is generally white as a result of pervasive argillic alteration of plagioclase. Foliation is westerly or northwesterly striking, but the rocks may have been tilted by younger intrusions.

Similar rocks are associated with metasedimentary rocks of the Nisling assemblage in adjacent map areas (Doherty and Hart 1988; Wheeler 1961). These rocks are considered to be the oldest in the map area and on the basis of field descriptions may be equivalent to the Triassic Klotassin granodiorite suite (Tempelman-Kluit 1976).

A preliminary age date of 190 Ma has been obtained from similar rocks south of the map area (R.L. Armstrong pers. comm. 1989) but may have been reset. Additional dating will be undertaken to confirm the true age of this unit.

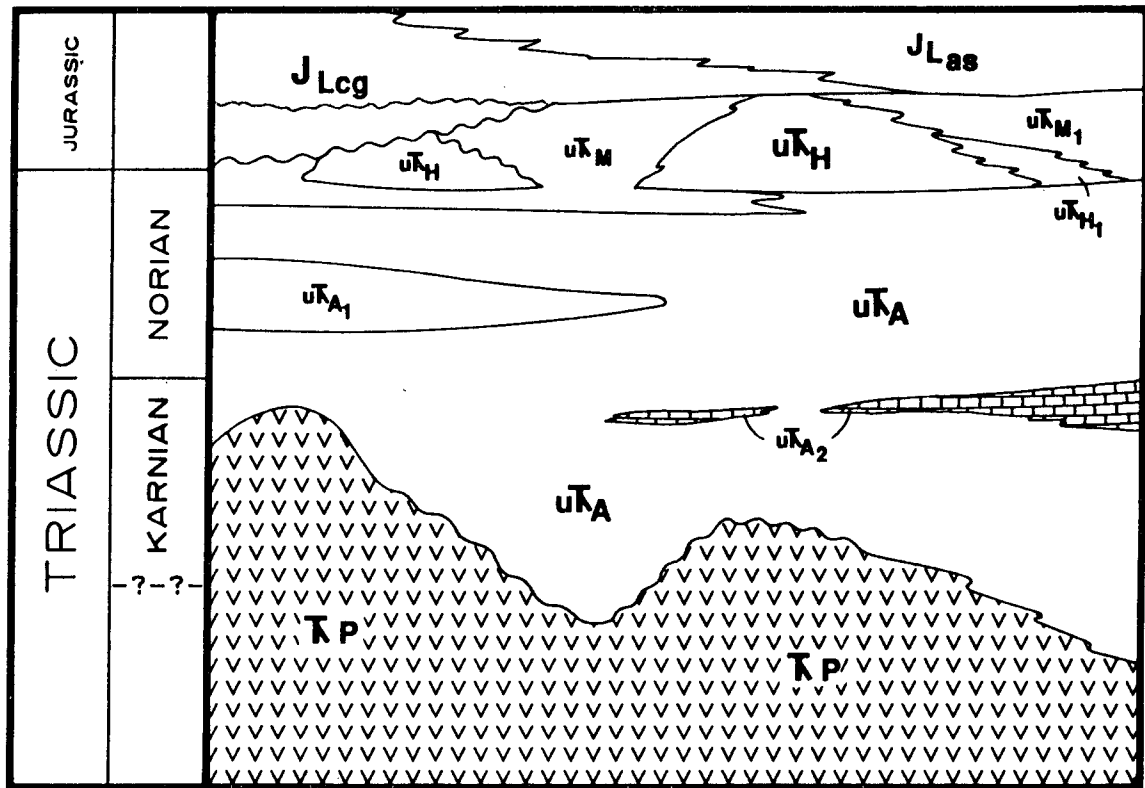
### LEWES RIVER GROUP

Rocks of the Lewes River Group represent a Middle to Late Triassic volcanic and sedimentary island arc assemblage which forms the basal sequence of the Whitehorse Trough. It has been stratigraphically divided into the Aksala and Povoas Formations by Tempelman-Kluit (1984). The Aksala Formation has been further divided into the Annie, Hannock and Mandanna members. The Povoas Formation includes predominantly volcanic rocks which are overlain by epiclastic and sedimentary rocks of the Aksala Formation.

Stratigraphic sections rarely include all units of the Lewes River Group as a result of lateral and vertical facies changes (Figure 3). In general, volcanic rocks of the Lewes River Group are thickest along the western margin of the Trough and thin to the east (Wheeler 1961).

### POVOAS FORMATION (Carnian and older?)

The oldest member of the Lewes River Group is composed of basic lava flows. Povoas Formation basalt is exposed on a lowlying terrace east of Ibex Lake where it is in fault contact with foliated granodiorite ( $P_{\text{gdn}}$ ), and east of the Ibex River where its base is not exposed. It is divided into a massive greenstone unit and an equivalent sheared metabasite unit.



**Figure 3.** Schematic stratigraphic section of the Lewes River Group identifying its facies relationships between members, and with Laberge Group rocks.

### Massive Greenstone Unit ( $Tr_p$ )

This unit is composed of undifferentiated basalt and basaltic andesite flows with intercalated agglomerate, volcanic breccia, epiclastic rocks, volcanoclastic greywacke and minor tuff. The flows are massive, light to dark green and maroon coloured and aphanitic or sparsely porphyritic. Phenocrysts are euhedral augite (5-15%) and plagioclase (5-10%), and range in size from 0.5-1.0 cm. Breccia forms massive, irregular shaped to lenticular beds composed of 35-70% subangular to angular volcanic fragments which average 1 to 10 cm, but may be up to 30 cm in diameter. The groundmass is aphanitic, green or maroon and similar in composition to the flows with which they are associated. They are interpreted to represent both massive flow breccia and slightly reworked epiclastic breccia. Immature, thin to medium-bedded feldspathic greywacke with interbedded airfall tuff occur locally.

### Sheared Metabasite Unit ( $Tr_{pm}$ )

Variably foliated to mylonitic actinolite, pyroxene and chlorite-pyroxene schist equivalent to the massive greenstone unit occurs in a 1 km wide fault bounded zone in the upper Ibex River valley. This exposure resembles those in the Tally Ho Shear

Zone as described by Doherty and Hart (1988) except for the lack of limestone and other sedimentary rocks.

## **AKSALA FORMATION**

### **ANNIE MEMBER (Carnian to Norian)**

The Annie member is a new member proposed by the authors to differentiate coarse volcanoclastic rocks from finer-grained marine sediments of the Mandanna member. It occurs east of the Ibex River, where it ranges in thickness up to 250 m. Its lower contact is not exposed in the map area. The member is composed predominantly of volcanic and epiclastic breccia and conglomerate, intermediate lava flows and minor limestone. It is divided into the following volcanoclastic, intermediate lava flow and limestone units.

#### **Volcanoclastic Unit (uTr<sub>A</sub>)**

The volcanoclastic unit is composed of pebble conglomerate and breccia intercalated with lithic arenite and minor airfall tuff. The conglomerate and breccia intervals are massive to poorly bedded and typically matrix supported but locally clast supported. Clasts are subangular to rounded and compose 40-75% of the rock. They are composed of augite porphyry, subvolcanic dacite porphyry and minor aphanitic volcanic and sedimentary rock fragments. The volcanic fragments were derived from the underlying Povoas Formation or from laterally equivalent lava flows. The matrix is composed of mudstone and greywacke. Volcanogenic breccia and conglomerate grade laterally into, or are interbedded with, immature massive to thick bedded, medium to coarse-grained, red and grey lithic arenite. The framework comprises mainly volcanic lithic fragments and pebbles and plagioclase feldspar. These rocks represent mainly epiclastic material and debris flows, but also in part synvolcanic agglomerates, all derived from nearby volcanoes.

#### **Intermediate Lava Flows (uTr<sub>A1</sub>)**

Andesite and dacite lava flows and associated breccia and epiclastic rocks form sections which are laterally equivalent to or intercalated with the volcanoclastic unit. The flows are light to dark green or maroon coloured and typically plagioclase and hornblende-phyric. Sub- to euhedral plagioclase phenocrysts (0.5 mm to 1.0 cm) comprise up to 30% of the flows. Subhedral hornblende phenocrysts (<5-10%) up to 0.75 cm are commonly partially to completely oxidized at crystal margins and are subsequently red coloured. The flows are both interbedded with and grade laterally into massive conglomerate and breccia beds (<1 m-20 m), composed of angular to subrounded flow fragments in an medium-grained to aphanitic green or red matrix. Like the volcanoclastic unit, these are largely agglomerates and debris flows, but may also represent flow breccias. Thin bedded and laminated red siltstone horizons (<10 m) occur interbedded with flow and breccia deposits.

### **Limestone Unit (uTr<sub>A2</sub>)**

Limestone and limestone breccia occur near the base of the Annie member. The limestone is grey, white to pink coloured, massive with no preserved primary structures, and generally less than 10 m thick. Breccias are composed of angular limestone clasts, ranging in size from a few centimetres to a metre, in a fine-grained calcilutite matrix.

### **HANCOCK MEMBER (Norian)**

The Hancock member overlies the Annie member in the western part of the map area, and interfingers with Mandanna member rocks east of the Fish Lake Syncline. It has a maximum thickness of 600 m, and has been divided into distinct lithofacies units of massive limestone and intercalated limestone and siltstone. This member hosts skarn deposits of the Whitehorse Copper Belt.

### **Massive Limestone Unit (uTr<sub>H</sub>)**

White to light grey weathering, massive and thick bedded limestone (and marble), and minor black, sooty limestone and tan dolostone is distributed throughout most of the map area. Massive limestone is generally recrystallized to form fine to medium-grained marble in which no primary textures are preserved. Locally the massive limestone includes bioclastic horizons and forms patch reefs; fossil fragments include rugose and tabulate (favocites?, syringapora) corals, gastropods, brachiopods and echinoid radiole (Wheeler 1961). Other fossils have been reported by Tozer (1958), Reid (1984), Wheeler (1961) and Morrison (1981). Thin bedded to laminated sooty limestone and dolostone horizons (<1-50m) occur locally interbedded with massive limestone in the Whitehorse Copper Belt area. In a section measured south of Jackson Creek this unit was 220 m thick.

### **Limestone and Siltstone Unit (uTr<sub>H1</sub>)**

Rhythmically bedded white limestone and tan weathering, dark grey, rusty weathering siltstone is stratigraphically equivalent with massive limestone units in the Whitehorse Copper Belt. It ranges in thickness up to 100 m, and is well developed on Jackson Hill. The limestone and siltstone intervals each range in thickness from less than 1 cm to up to 50 cm. Limestone is white, grey to tan colored, and typically has undulatory bedding surfaces. Siltstone horizons are thin bedded to massive. On Jackson Hill, limestone gradually decreases upsection and is absent from the uppermost part of the unit.

### **MANDANNA MEMBER (Late Norian to Simemurian)**

The Mandanna member both overlies and underlies carbonate rocks of the Hancock member. It is composed of immature, crystal-rich volcanogenic sandstone and minor interbedded conglomerate, siltstone and shale. It forms sections ranging up to 125 m thick in the northwest corner of the map, and thin (<20m),

discontinuous units in the Whitehorse Copper Belt beneath Hancock member limestones. The member is divided into three units, each representing facies equivalents distinguished mainly on the basis of grain size and compositional character.

### **Sandstone Unit (uTr<sub>M</sub>)**

Crystal-rich, red, purple, grey and green greywacke and arenite are intercalated with shale and minor conglomerate. The sandstones are medium to thick, planar bedded and massive with thin, red, typically bioturbated siltstone layers (0.5-5 m). They are composed of angular to subangular plagioclase crystals and less abundant subrounded quartz, mafic minerals and lithic fragments. The matrix (30-65%) is composed of intergranular chlorite and white mica. Pebble-rich and coarse-grained sandstone horizons occur locally. The pebble-rich horizons form distinct basal lag type layers which grade upwards into greywacke and finer-grained silty horizons. Pebbles range in abundance from 10-25% and are composed mainly of intermediate volcanic rock fragments.

### **Lithic Arenite Unit (uTr<sub>M1</sub>)**

This unit is distinguished from the sandstone unit by an increase in lithic fragments and by its lighter colour. It is found in the Whitehorse Copper Belt below massive limestone of the Hancock member. The unit is composed of tan colored, immature, coarse-grained lithic-rich arenite with minor pebble conglomerate and lesser facies equivalent dark grey to black coloured, pyritiferous shale. The arenite is massive bedded with scoured bedding surfaces and channels ranging up to 2 m in depth. The conglomerate beds contain angular mudstone rip-up clasts ranging from 5-15 cm in size in an arenaceous matrix.

### **Siltstone Unit (uTr<sub>M2</sub>)**

Maroon and red, thin bedded to laminated siltstone and minor crystal-rich greywacke occurs west of Jackson Lake, where approximately 30 m of siltstone is overlain by 15 m of greywacke. Greywacke beds are composed of 45-60% angular feldspar crystals in a red aphanitic matrix and range in thickness from 1-10 cm. Graded bedding, ripple laminations and bioturbations are common.

### **Age and Interpretation**

The Lewes River Group has returned fossil ages ranging from Carnian to Sinemurian (Wheeler 1961, Reid and Tempelman-Kluit 1987, Doherty and Hart 1988).

The volcanic and sedimentary rocks of the Lewes River Group represent an island arc assemblage and its erosional equivalents, and the base of the arc succession is not reported in the Whitehorse Trough.

Povoas Formation basalt, the oldest exposed rocks of the Lewes River Group, was deposited as massive lavas in a marine environment offshore of a volcanic island arc (Wheeler 1961, Tempelman-Kluit 1974), and is thought to be largely subvolcanic in adjacent map areas to the south (Doherty and Hart 1988, Hart and Pelletier 1989).

As the arc evolved, volcanic rocks became less basic as shown by Annie member andesite and dacite flows. Abundant epiclastic material associated with these volcanic rocks suggests that by this time the volcanic pile was at or near wave base, and the presence of oxidized volcanic rocks suggest that volcanoes locally built above sea level. The rapid lateral facies change seen within the Annie member section on the southwest limb of the Fish Lake Syncline supports this interpretation. Here, massive andesite flows grade laterally north and south to epiclastic breccias and volcanoclastic sediments, and were eroded prior to onlapping of carbonate rocks of the overlying Hancock member.

The upper Aksala Formation represents a shallowing marine sequence in which carbonate deposition competes with clastic sedimentation. Reef, inter-reef and lagoonal sequences (Hancock member) formed concurrently with beach deposits (Mandanna member) on or near eroded volcanoes (Morrison 1981, Reid and Tempelman-Kluit 1987). As a result of decreased detrital input, carbonate deposition became increasingly dominant, and widespread. The shallow sea level in the uppermost Triassic resulted in the onlapping of predominantly beach and tidal flat facies rocks of the Mandanna member, or in erosion of the upper Aksala Formation.

#### **LABERGE GROUP (Hettangian to Aalenian)**

The Lower and Middle Jurassic Laberge Group is the most extensive unit in the map area. The greatest exposure occurs in the core of the Fish Lake Syncline where minimum measured thicknesses of 2400 m have been recorded by Wheeler (1961). Rocks of this group are divisible into three units: polymictic cobble conglomerate; greywacke and arenite; and argillite and siltstone. The units both interfinger with and grade into one another reflecting lateral and upsection facies variations that characterize the depositional history of the Laberge Group.

Contacts with the underlying Lewes River Group are conformable except on the southwest limb of the Fish Lake Syncline where several hundred metres of section are missing and Laberge Group rocks sit unconformably on the Hancock member on the north and the Annie member on the south. Stratigraphic relationships vary due to facies changes and local unconformities.

#### **CONGLOMERATE UNIT (J<sub>Lcg</sub>)**

Polymictic cobble conglomerate intercalated with arenite, greywacke and argillite has a minimum thickness of 1700 m on the southwest limb of the Fish Lake

Syncline. Finer grained horizons range in thickness from a few metres to up to tens of metres.

Conglomerate typically forms well indurated steep sided, hummocky outcrops with distinctive rusty orange weathering surfaces. It is green-grey coloured, thick-bedded to massive, poorly sorted and both clast and matrix supported. The matrix is composed of immature, medium to coarse-grained feldspathic arenite and greywacke.

Clasts are sub- to well-rounded, range from 60% to 85% in abundance and from 1 cm to up to 50 cm (average 8-15 cm) in size. Granitic and volcanic rocks are the most common, including aphanitic to feldspar porphyritic andesite, crystal-rich dacite, biotite and biotite-hornblende granite and granodiorite, leucogranite and quartz diorite. Intrusive clasts become more abundant upsection, and comprise up to two-thirds of the clast population. Sedimentary rock fragments are less abundant, and include greywacke, siltstone and rare chert. Foliated quartzite and quartz-mica schist fragments are both large and abundant (15%) in exposures near Fish Lake but are uncommon elsewhere (Figure 4).

#### **SANDSTONE UNIT (J<sub>LS</sub>)**

Immature, feldspathic greywacke and arenite with minor intercalated argillite and conglomerate forms sections up to 450 m thick east of Fish Lake.

Sandstone is dark grey, medium to thick bedded or massive, medium to coarse-grained, and poorly sorted. The framework is composed of angular to subrounded feldspar (35-60%), quartz (5-15%), lithic fragments (10-30%) and oxidized mafic minerals (5-10%). The matrix is composed of aphanitic to very fine-grained chlorite and white mica. Pebbly sandstone horizons are common, and contain between 10-35% subangular to rounded volcanic, chert and other sedimentary rock fragments. Conglomerate lenses and argillite intervals occur locally.

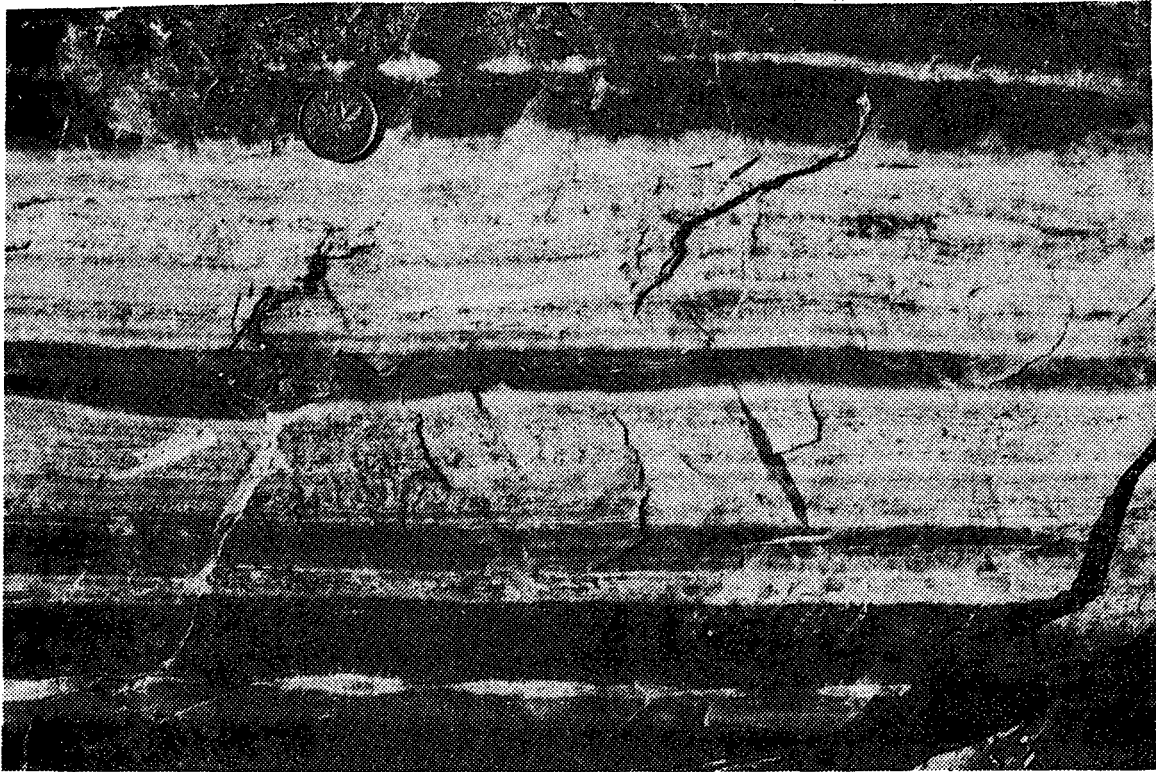
#### **ARGILLITE UNIT (J<sub>La</sub>)**

The argillite unit is composed of interbedded argillaceous mudstone, siltstone and minor fine-grained sandstone. West of Fish Lake it occurs as thin intervals interbedded with conglomerate, while on Mount Golden Horn to the east it is up to 300 m thick.

The argillite is dark rusty red-brown weathering, light to dark grey and green coloured, generally siliceous and contains abundant ammonites. Intercalated sandstone is composed primarily of fine-grained quartz and feldspar. Mudstone and siltstone beds range in thickness from <1 cm to 4 cm, and sandstones from 1-2 cm. Primary features are commonly well exposed in hornfelses sections and include ripple laminations, starved ripples, graded bedding, pinch and swell structures and soft sediment deformation. Graded, alternating arenite-mudstone couplets (Figure 5) compose sections several hundreds of metres thick east of Fish Lake.



**Figure 4.** Massive, unsorted, polymictic Laberge Group conglomerate near Fish Lake. Note foliated quartzite clast left of coin.



**Figure 5.** Rhythmic deposition of sandstone and argillite as Bouma BC(E) turbidite sequences. These couplets often accumulate to thicknesses of several hundreds of metres.

### **Age and Interpretation**

Ammonites collected in the Whitehorse map area by Wheeler (1961) range from earliest Jurassic to early Middle Jurassic. Equivalent Inklin facies rocks in northern B.C. contain Pleinsbachian (Bultman 1979) and Toarcian (Mihalynuk and Rouse 1988) ammonites. Reid and Tempelman-Kluit (1987) report Laberge Group fossils ranging from Sinemurian to Aalenian in age.

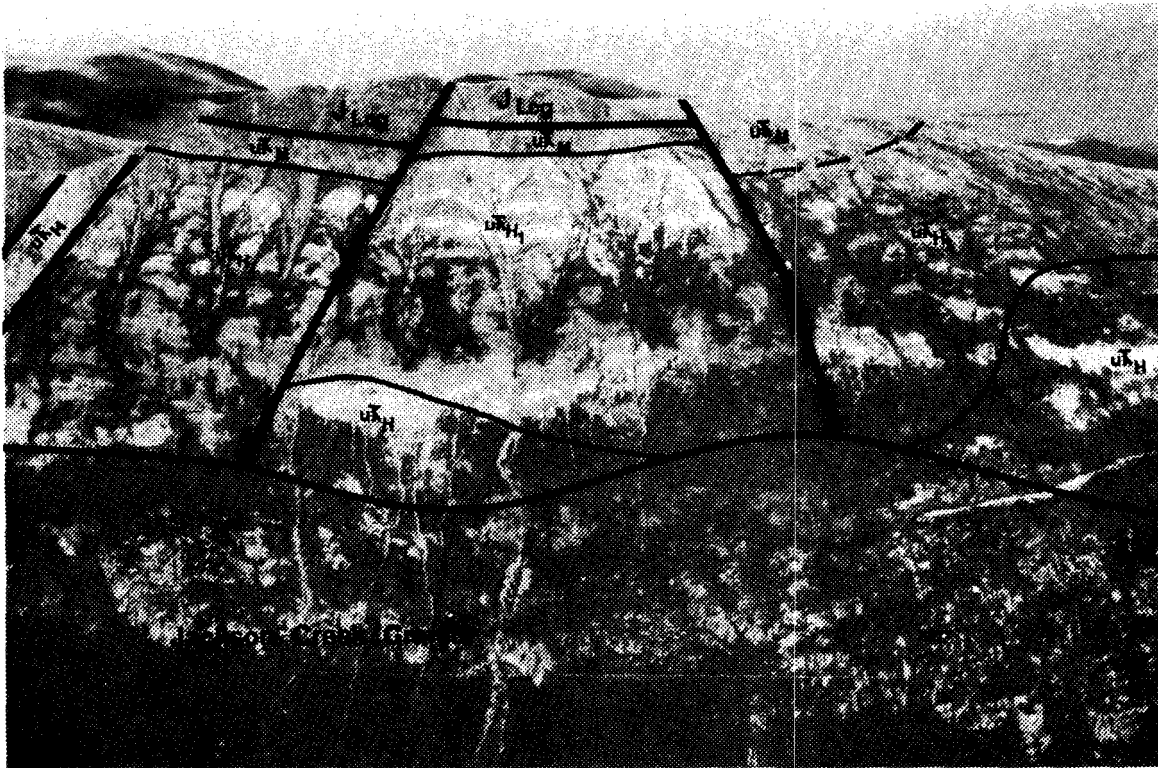
The Laberge Group was deposited in a variety of environments characterized by lateral and upsection facies changes.

Conglomerate was deposited as coalescing marine fan conglomerate and debris flows with lesser deposits in alluvial bars and submarine channel complexes as indicated by planar tabular cross-bedding and extensively scoured bases respectively. Massive feldspathic greywacke and arenite were deposited basinward and above the fan complexes. Low angle and planar stratified sandstone occasionally contains magnetite laminae indicative of beach facies. Graded sandstone-mudstone couplets are representative of Bouma BC(E) turbiditic sequences (Dickie 1988a) deposited in distal environments.

Proximal to distal facies relationships are well documented in the map area. West of Fish Lake, conglomerate predominates, but east of Fish Lake sandstone content increases progressively until argillaceous rocks dominate near Mount Golden Horn.

The progressive vertical increase in granitic clasts represents deeper erosion of the source arc. The high degree of rounding and sphericity of the clasts probably took place in braided fluvial systems subject to periodic flooding which may have acted as the triggering mechanism for the massive debris flow conglomerate and greywacke.

The contact between the Laberge Group and underlying Lewes River Group is problematic. In much of the map sheet the contact is conformable (Figure 6). However, on the southwest limb of the Fish Lake Syncline hundreds of metres of section have been removed by erosion and Laberge Group unconformably overlies Povoas Formation of the Lewes River Group.



**Figure 6.** Transition between Lewes River Group and Laberge Group sedimentary rocks as exposed on Jackson Hill.

The Lewes River/Laberge Groups contact is facies controlled and therefore isn't always represented by the same lithological sequence. The contact has previously been determined as either the top of the highest carbonate (Hancock member) or the lowest granite clast-bearing conglomerate. Detailed mapping has indicated that in many places, shallow water sandstone (Mandanna member) occurs both above and below the carbonate. As a result, Mandanna member sediments above the carbonate have previously been mapped as belonging to the Laberge Group.

Laberge Group conglomerate is often gradational with the Mandanna member, or sandstone or argillite may be deposited as facies equivalents of the conglomerate. Both scenarios make the contact between Lewes River and Laberge Groups indefinite.

### TANTALUS FORMATION ( $K_{Tcg}$ )

Lower and middle Cretaceous clastic sediments of the Tantalus Formation are exposed in a 0.5 km wide, east and northeast-dipping, fault bounded slice extending from the east slope of the Ibex River southward into the adjacent map sheet (Alligator Lake, 105D/6). Although the base of the Formation is not exposed in the map area, it unconformably overlies both Whitehorse Trough and Nisling Terrane rocks in the southernmost Yukon (Doherty and Hart 1988; Wheeler 1961).

A section south of the map area (at Whitehorse Coal; YEX No. 105D-41) is estimated to be 670 m (Bremner 1989). A compilation of measured sections returned a minimum thickness of 430 m (J. Hunt, unpublished data).

The Tantalus Formation comprises approximately equal amounts of conglomerate and sandstone to shale and siltstone. Dark grey to brown weathering, massive to thick bedded, clast supported pebble conglomerate forms resistant, well indurated outcrops. Clasts are composed of well-rounded, 1-4 cm pebbles of grey, black, grey-blue and white chert and quartzite with minor quartz. Conglomerate commonly grades upsection to poorly indurated gritty sandstone composed of grey, black and white chert and quartz.

In general, the sandstones are brown and contain a higher percentage of lithic and feldspar clasts. They are less gritty and poorly indurated. Shale, siltstone and sandy siltstone is well bedded, black or dark grey, fissile and often contains abundant carbonaceous plant fragments. Some exposures also contain impure coal layers.

Three thick, fining upwards fluvial sequences are exposed on the east slope above the Ibex River. Channel-fill conglomerate forms scour based lateral-accretion deposits which grade up to coarse-grained sandstones representing gradual channel abandonment. Vertical-accretion deposits are represented by mud and siltstone which contain numerous plant fragments. Coal is not found in significant amounts within this section.

Exposures southeast of Mt. Granger, near and at the Whitehorse Coal locality have been examined by Bremner (1989) and Hunt (1989). Sediments there are less well classified than those described above. Conglomerate has sharp lower contacts with finer grained rocks and coal beds, scours, rip-up clasts and lag deposits are common. Conglomerate is massive and often contains a sandy matrix. Trough cross-bedding is rare in the conglomerate but more common in the overlying sands which also contain planar cross-stratified facies. Thin beds of magnetite sands are associated with this facies.

Siltstone, mudstone and coal were deposited along with sandy layers during periods of overbank flooding until succeeded by higher energy deposition of massive sandy conglomerate during channel migration, flooding or storm events. Most facies sequences are incomplete and have been terminated prematurely by massive conglomerate deposited during periods of high discharge. Only those sections capped by coal horizons are considered complete.

Examination of palynological samples by Lowey (1984) indicates a dominance of terrestrial palynomorphs with rare marine dinoflagellates. The Tantalus Formation is therefore interpreted to be paralic in origin (Lowey and Hills 1988).

### **Coal**

Six separate coal horizons have been described in the Whitehorse exposures of the Tantalus Formation (Bremner 1989). Two distinct coal seams of anthracite (random reflectance 2.98%; Hunt 1989), each less than 2 m thick are exposed in a creek outcrop at the Luscar coal occurrence (YEX No. 81). They appear to be equivalent to the upper and lower coal seams of the Whitehorse Coal deposit and are possibly continuous with coal seams exposed on Coal Ridge and Double Mountain. If so, these coal horizons have a strike length of 10 km. The coal seams are contained in mudstone and siltstone which are considered by Bremner to have been deposited in floodplains.

### **Interpretation**

The Ibex Valley section represents a meandering fluvial system. Outcrops exposed further south, near the Whitehorse coal deposit indicate a more complex environment, part of which is similar to those found in distal gravelly braided fluvial or braidplain environments as described by Rust and Koster (1984).

Some aspects of the local sedimentology indicate the presence of beach facies and possibly storm generated transgressive barrier island successions. A gravelly barrier island model (Rahmani 1983; Reinson 1984) would provide a back barrier (lagoonal) facies in which thin, laterally extensive coal deposits could be deposited. Such environments could also account for the presence of marine dinoflagellates in paralic environments. Further sedimentological and palynological study is required to definitively determine the depositional environment.

Paleoflow indicators measured by the authors suggest a northeasterly source which partially supports a northwest to northeasterly source proposed by Bremner (1989). Doherty and Hart (1988) have suggested Cache Creek chert of the Atlin Terrane as a potential source for the Tantalus Formation, and Lowey (pers. comm. 1987) has suggested multiple source areas including the Anvil Range Group (Lowey and Hills 1988).

The Tantalus Formation was deposited in a marine accessible, intra-suture successor basin developed during Mesozoic deformation of the Whitehorse Trough (Lowey and Hills 1988).

#### Age

Fossil collections from the Tantalus Formation at Tantalus Butte near Carmacks previously classed as Jurassic (Wilson 1916) are described as definitely being Lower Cretaceous in age (Cockfield and Bell 1944). Palynomorphs collected from the same locality by Lowey (1984) defined an Albian (middle Cretaceous) age for the strata.

Tantalus Formation exposed in the Whitehorse map sheet (105D) has been involved in Cretaceous deformation. The 116 Ma Whitehorse Pluton has not (Morrison 1981) and therefore Tantalus Formation was deposited during pre-middle Cretaceous time.

## **EOCENE VOLCANIC ROCKS ( $E_{va}$ )**

Dark grey to black vitreous felsic volcanics form the roof of the Ibex Alaskite on Ibex Mtn. in the southwestern corner of the map-sheet. Most of the unit is massive although flow banding is apparent in some exposures. Textures grade from fine-grained to porphyritic with crowded phases containing up to 40% plagioclase and 5% hornblende phenocrysts. This unit is intruded by the Eocene Ibex Alaskite and associated dykes.

### **Age and Interpretation**

Similar rocks in the Alligator Lake map-area are considered by Doherty and Hart (1988) to represent a volcanic cycle predating Middle Eocene volcanic activity at the Mt. Skukum Complex. This unit is older than (or coeval with) the 58 Ma Ibex Alaskite.

These rocks are (probably) dacitic to trachytic in composition and formed as a small sub-volcanic intrusion or thick proximal flows.

## **OLIGOCENE(?) FELSITE ( $O_f$ )**

A small circular exposure of blocky, resistant, orange-brown weathering felsenmeer is exposed on Hill 6108. The unit contains medium-grained orange felsite and olive green pyroxene(?)phyric dacite(?). Both rock types are somewhat porphyritic and have siliceous aphanitic matrixes. The perimeter of the hill is slightly hornfelsed and may have been modified by faults associated with its intrusion. A 3 m thick rhyolite dike is found along its southern margin.

Extrusive textures were not found, leading the authors to suggest it is intrusive or sub-volcanic in nature. The age of this unit has been radiometrically determined at 33 Ma (R.L. Armstrong pers. comm. 1989; K-Ar method). Oligocene igneous rocks are previously unrecognized east of the Shakwak fault and as a result, this determination is being re-evaluated. The significance of this unit is unknown.

## **MILES CANYON BASALT ( $PP_{MC}$ )**

Miles Canyon Basalt form steep sided butte-like exposures or (where covered in glacial drift) steep talus-covered cliff faces. The most laterally extensive exposure in the map area is between the Whitehorse hydro plant and the area east of the Whitehorse Copper mine. Most exposures occur as erosional remnants and occupy  $<1\text{km}^2$ . These are located between Mts. Granger and Golden Horn, on the plateau between Fish Creek. and the Ibex River, a cliff west of Ibex River, and north of Jackson Hill. These rocks are the youngest in the area and unconformably overlie all others. They have previously been described by Fyles (1950), Wheeler (1961), Eiche (1985) and Doherty and Hart (1988).

Weathered outcrops are brown weathering and commonly covered in a conspicuous orange lichen while fresher outcrops are a hematitic dark-red colour. The basalt forms columnar jointed, black or grey, amygdaloidal and vesicular, sub-aerial and submarine autobrecciated and pillowed basalt flows. The basalt is typically aphanitic with locally visible trachytic feldspars or olivine phenocrysts. Amygdules are mainly calcite but also include chlorite and white zeolites. Scoria is common and is especially thick near Copper Cliff. Associated dykes are massive and dark weathering, 1-3 m wide and occur in small swarms of 3 to 10 dykes.

Flows were deposited unconformably on unconsolidated (glacial?) material which is commonly incorporated into basal units. Drilling near Copper Cliff intersected a 22 m section of basalt overlying 23 m of overburden (INAC 1988, p. 129). Most outcrops appear to include several thin (2-3 m) flows and at Miles Canyon at least 6 individual flows are recognized. Some flows are intercalated with sands, gravels or peat layers (Wheeler 1961).

Estimated thicknesses range from 30 m at Miles Canyon (Dawson 1889) to 55 m at Pass Lake.

Vertically radiating columnar joints in exposures 100 m downstream from Miles Canyon have been interpreted by Wheeler (1961) as representing a feeder since joints forming perpendicular to the cooling surface would require a hump to exhibit the radiating pattern. Alternatively, since the lava was deposited on an irregular surface, lava could pool in a depression and remain hot longer at this point and hence raise the cooling surface and allow fractures to radiate from the surface inward through progressively cooler concentric horizons.


The thickest exposures in the area are at Copper Cliff where notable accumulations of scoria suggest a vent nearby. Swarms of thick dykes trend northeasterly under the flows and may be radiating from a vent located on the north flank of Mt. Golden Horn. This is the interpreted source of the Miles Canyon flows.

### **Age and Interpretation**

Miles Canyon Basalt near Ixex Mountain has been dated at 2.4 Ma (R.L. Armstrong pers. comm. 1988). Equivalent Selkirk Group lavas in central Yukon have returned K-Ar ages of  $1.08 \pm 0.05$  Ma (Hughes 1987) and older. Exposures in the map area either pre-, or interglacial.

Several exposures of Miles Canyon Basalt are located at high elevations (above 5000') near the head of the Ixex River, but are not found in the Ixex Valley where they should have accumulated. They may represent numerous different vents, or remnants from a single source if flows crossed valleys over glaciers and were thus prevented from flowing into the valleys and remain exposed at topographically high levels.

Flows found at topographically low levels (ie. Miles Canyon) may have been extruded during interglacial periods.



Miles Canyon basalts in the Whitehorse area are overlain by Pleistocene till and proglacial sediments and are therefore either pre- or interglacial. It follows that at the time the basalt was deposited, the Yukon River valley existed at or near its present level, and the presence of pillows near the damsite (previously Whitehorse Rapids) suggests that water filled the valley at that time.

Olivine and spinel-lherzolite xenoliths (Eiche 1985) found in some flow units suggest a deep mantle source.

## COAST PLUTONIC COMPLEX

Recent mapping in the project area has defined approximately 20 different plutonic units in the Coast Plutonic Complex (Doherty and Hart 1988, Hart and Pelletier 1989). They range in age from Late Triassic (or older?) to Eocene and their morphological and mineralogical characteristics vary according to their age.

The actual age of the foliated to gneissic hornblende granodiorite to diorite unit is unknown but is suspected to be Paleozoic. If this suspicion is realized, the unit precedes the development of Coast Plutonic Complex and is not a member.

Triassic intrusions form large concordant batholiths of medium- to coarse-grained, megacrystic potassium feldspar granite to granodiorite which may be weakly foliated. Middle Cretaceous intrusions are elongate, northwest trending plutons commonly longer than 10 km and composed of medium grained hornblende granodiorite to diorite. Late Cretaceous to Paleocene intrusions are large and may be either circular or elliptical in plan. They are characterized by a predominance of biotite over hornblende as the primary mafic mineral and coarsely crystalline granite to quartz monzonite with megacrystic perthitic pink feldspar. Eocene intrusions form small (diameter < 5 km), high-level discordant, alaskite or leucogranite stocks with characteristic smokey quartz-eyes and very few mafic minerals.

### IBEX GRANODIORITE ( $Tr_{gd}$ )

Light orange-brown, spheroidal weathering, closely jointed, medium- to coarse-grained hornblende granodiorite to diorite outcrops along the east slope of the upper Ibez River valley. Hornblende occurs as dark green agglomerated phenocrysts which are strongly altered to chlorite. It composes up to 50% of the rock, but averages about 35%. Biotite is rare. Quartz ranges from approximately 20% to non-existent and is often difficult to distinguish from plagioclase which is typically translucent pale grey or blue in colour.

The unit is a 7 km long, 1 km wide and fault bounded. It is bounded to the east by Cretaceous Tantalus siliciclastic rocks and to the west by Triassic (or older?) mylonitic chlorite augite schist. Neither unit shows evidence of contact metamorphism or contains dykes of the intrusion. The contacts, although covered, are assumed to be faults as they are parallel to other known faults in the area. Alternatively, the east contact may be unconformable with Tantalus clastic rocks. Fractures in the Ibez granodiorite are north-trending and striae show evidence of strike slip motion.

The age of this unit is unknown although the general weathering and alteration characteristics differ from Cretaceous granitic rocks. Very similar rocks have been found as clasts in the Jurassic Laberge conglomerate giving rise to speculation of a Triassic age.

## CRETACEOUS GRANODIORITE ( $K_{gd}$ )

Massive, dark grey weathering, medium- to coarse-grained biotite-hornblende granodiorite is exposed along the western margin of the map area. Hornblende is commonly euhedral and dominant over biotite. Xenolithic phases are not uncommon. This unit is variable in grain-size, percent and proportions of mafic minerals and degree of alteration. Some exposures are weakly foliated.

The unit resembles the Mt. Anderson granodiorite of Doherty and Hart (1988) which was dated at  $119 \pm 5$  Ma (Zircon U-Pb method). It is part of a middle Cretaceous suite of granodiorite which is extensive in its distribution throughout the Coast Plutonic Complex. It is similar to the Whitehorse Pluton which is also middle Cretaceous in age.

## WHITEHORSE PLUTON ( $MK_w$ )

The Whitehorse Pluton belongs to the mid-Cretaceous plutonic suite, is 27 km long, approximately 6 km wide and trends northwest across the northeast portion of the map area. It intrudes the Lewes River Group along its north, west and south margins and alluvium of the Yukon River valley covers the eastern margin. Government and industry aeromagnetic surveys define a steeply dipping eastern contact beneath the suburb of Riverdale. Drilling has indicated the western contact to be steep or locally overhanging while the north and south ends dip shallowly outward (Morrison 1981). The abundance of flat lying pendants near the west margin suggest that the shoulder of the batholith is exposed along the west margin.

Small portions of the Whitehorse Pluton are exposed on Jackson Hill.

The pluton's interior is massive, uniform, medium-grained, equigranular biotite hornblende quartz monzonite to granodiorite. Margins are typically xenolithic and transitional to coarser grained hornblende quartz diorite with discrete diorite and gabbroic phases. Mafic phases often contain subhedral hornblende aggregates with clinopyroxene cores. Accessory minerals include sphene, apatite, magnetite and zircon. Muscovite was found in quartz monzonite 1 km south of the Little Chief deposit. Local saussuritisation or chloritic alteration of mafic minerals is common. Epidote filled fractures are common peripheral to areas of local alteration or skarns.

## Age and Interpretation

The Whitehorse batholith intrudes rocks as young as middle Jurassic and is cut by the younger Mt. McIntyre pluton. Wheeler (1961) interpreted the Whitehorse pluton as belonging to a mid-Cretaceous granodiorite suite. Morrison et al (1979) obtained a whole-rock Rb-Sr isochron which defined a mid-Cretaceous age of  $116 \pm 2.0$  Ma. This was supported by K-Ar hornblende-biotite mineral pair ages

between  $108 \pm 5$  and  $116 \pm 4$  Ma. A sample has been collected for U-Pb zircon dating by R.L. Armstrong (Univ. of British Columbia).

Major element analysis undertaken by Morrison (1981) indicates the pluton to be a slightly alkali enriched calc-alkaline I-type granite comparable to those found in orogenic suites of island arc terranes.

### **MOUNT McINTYRE PLUTON, (MK<sub>M</sub>)**

The Mount McIntyre pluton is located in the southeastern part of the map area where it forms a 12 km long, oblong body extending from Mount McIntyre southward to Mount Golden Horn. Two related stocks occur to the southwest, on Mount Granger and near Coal Lake. Three distinct compositional and textural phases occur in the Mount McIntyre Pluton and are designated separately on the map. The Mount McIntyre Pluton and related stocks intrude mainly Jurassic sedimentary rocks of the Laberge Group and the Whitehorse Pluton on the east. It also intrudes upper Lewes River Group in the area where the two plutons are separated by the thin wedge of sediments forming the Whitehorse Copper Belt.

The western margin of the pluton comprises fine-grained monzonite porphyry and medium-grained granophyric quartz monzonite. It is composed of plagioclase phenocrysts (25-35%) in an aphanitic to fine-grained pink matrix composed of intergranular potassium feldspar, plagioclase, and biotite. Spacially related to the porphyry are zones of very fine-grained, white to light pink and red quartz monzonite containing 20-35% accicular hornblende phenocrysts (0.5-1.0 cm). To the south, the porphyry grades to medium-grained quartz monzonite composed of equigranular plagioclase (40-50%), potassium feldspar (25-30%), quartz (5-10%), biotite (10-15%) and hornblende (<2-5%). This phase also forms the small stock west of Coal Lake and the northern part of the Mount Granger stock.

Medium to coarse-grained, white weathering biotite hornblende granodiorite and quartz diorite (MK<sub>M1</sub>) form the north and east parts of the pluton and the southern part of the Mount Granger stock. This phase of the pluton is relatively homogeneous throughout, composed of equigranular plagioclase (55-65%), quartz (<5-15%), hornblende (15-30%) and hornblende (<2-5%). This phase contains dykes and pods of porphyry phase (MK<sub>M</sub>) throughout.

Grey-blue, medium-grained anorthositic, biotite quartz syenite (MK<sub>y</sub>) occurs as a small phase near the southern margin of the Coal Lake stock.

### **Age and Interpretation**

Dykes of Mount McIntyre pluton cut granodiorite of the Whitehorse pluton. Such a relationship is supported by hornblende K-Ar dates of  $97.3 \pm 3.3$  and  $105 \pm 4$  Ma obtained by Morrison et al. (1979). The older of the two dates was obtained

from the granodiorite border phase of the Mount McIntyre Pluton. Both dates are ~~older~~ than those from the Whitehorse Pluton.

*younger*

Morrison et al. (1979) indicated that the border phase of the Mount McIntyre Pluton may be part of the Whitehorse Pluton. While the age difference between the two plutons is small, the Whitehorse Pluton is characteristically more mafic near its margins. Nowhere in the granodiorite border phase of the Mount McIntyre Pluton are mesocratic diorite or gabbro phases observed, which are common in the Whitehorse Pluton.

### **IBEX ALASKITE (E<sub>al</sub>)**

The Ibez Alaskite underlies the southern portion of Ibez Mountain and a small area 5 km to the east. This unit is blocky and well-jointed, pale pink to light grey weathering, medium-grained leucocratic, smokey quartz-eye biotite alaskite and granite. It is commonly miarolitic and some parts contain excess amounts of residual quartz giving the appearance of a crowded porphyry in a quartz matrix. Margins of this pluton are commonly rhyolitic. On Ibez Mountain this unit intrudes coeval(?) sub-volcanic rocks of undetermined age.

### **Age and Interpretation**

Ibez Alaskite 12 km south of Ibez Mountain has returned a maximum zircon U-Pb age of  $58 \pm 1$  Ma (Doherty and Hart 1988). These rocks are part of a suite of small, high-level, discordant, hypabyssal plutons located along the eastern margin of the Coast Plutonic Complex known as the Nisling Range Alaskite.

This unit has consistently yielded Eocene ages between 50 and 60 Ma (Tempelman-Kluit and Wanless 1975), and therefore has a temporal relationship with volcanic rocks of the Skukum and Sloko Groups.

### **JACKSON CREEK GRANITE (E<sub>gr</sub>)**

The Jackson Creek Granite forms an arcuate, east-trending pluton at least 35 km long and 5-10 km wide, which outcrops in part in the northwest corner of the map area. Related stocks occur approximately 1 km north of Jackson Creek on Hill 5582, and 20 km to the southeast on the eastern flank of Mount Golden Horn.

The unit is composed of massive, blocky, light grey weathering, medium to coarse-grained, homogeneous biotite granite, and is locally weakly foliated near its margins. It comprises euhedral plagioclase (25-30%), typically phenocrystic (2-3 cm), white potassium feldspar (35-40%) and biotite (10-15%). Quartz characteristically forms equigranular smokey quartz eyes (15-20%).

## Age and Interpretation

The Jackson Creek Granite intrudes early to middle Mesozoic sediments, and on Mount Golden Horn it also cuts the Middle Cretaceous Whitehorse Pluton. A biotite K-Ar age date of  $55 \pm 1.9$  Ma has been obtained from the main pluton, near Jackson Creek (Morrison et. al. 1979). It is probably part of the Nisling Alaskite suite (Templeman-Kluit 1974), although is much coarser grained than the Ibex Alaskite and other Tertiary stocks in the project area (Doherty and Hart 1988). The finer grained intrusions all intrude the Coast Plutonic Complex and may have been emplaced at higher levels (as evidenced by their smaller and circular exposures) or cooled more quickly than intrusions hosted in rocks of the Whitehorse Trough.

## STRUCTURAL GEOLOGY

Structure in the Whitehorse map area is dominated by the Fish Lake Syncline and the Ibex Thrust Faults. Eocene or younger northeast-trending normal faults cut these older structures in the western half of the map area, and east trending faults cut mid-Cretaceous rocks in the east.

### FOLDS

Strata of the Whitehorse Trough are broadly folded about north- to northwest-trending axes. The Fish Lake Syncline, the dominant structure, plunges moderately steeply to the southeast, and has a wavelength of approximately 12 km (see cross-section A-A' on the geological map, enclosed). The syncline is asymmetrical with the eastern limb significantly steeper than the west. It is cut along its southwestern limb by the Ibex Thrust Fault.

A poorly exposed, open, upright anticline parallels the Fish Lake Syncline to the east. Rocks west of Mount McIntyre pluton are mainly east-dipping and east of the pluton are west-dipping, indicating an anticline existed approximately where the intrusion was emplaced. A north-trending syncline is exposed in the narrow belt of sedimentary rocks between the Whitehorse and Mount MacIntyre Plutons (Whitehorse Copper Belt).

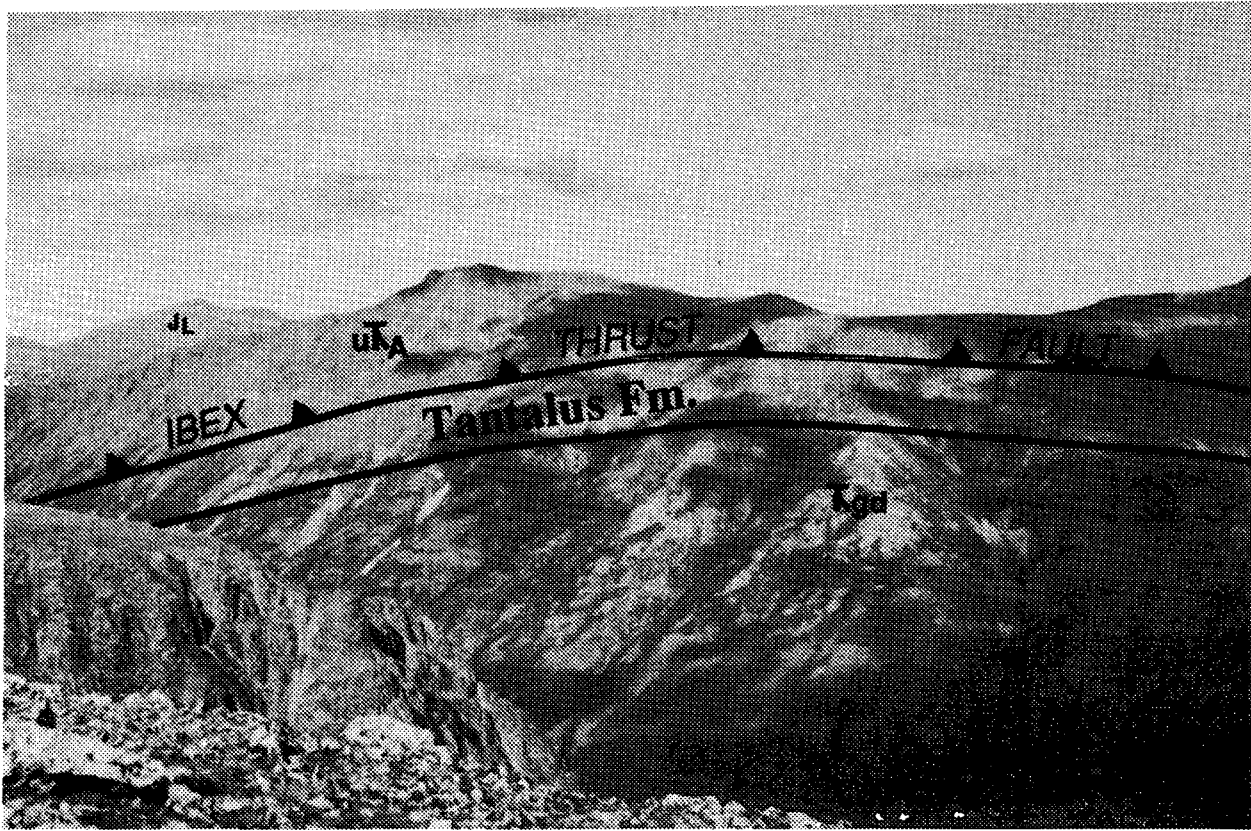
### FAULTS

#### Ibex Faults

Structures in and along the eastern slope of the Ibex River valley are complex and their relationships to each other are poorly understood.

The easternmost fault juxtaposes Triassic Lewes River Group over Cretaceous Tantalus Formation and is here termed the Ibex Thrust Fault (Figure 7). The fault dips shallowly to the east and is represented by a several metre thick zone of protomylonite developed primarily in the Tantalus sandstone. It contains brecciated and ductily deformed fragments of Lewes River limestone.

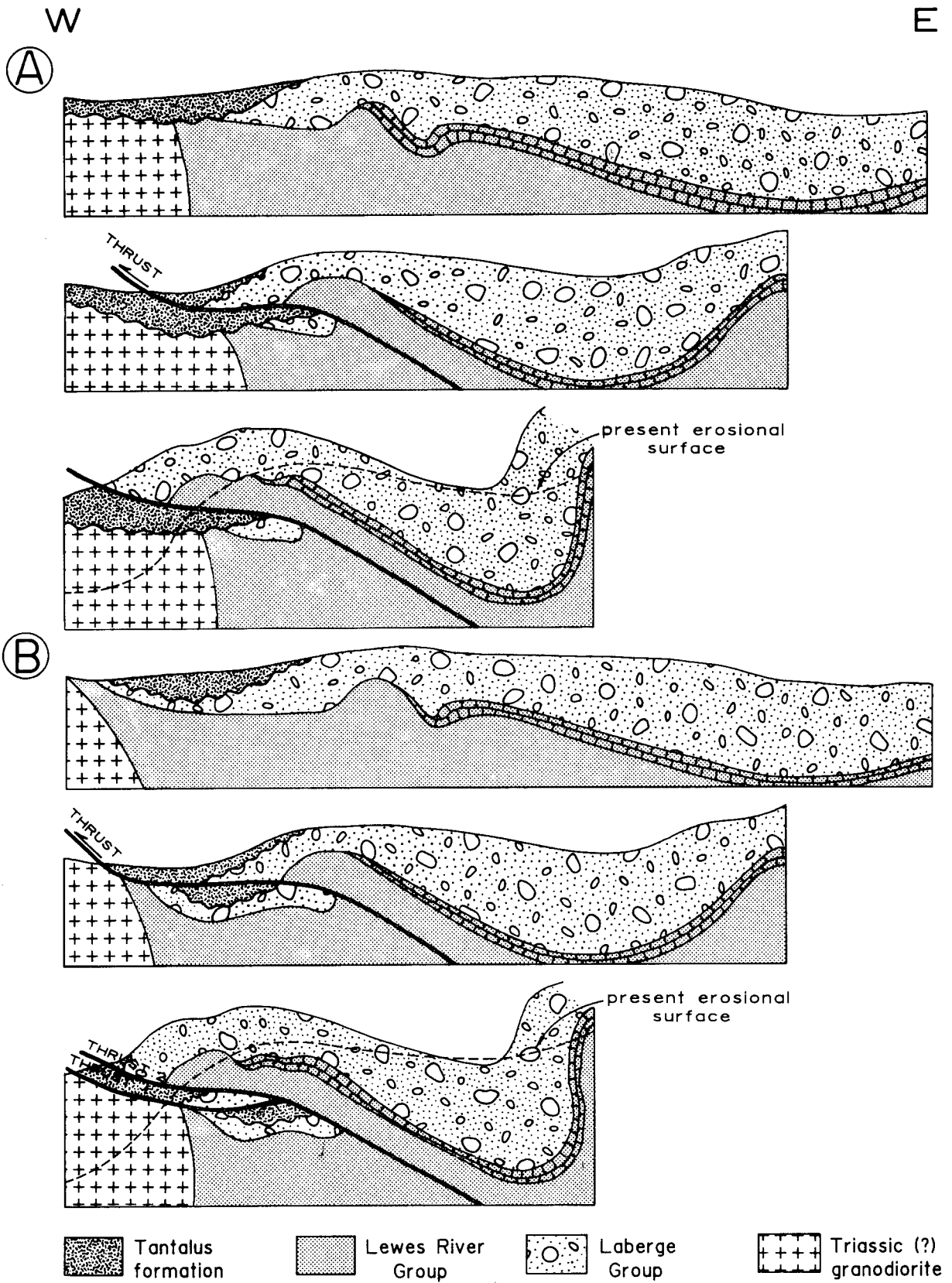
Faults located west of the Ibex Thrust Fault juxtapose metamorphosed Povoas Formation augite porphyry against mid-Cretaceous(?) intrusive rocks of the Coast Plutonic Complex on the west and Triassic(?) Ibex granodiorite on the east. The Povoas Formation is intensely deformed and similar in character to rocks of the Tally Ho Shear Zone (Doherty and Hart 1988). Coast Plutonic Complex intrusive rocks are weakly foliated and locally similar to unit Pgd. The traces of all faults are covered and have been assumed on the basis of internal deformation, a lack of cross-cutting dykes or alteration associated with the adjacent granodiorite and aeromagnetic data. The geometry of the faults, their movement and mechanisms are unknown. The occurrence of rocks similar to those of the Tally Ho Shear Zone



**Figure 7.** Looking northeast along the east slope of the IbeX River valley where Tantalus Formation rocks are bound by the Lewes River Group above the IbeX Thrust Fault, and the lower Triassic(?) granodiorite.

indicate a possible northern extension of the Llewellyn Fault but this suggestion requires further study.

The contact between Triassic(?) IbeX granodiorite and the Tantalus Formation is covered but juxtaposition of the units demands that the contact be faulted. The fault is assumed to be a steep, west-dipping reverse fault as represented in the cross-section on the map (enclosed). Neither the Tantalus Formation or the granodiorite proximal to the fault trace are deformed and Tantalus Formation rocks are not thermally metamorphosed. Therefore, it is possible that Tantalus Formation sedimentary rocks were deposited uncomformably on the granodiorite (Figure 8A). It is unlikely that such an unconformity could exist considering the vast thickness of the local stratigraphy which would have to be eroded in order to expose the granodiorite. Alternatively, rocks east of the fault may be allochthonous and transported westward a considerable distance in which case the local strata may have been thin and easily eroded down to the level of the granodiorite.



**Figure 8.** Cross-sections showing possible formation of structural relationships of rocks on the east slope of the Ibex River valley. Part A - Tantalus Formation is deposited unconformably on Triassic granodiorite then Whitehorse Trough strata are thrust westward. Part B - Whitehorse Trough strata and Tantalus Formation are thrust westward, then cut by a second thrust.

An alternative model may be the development of a duplex-type structure by the Ibex Thrust Fault such that Tantalus Formation rocks are bounded on both sides by thrust faults, and thrust upon previously uplifted Triassic(?) granodiorite (Fig. 8B)

The northern continuation of the Ibex Faults juxtaposes Lewes River Group rocks against Laberge Group strata. In the southern part of the map area the faults abut Lewes River Group rocks against both sides of the Tantalus Formation. The southern extension of these faults, onto the adjacent map sheet, merge to become one structure and continue south along the eastern portions of Lakeview and Goat Mountains.

The Ibex Faults are cut by the 55 Ma Jackson Creek granite and involve Tantalus conglomerate deposited pre-Whitehorse Pluton (116 Ma). The timing and style of motion along these structures is similar to that of the Nahlin Fault found 30 km southwest along strike (Hart and Pelletier 1989).

### **Younger Faults**

Closely spaced, northeast-trending faults dissect all other structures in the southern half of the map area. Displacement along these faults is typically less than 0.5 km in the map area, but as much as 2 km for related faults on the adjacent Alligator Lake map sheet (105D/6) to the south (Doherty and Hart 1988). There, the faults trend more easterly and cut Eocene volcanic rocks of the Skukum complex. Normal displacement is thought to be the dominant motion along these faults and may account for the apparent dextral and sinistral displacements. A component of transcurrent motion is also possible.

Generally east-trending faults which displace the western contacts of the Whitehorse Pluton may be related to the Eocene faults.

## ECONOMIC GEOLOGY

Economic mineral deposits of the Whitehorse map area is dominated by the skarns of the Whitehorse Copper Belt (WCB). Mineralization of the WCB has previously been examined by McConnell (1909), Kindle (1964), Grabher (1974), Tenny (1981), Morrison (1981), Watson (1984) and Meinert (1986). This report summarizes the salient information from previous authors and offers new data and interpretation on some aspects of copper belt mineralization.

### HISTORY

The first claim in the area, the Copper King, was staked in 1898 by Jack McIntyre on a discovery made in 1897. He and others were part of the rush of would-be miners on their way to the Klondike, who discovered copper mineralization while hunting. By 1899, the district was thoroughly prospected and the Big and Little Chief, Pueblo, Best Chance, Arctic Chief, Grafter, Valerie, War Eagle and numerous other deposits were discovered and staked.

Development work progressed in the district and in 1900 the Copper King claim yielded nine tons of bornite ore grading 46.4% Cu followed by 460 tons of ore in 1903. By 1907 total shipments to smelters from the Copper Belt totalled approximately 4,000 tons. The Pueblo was the largest of the early mines and between 1912-20 produced 127 000 tonnes of 3.5% Cu.

Sporadic and limited exploration programs were carried out on the Cowley Park, Keewenaw, Middle and Little Chief and Pueblo deposits in 1946-47, and the Arctic Chief and Best Chance deposits in the mid-1950's. Reorganization and financing of a new company; New Imperial Mines, ushered in the modern era with the milling of ore from the Little Chief pit in 1967. By 1969 the Little Chief and Arctic Chief pits were mined out and production on the War Eagle, Black Cub South and Keewenaw pits began, as did underground development work on the Little Chief. In 1971 the company changed their name to Whitehorse Copper Mines.

Extensive geophysical exploration and follow up drilling in the early 1970's was financed mainly by Hudson Bay Mining and Smelting who bought out all remaining shares in 1978. Mining operations ceased in 1982. Total production between 1967-1982 was 10 million tonnes containing 123 000 tonnes Cu, 90 tonnes silver and 7 tonnes gold with an average grade of approximately 1.5% copper. Current reserves are estimated at approximately 2.8 million tonnes of 1.0% Cu divided between 5 deposits.

### SETTING AND DESCRIPTION OF DEPOSITS

Of the 27 known metallic mineral occurrences on the map sheet, 24 are copper-bearing skarns and three are quartz copper veins. All mineral occurrences but two, are found in the WCB. General information regarding all occurrences is listed in Table 2.

## **Whitehorse Copper Belt (YEX No. 49, 190-212, 225, 226, 274, 275)**

The skarns of the Whitehorse Copper Belt form a 30 km long, northwest-trending zone, 5 km west of Whitehorse. All skarns are hosted in upper Triassic Lewes River Group carbonate or their facies equivalents at, or near their contact with diorite to granodiorite of the mid-Cretaceous Whitehorse pluton. Contact metamorphic mineral assemblages are typically poorly developed, indicating that skarn formation is mainly the result of metasomatic reactions. The largest deposits of the area are hosted in roof pendants or peninsulas of carbonate rocks totally surrounded by the pluton.

Skarns are divisible according to variations in iron (magnetite) and silicate-rich-skarn end members (Table 2). Skarn mineralogy is often well zoned (Figure 9). The nature of the skarn assemblage and mineralization is a function of its protolith (Morrison 1981, Meinert 1986). Non-dolomitic protoliths form skarns rich in hedenbergite and light brown garnet with idocrase and wollastonite. Dolomitic protoliths are richer in iron and form diopside and red-brown garnet skarns with considerable magnesium rich olivine (Meinert 1987). Olivine is easily retrograded during hydrothermal alteration and consequently leads to the formation of serpentinite, talc, phlogopite, brucite and magnetite.

Bornite is the primary ore mineral in iron-rich skarns and chalcopyrite predominates in silicate skarns. Iron-rich skarns generally contain higher precious metal values while silicate skarns are richer in molybdenum.

## **Grouse (YEX No. 67)**

The general skarn assemblage of this deposit is similar to others hosted in dolomitic protoliths. This occurrence is of interest because it is: i) outside of the WCB; ii) hosted in the same lithology as the gold-rich Little Chief mine; and iii) rich in bismuth, gold and zinc (87 g/t Au and 5.8% Bi over 0.4 m; INAC 1987).

Morrison (1981) suggested it developed as a result of intrusion of the Eocene Jackson Creek granite. Detailed mapping by M. Cosec (unpublished DIAND map) indicates that all skarn development is adjacent to a thick band of medium- to coarse-grained gabbro. This lithology is characteristic of border phases of the Whitehorse Pluton and not the more siliceous Jackson Creek granite which is exposed below the gabbro. In addition, biotite-hornblende granodiorite similar to the Whitehorse Pluton is exposed at the western end of Jackson Hill.

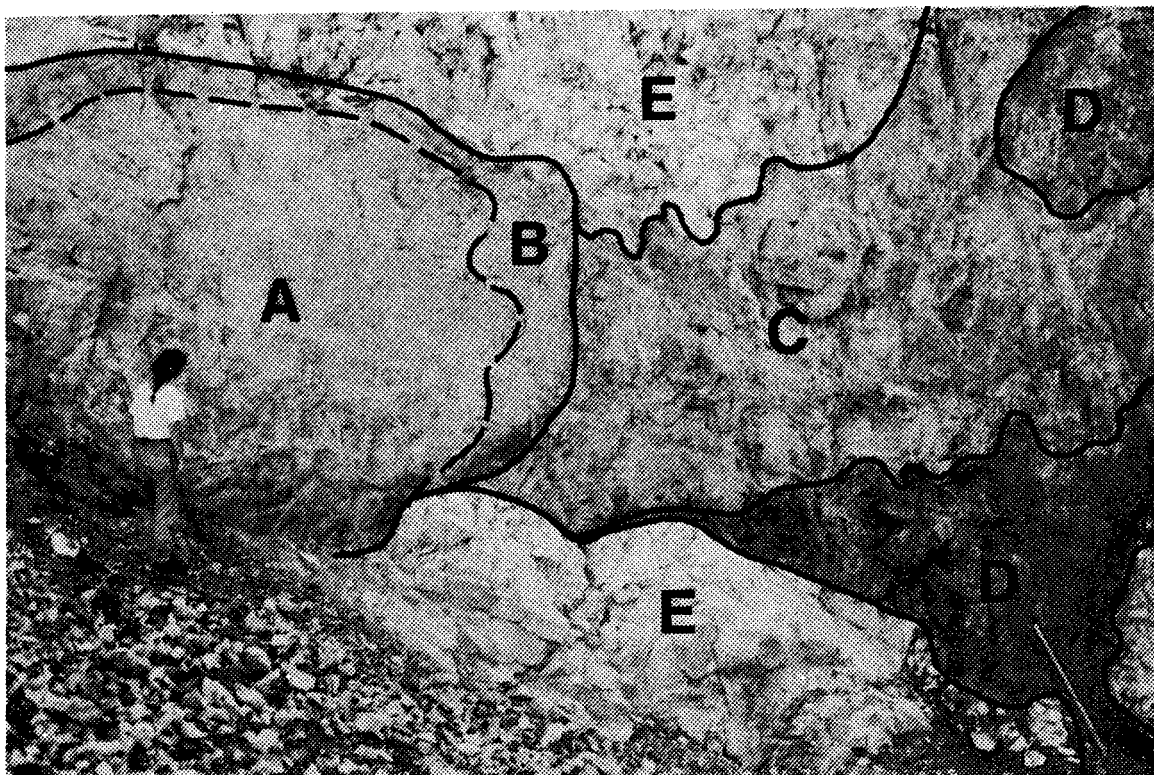
Skarn assemblages developed at the Grouse property are similar to those of the WCB except they contain clay-mica-pyrite alteration and veins proximal to the skarns. Barren magnetite skarn at the western extreme of the property contained large (2 cm) books of black biotite.

DEPOSIT TYPE	Cu Fe Au Ag	Cu Fe (Au Ag)	Cu	Cu Mo	Other (Cu+)
DEPOSITS	Little Chief+ Middle Chief+ Big Chief+ North Star *Black Cub N *Black Cub S *Kodiak Cub *Gem Grouse= Valerie	Arctic Chief# Pueblo@ Best Chance Grafter# Verona Suburban	Carlisle Rabbits Foot Anaconda Spring Creek Empress of India Retribution Pass Lake Copper Cliff	War Eagle Copper King# *Cowley Park	Scheelite (W) Reservoir Lake (Mo,W) Polar *Keewenaw (Au,Mo) Harniak= (Au,Ag)
HOST	dolostone	dolomitic limestone	interbedded limestone/siltstone	limestone and pyritic siltstone	granodiorite
MINERALOGY	bornite-rich  magnetite-rich			chalcopyrite-rich  magnetite poor	
PRODUCTION (tonnes)	8,723,527	341,635	907	905,217	159,000
RESERVES (tonnes)	858,000	447,000	0	1,712,000	202,000
TOTAL	9,581,527	788,635	907	2,457,217	361,000

Table 2. General description of deposits of the Whitehorse Copper Belt.

\* Not on map-sheet 105 D/11: +, plus As,Sb,Bi,Co and Te: # ,plus Mo: Grouse (+Bi,Zn): Valerie (+As,Co,Ni War Eagle (+Au,Ag): @, Fe as specular hematite and Cu as chalcopyrite or oxides: =, outside copper belt  
Production and reserve figures are approximate at 1.0% average: Total Production 10 130 286 tonnes,  
total reserves 3 059 000 tonnes.

The Grouse occurrence contains several characteristics associated with gold skarns. Skarn mineralization formed as a result of the intrusion of Whitehorse Pluton granodiorite and was later modified by the intrusion of the Jackson Creek pluton. The origin of highly anomalous gold, bismuth and zinc values are unknown.



**Figure 9.** Multi-stage skarn zonation from: A) quartz diorite dyke; B) quartz-potash feldspar-chlorite-epidote; C) diopside-garnet-thulite; D) magnetite-serpentinite-bornite; E) marble; in Arctic Chief open pit. Zone A grades 162 ppm copper, 30 ppm silver and 114 ppb gold; Zone D grades 1.44% copper, 17 g/t silver and 1.1 g/t gold.

#### **Harniak (YEX No. 71)**

At least two, north-trending quartz veins with bornite and lesser chalcopyrite are hosted in propylitically altered, medium-grained hornblende granodiorite on the slopes west of the Ibex River. The main vein is up to 0.45 m wide and traceable for almost 200 m (NCMI 1983). Values up to 15% Cu, 7.4 opt Ag (255 g/t) (NCMI 1983) and 0.22 opt Au (76 g/t) (Noranda Exploration Co., company files) have been obtained.

This occurrence is similar to the Keewenaw deposit of the WCB in its style, mineralization and alteration, but is less brecciated. The host intrusive is akin to the Whitehorse Pluton. If it formed in a manner similar to the Keewenaw (Morrison 1981), a skarn is required to supply mineralization to the fissure. Skarns are nowhere proximal and may have long since eroded. Alternatively, mineralization may be magmatic.

### **GOLD IN WHITEHORSE SKARNS**

Worldwide, gold-rich skarns are set in accreted terrains and hosted in rocks with significant amounts of clastic or volcanoclastic material. Typically, they are associated with mafic plutons, have high sulphide content and retrograde alteration of iron-rich garnet-pyroxene assemblages. Arsenopyrite and pyrrhotite are common sulphides with bismuth and occasional telluride minerals in some deposits (Meinert 1987).

While deposits of the WCB do not show all of these characteristics (and is not recognized as a "gold" skarn), this information is useful in searching for gold-rich areas in the copper belt. Meinert (1986) has suggested that gold in the WCB was emplaced during a final hydrothermal event which was responsible for forming the retrograde mineral assemblage.

Sulphide-rich, magnetite skarns hosted in dolomitic assemblages which have undergone retrograde alteration are most likely to be enriched in precious metals. Of 17 samples collected from four deposits, chosen on the basis of their mineralogy, gold values were highest in bornite-rich ores. Chalcocite and numerous copper-silver or silver-iron sulphides are sometimes exsolved in bornite (Morrison 1981), and gold values may be limited to bornite which has undergone this exsolution.

## **SUMMARY**

Morrison (1981) considers the metals of the WCB deposits to be derived through assimilation of Lewes River Group volcanoclastic rocks (which are recognized as containing high background copper values (Tempelman-Kluit and Currie 1978)) when digested in the granite. The metals were then concentrated in hydrothermal fluids and emplaced in chemically suitable, porosity controlled facies boundaries.

If this thesis is correct, any intrusion emplaced in Lewes River Group volcanoclastic rocks adjacent to calcareous rocks are capable of producing copper skarns. However, nowhere else in the Whitehorse Trough are copper skarns of similar magnitude evident. The limited extent of alteration and lack of evidence for the involvement of magmatic fluids in the alteration or mineralization of the pluton supports the suggestion.

Vein-style quartz-copper mineralization (Reservoir Lake, Keewenaw, Polar) which cuts relatively unaltered granodiorite are suggested by Morrison (1981) to be extensions of the skarn alteration system into the pluton along shear zones. Porphyry style mineralization has not been found in the WCB.

## **EXPLORATION METHODS**

Surface and airborne exploration methods used in the Whitehorse Copper Belt were described by Tenney (1981). Historically, most deposits were found through surface prospecting but in recent times geophysical and geochemical methods have been employed.

### **Geophysical Methods**

Magnetometer surveys are considered the most effective exploration tool in the copper belt and can be credited with at least three discoveries. Magnetite skarns have average readings 3000-8000 gammas above background. Miles Canyon basalt, which has a response up to 4000 gammas above background, may be differentiated by its flat, typically larger areal extent. Airborne and surface magnetometer surveys were useful in uncovering the locations of magnetite-rich skarns, but failed to identify silicate skarns.

Induced polarization surveys work well, with good anomaly contrast but problems in differentiating chargeability peaks of graphitic or pyritic sediments with skarns are common. Resistivity readings have no use in determining the extent of ore bodies but may be helpful in determining the position of geological contacts.

Crossover response of VLF EM-16 surveys is typically low.

## Geochemical Methods

Geochemical soil anomalies are associated with 'train shaped' dispersion patterns related to glacial transport, topography and drainage. As a result they are typically well developed (glacially) downstream, or north of deposits. For this reason they are poor indicators of deposit location. Background readings are approximately 15 ppm but anomalous values can be greater than 10 000 ppm.

## NOTES TO PROSPECTORS

If, as suggested by Morrison, copper mineralization originated through assimilation of copper-rich sediments by an invading pluton, prospective geological targets exist at carbonate-intrusive contacts north and west of Jackson Hill, and between Fish Lake and Mount McIntyre.

If the dissertation is false and the source of the WCB metals is magmatic (ie. derived from the Whitehorse Pluton), it would seem reasonable to suggest that other plutons of similar age and chemical characteristics may contain metals. The granodiorite hosting the Red Ridge (105D/6; Yex No. 78, 224) or Harniak occurrences may be examples. In addition, exploration in the WCB has concentrated on the margins of the Whitehorse Pluton but the potential would exist for vein or porphyry style mineralization to be hosted in the interior of the pluton.

Outside of the WCB, the stock underlying Ibex Mountain is part of the Nisling Range Alaskite suite which are proven hosts to mineralization (Tempelman-Kluit 1974). Drainages below Oligocene felsite east of the Ibex River are anomalous in zinc, copper, lead, silver, cobalt, nickle, arsenic, cadmium and antimony (G.S.C. 1985). On the west flanks of Mount Granger drainages are anomalous in zinc, copper and arsenic (G.S.C. 1985).

## REFERENCES

- BREMNER, T., 1989.** Geology of Whitehorse Coal Deposit; in Yukon Geology Vol. 2, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.
- BULTMAN, T.R., 1979.** Geology and Tectonic History of the Whitehorse Trough west of Atlin, British Columbia; Unpublished Ph.D. thesis, Yale University, 284 p.
- COCKFIELD, W.E. and BELL A.H., 1926.** Whitehorse District, Yukon; Geological Survey of Canada Memoir 150, 63 p.
- DAWSON, G.M., 1889.** Report on Exploration in the Yukon District, N.W.T., and adjacent portions of B.C.; Geol. and Nat. Hist. Survey of Canada, Annual Report for 1887-1888, Vol. 3 (part 1); Report B, p. 5-261. See also Geological Survey of Canada, Pub. No. 626 in 1888.
- DICKIE, J.R., 1988a.** Laberge Conglomerates, Yukon: Evidence of a Late Triassic-Jurassic volcanic arc-continent collision; in GAC 1988, Program with Abstracts.
- DICKIE, J.R., 1988b.** Laberge Conglomerates; Poster given at Yukon Geoscience Forum, November 1988, Whitehorse.
- DOHERTY, R.L. and HART, C.J.R., 1988.** Preliminary Geology of Fenwick Creek (105D/3) and Alligator Lake (105D/6) map areas; Indian and Northern Affairs Canada:Yukon Region. Open File 1988-2, two 1:50 000 maps and text, 65 p.
- EICHE, G.E., 1985.** Petrology of Quaternary Alkaline Lavas from the Alligator Lake Volcanic Complex, Yukon Territory; Unpublished M.Sc thesis, McGill University, Montreal.
- FYLES, J.G., 1950.** Geology of the Northwest Quarter of Whitehorse Map-area, Yukon, and Studies of Weathered Granitic Rocks near Whitehorse; Unpublished M.A.Sc. thesis, University of British Columbia.
- GRABHER, D.H., 1974.** Skarn-ore Relations in a Contact Metasomatic Cu-Fe deposit, Little Chief Mine, Whitehorse, Yukon; Unpublished M.Sc. thesis, University of Wisconsin, Madison, 103 p.
- GEOLOGICAL SURVEY OF CANADA 1985.** Regional Stream Sediment and Water Geochemical Reconnaissance Data, Whitehorse map sheet (105D) Yukon; Open File 1218.

- HART, C.J.R. and PELLETIER, K.S., 1989.** Geology of the Carcross (105D/2) and part of Robinson (105D/7) map areas; Indian and Northern Affairs Canada: Yukon Region. Open File 1988-1, two 1:50 000 maps and text.
- HUGHES, O.L., 1988.** Quaternary Geology; in Guidebook to Quaternary Research in Yukon, S.R. Morisson and C.A.S. Scott Eds., XII INQUA Congress, Ottawa, p. 12-16.
- HUNT, J.A., 1989.** Thermal Maturation and Source Rock Potential of the Tantalus Formation, Whitehorse area, southern Yukon; Unpublished B.Sc. thesis, University of British Columbia, Vancouver.
- INAC 1988.** Yukon Exploration 1987; Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, 364 p.
- INAC 1987.** Yukon Exploration 1985-86; Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, 451 p.
- KINDLE, E.D., 1964.** Copper and Iron Resources, Whitehorse Copper Belt, Yukon Territory; Geological Survey of Canada, Paper 63-41. 46 p.
- LOWEY, G.W., 1974.** The Stratigraphy and Sedimentology of Siliciclastic rocks, west-central Yukon, and their tectonic implications; Unpublished Ph.D. thesis, University of Calgary, Alberta, 620 p.
- LOWEY, G.W. and HILLS, L.V., 1988.** Lithofacies, petrology and environments of deposition, Tantalus Formation (Lower Cretaceous) Indian River area, west-central Yukon; Canadian Society of Petroleum Geologists, Vol. 36, No. 3, p. 296-310.
- McCONNELL, R.G., 1909.** The Whitehorse Copper Belt; Geological Survey of Canada, Publication 1050.
- MEINERT, L.D., 1986.** Gold in skarns of the Whitehorse Copper Belt; in Yukon Geology, Vol. 1, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p.19-44.
- MEINERT, L.D., 1987.** Gold in skarn deposits-A preliminary overview; in Proceedings of the 7th IAGOD Symposium, E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.
- MIHALYNUK, M.G. and ROUSE, J.N., 1988.** Preliminary geology of the Tutshi Lake area, northwestern British Columbia (104M/15); in Geological Fieldwork 1987, British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1988-1, p. 217-231.

- MORRISON, G.W., 1979.** Metallogeny of the Whitehorse map area (105D); Indian and Northern Affairs, Yukon, Open File.
- MORRISON, G.W., 1981.** Setting and Origin of Skarn Deposits in the Whitehorse Copper Belt, Yukon; Unpublished Ph.D. thesis, University of Western Ontario, London, 306 p.
- MORRISON, G.W., GODWIN, C.I., and ARMSTRONG, R.L., 1979.** Interpretation of isotopic ages and  $^{87}\text{Sr}/^{86}\text{Sr}$  initial ratios for plutonic rocks in the Whitehorse map area, Yukon; Canadian Journal of Earth Sciences, Vol. 16, p. 1988-1997.
- NCMI 1983.** Private File, Northern Cordillera Mineral Inventory; Archer, Cathro and Associates (1981), Ltd.
- RAHMANI, R.A., 1983.** Facies relationships and paleoenvironments of a Late Cretaceous tide-dominated delta, Drumheller, Alberta; Canadian Society of Petroleum Geologists, Mesozoic of middle North America Conference, May 1983, Field Trip Guidebook, 36 p.
- REID, R.P., 1984.** The Facies and Evolution of an Upper Triassic Reef Complex in northern Canada; Unpublished Ph.D. thesis, University of Miami, Florida, 437 p.
- REID, R.P., and TEMPELMAN-KLUIT, D.J., 1987.** Upper Triassic Tethyan-type reefs in the Yukon; Bulletin of Canadian Petroleum Geology, Vol. 35, No. 3, p. 316-332.
- REINSON, G.E., 1984.** Barrier-island and associate strand-plain systems; in Facies Models (2nd ed.), R.G. Walker, Ed., Geoscience Canada Reprint Series 1, Geological Association of Canada, p. 119-140.
- RUST, B.R., and KOSTER, E.H., 1984.** Coarse alluvial deposits; in Facies Models, R.G. Walker, ed., Geoscience Canada Reprint Series 1, 2nd edition, Geological Association of Canada, p. 53-70.
- TEMPELMAN-KLUIT, D.J., (in press).** Geology of Laberge and Carmacks map sheets; Geological Survey of Canada, Memoir.
- TEMPELMAN-KLUIT, D.J., 1974.** Reconnaissance geology of Aishihik Lake, Snag and part of Stewart River map-areas, west-central Yukon; Geological Survey of Canada, Paper 73-41.
- TEMPELMAN-KLUIT, D.J., 1976.** The Yukon Crystalline Terrane; enigma in the Canadian Cordillera; Geological Society of America Bulletin, Vol. 87, p. 1343-1357.

- TEMPELMAN-KLUIT, D.J., 1979.** Transported Cataclasite, Ophiolite and Granodiorite in Yukon: Evidence of Arc-Continent Collision; Geological Survey of Canada, Paper 79-14, 27 p.
- TEMPELMAN-KLUIT, D.J., 1981.** Geology and mineral deposits of southern Yukon; *in* Yukon Geology and Exploration 1979-80, Dept. of Indian and Northern Affairs, Yukon, p. 7-32.
- TEMPELMAN-KLUIT, D.J., 1984.** Maps of Laberge (105E) and Carmacks (115I) map sheets, with legends. Geological Survey of Canada, Open File 1101.
- TEMPELMAN-KLUIT, D.J., and CURRIE, R.G., 1978.** Reconnaissance rock geochemistry of Aishihik Lake, Snag and Stewart River map-areas in the Yukon Crystalline Terrane; Geological Survey of Canada Paper 77-8, 72 p.
- TEMPELMAN-KLUIT, D.J., and WANLESS, R.K., 1975.** Potassium-Argon age determinations of metamorphic and plutonic rocks in the Yukon Crystalline Terrane; Canadian Journal of Earth Sciences, Vol. 12, p. 1895-1909.
- TENNEY, D., 1981.** The Whitehorse Copper Belt: Mining, Exploration and Geology (1967-1980); Dept. of Indian and Northern Affairs, Geology Section, Yukon, Bulletin 1, 29 p.
- TOZER, E.T., 1958.** Stratigraphy of the Lewes River Group (Triassic), Central Laberge area, Yukon Territory; Geological Survey of Canada, Bulletin 43.
- WATSON, P.H., 1984.** The Whitehorse Copper Belt - A compilation; Indian and Northern Affairs Canada; Yukon Region, Open File, 1:25 000 scale map with marginal notes.
- WHEELER, J.O., 1952.** Geology and Mineral Deposits of the Whitehorse Map area, Yukon Territory; Geological Survey of Canada, Paper 52-30.
- WHEELER, J.O., 1961.** Whitehorse map-area, Yukon Territory; Geological Survey of Canada, Memoir 312.
- WHEELER, J.O., and McFEELY, P., 1988.** Tectonic Assemblage map of the Canadian Cordillera; Geological Survey of Canada, Open File 1565.
- WILSON, W.J., 1916.** Paleobotany; Geological Survey of Canada, in Summary Report 1915.

**APPENDIX A**  
**ASSAY AND GEOCHEMICAL ANALYSES**

**ABBREVIATIONS FOR APPENDIX A**

bio	biotite	altn.	alteration
bo	bornite	app.	approximately
cpy	chalcopyrite	bx	breccia
Fe	iron	diss.	disseminated
fsp	feldspar	med	medium
gd	granodiorite	MnO	manganese oxide
gnt	garnet	occ.	occurs
mag	magnetite	sl.	slightly
moly	molybdenum	vis.	visible
po	pyrrhotite		
pyx	pyroxene		
qtz.	quartz		

Analyses performed by Bondar-Clegg & Company Ltd., Vancouver, B.C.



SAMPLE NO.	LOCATION	Au(ppb)	Au(opt)	Ag(ppm)	Ag(opt)	Cu	Mo	Pb	Sb	Zn	Bi	As	Te	W	Hg	Ba	Ni
CH88 42-5	MT GRANGER	6		<0.5		140	<1	10	26	31	<2	65	<10	<10	50	470	8
CH88 58-4	IBEX MTN. 6500'	48		1.0													
CH88 62-2	IBEX JCTN LOW	12		0.3													
CH88 20-2	JACKSON HILL	7		1.3		63	<1	209	23	118	9	33	-	<10	5	2000	74
CH88 22-5	6 KM W. BONNEVILLE LAKES	10		8.0		21	<1	343	11	87	36	167	-	<10	10	<20	35
CH88 22-6	6 KM W. BONNEVILLE LAKES	5		2.0		16	<1	257	<5	63	355	16	-	<10	5	<20	28
CH88 22-7	6 KM W. BONNEVILLE LAKES	<5		1.2		246	<1	188	9	127	11	13	-	<10	10	700	168
CH88 22-8	6 KM W. BONNEVILLE LAKES	5		0.9		130	3	199	<5	77	3	6	-	<10	10	170	57

## Sample Descriptions

SAMPLE NO	DESCRIPTION	LAT	LONG
C-1S	Sulphide-rich, massive cpy fills open space in qtz. Sulphide-rich bo.	60 44' 10"N	135 07' 56"W
C-2Q	Qtz.-rich, white massive qtz. with silicified granite wall rock, minor sulphides bo & cpy. Qtz-bo-cpy	60 44' 10"N	135 07' 56"W
KK-1	Bornite and chalcopyrite stringers through lt. coloured skarn, minor malachite, 8% sulphides	60 44' 25"N	135 08' 20"W
KK-2M	Massive gnt skarn with 2% diss. blebs of moly with minor cpy with pyroxene.	60 44' 25"N	135 08' 20"W
KK-3	Diss. blebs of bornite and cpy in endoskarn, 2% sulphides appear to have replaced mafics.	60 44' 25"N	135 08' 20"W
KK-4Q	Massive white (bull) qtz with minor malachite, no vis. sulphides.	60 44' 25"N	135 08' 20"W
CH88 34-6	Only sl. altn. of mafics and clay of fsp. Med-fine grained granodiorite.	60 39' 42"N	135 06' 50"W
CH88 35-1	Qtz.-rich, massive white, with <1% diss. cpy and occ. portions of wall rock.	60 39' 42"N	135 06' 50"W
CH88 35-2	Cpy-rich magnetite skarn with 50% cpy, 20% magnetite, 10% biotite, 10% other gangue. Med-grained	60 39' 42"W	135 06' 50"W
CH88 35-3	Bornite-rich, mag., (serp) actinolite skarn, 50% bornite, 5% cpy, 25% mag.	60 39' 42"N	135 06' 50"W
CH88 35-4	Magnetite-rich, med-fine grained with minor cpy and skarn (gnt-pyx).	60 39' 42"N	135 06' 50"W
CH88 35-5	Massive-sulphide, bornite, cpy, magnetite ore. Selected sample. Coarse-grained.	60 39' 42"N	135 06' 50"W
CH88 41-4	Greyish-white weathering gd with up to 40% cpy as blebs up to 3cm across. Minor covellite. Gangue contains calcite and clay minerals resulting from altn. of fsp.	60 44' 39"N	135 10' 29"W
CH88 41-5	Reddish-brown weathering rock with up to 30% mag. as anhedral to subhedral crystals with app. 60% qtz and 10% calcite making up rest. Rock is fractured and contains a minor limonite.	60 43' 48"N	135 10' 20"W
CH88 42-5	Medium-grained, equigranular gd with app. 5% py as irregular blebs and disseminations. Fe-staining occurring throughout 80% of rock.	60 32' 11"N	135 17' 08"W
CH88 58-4	Translucent, glassy sl. smokey qtz vein with bx granite, no sulphides	60 31' 03"N	135 29' 33"W
CH88 62-2	Massive white bull qtz. with minor bx(rusty) and MnO	60 41' 45"N	135 27' 40"W
CH88 20-2	Coarse-grained, black bio., mag., tremolite skarn with minor py.	60 42' 10"N	135 22' 48"W
CH88 22-5	Sl. rusty weathering massive white qtz. with weathered out py cubes.	60 36' 56"N	135 25' 20"W
CH88 22-6	Sl. rusty white coxcomb qtz vein (.40m)	60 36' 56"N	135 25' 20"W
CH88 22-7	Translucent apple green qtz vein	60 36' 56"N	135 25' 20"W
CH88 22-8	Translucent apple green qtz vein with 5% diss po.	60 36' 56"N	135 25' 20"W

**APPENDIX B**  
**WHOLE ROCK GEOCHEMISTRY**

**ABBREVIATIONS FOR APPENDIX B**

chl.	chlorite	diss.	disseminated
gd	granodiorite	lt.	light
hb	hornblende	occ.	occurs
plag	plagioclase	phenos	phenocrysts
k-spar	potassium feldspar	sim.	similar
pyx	pyroxene	sl.	slightly
qtz	quartz	v	very

Analyses performed by Acme Analytical Laboratories Ltd., Vancouver, B.C.

	CH30-1	CH30-2	CH34-6	CH69	P8813	CH65-2	P8815	J30-3	J31-1	CH28-1	P8862	CH43-2	CH71	MF64-2	M61	J22-2	P8838	CH62-1	CH58-6
SI02	53.83	62.90	65.03	52.38	68.74	61.77	61.72	56.96	67.63	72.31	68.52	59.87	57.71	66.84	69.17	56.47	52.03	63.88	64.44
TI02	0.47	0.46	0.35	1.51	0.42	0.64	1.01	0.88	0.36	0.27	0.50	0.62	1.44	0.72	0.52	0.86	1.16	0.50	0.47
AL203	17.90	16.12	14.96	17.85	14.30	15.38	15.38	17.55	15.18	13.19	15.11	18.35	15.82	15.33	14.82	17.16	18.12	16.56	15.64
FE203	5.00	4.29	3.29	9.91	2.46	5.86	5.44	5.70	3.25	1.75	2.85	4.74	7.96	4.09	3.11	6.40	8.90	4.29	4.58
FEO	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
MNO	0.08	0.06	0.13	0.16	0.07	0.09	0.11	0.08	0.05	0.04	0.08	0.07	0.13	0.10	0.09	0.09	0.12	0.10	0.09
MGO	3.39	2.34	1.84	3.01	0.56	2.75	1.85	2.71	1.73	0.46	0.92	1.72	3.21	1.30	0.92	3.46	4.08	1.69	2.02
CAO	5.84	5.07	5.02	9.01	1.19	5.47	3.70	5.98	3.41	0.28	1.61	6.14	6.21	2.91	1.84	5.43	7.83	4.01	3.50
NA2O	5.30	4.72	4.25	3.38	4.86	3.49	4.81	5.51	4.12	4.42	4.90	3.74	3.80	4.76	4.51	3.93	3.90	5.28	4.21
K2O	2.29	2.67	3.40	0.97	5.31	2.70	4.12	2.22	1.96	5.56	3.45	2.53	2.17	2.60	3.41	1.81	1.35	1.88	2.65
H2O+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
H2O-	5.00	0.60	1.30	1.00	1.40	1.30	0.90	1.60	1.70	1.20	1.60	0.40	0.80	0.70	1.10	3.70	1.80	1.30	1.80
P2O5	0.29	0.19	0.14	0.49	0.11	0.19	0.30	0.35	0.13	0.07	0.15	0.23	0.40	0.28	0.16	0.24	0.47	0.22	0.19
TOTAL	99.39	99.42	99.71	99.67	99.42	99.64	99.34	99.54	99.52	99.55	99.69	98.41	99.65	99.63	99.65	99.55	99.76	99.71	99.59
BA	910	1137	914	737	1207	1269	1307	870	1125	835	1206	1468	884	1186	1189	829	597	687	1527
ZR	nd	nd	138	98.00	nd	201	nd	nd	nd	nd	298	146	333	366	330	nd	53.00	140	120
CR203	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.01000	.02000	.01000	.01000	.01000
Ba	nd	nd	nd	nd	nd	n	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Zr	nd	nd	nd	nd	nd	n	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

50

	CH21-1	Y8814	P8872	P888	CH2-3	P8861
SI02	73.32	66.30	73.05	49.86	61.42	43.92
TI02	0.23	0.53	0.30	0.75	0.98	2.24
AL203	13.27	15.48	13.92	13.85	16.15	12.46
FE203	2.31	3.99	2.05	9.47	6.35	12.40
FEO	nd	nd	nd	nd	nd	nd
MNO	0.05	0.09	0.04	0.13	0.07	0.17
MGO	0.47	1.52	0.61	6.14	2.32	10.31
CAO	1.36	3.32	1.74	3.30	3.96	10.18
NA2O	3.94	4.52	3.35	2.01	3.99	4.45
K2O	4.12	2.81	4.16	2.55	4.44	2.08
H2O+	nd	nd	nd	nd	nd	nd
H2O-	0.60	0.80	0.40	5.00	nd	0.10
P2O5	0.07	0.20	0.07	0.28	0.32	1.06
TOTAL	99.74	99.56	99.69	99.43	100.00	99.37
BA	952	1438	1312	1459	1124	662
ZR	263	184	194	23.00	nd	196
CR203	.01000	.01000	.01000	.07000	.01000	.04000
Ba	nd	nd	nd	nd	nd	nd
Zr	nd	nd	nd	nd	nd	nd

## Sample Descriptions

SAMPLE NO	UNIT	LOCATION	DESCRIPTION
CH 30-1	mKw	Kopper King	Medium-grained sl. altered (chl.) hb. granodiorite.
CH 30-2	mKw	Carlisle	Coarse-grained salt & pepper textured biotite-hb grano-diorite.
CH 34-6	mKw	Arctic Chief	Fine-grained granite, 55-60% k-spar, 10-15% mafics in grey siliceous matrix.
CH69	mKw	Jackson Hill	Coarse-grained, sl. rusty and altered pyx(?) rich gabbro with 1% diss sulphides. Adjacent to skarn.
P88-13	mKm	W. of Golden Horn	Plagioclase porphyritic syenite with aplite stringers
CH 65-2	mKm	Coal Ridge	Fine-medium grained hb gd with occ. coarse grained plag and rare qtz.
P88-15	mKm1	W. of Golden Horn	Medium to coarse-grained granodiorite, contains 25-30% biotite.
J30-3	mKm1	Mt. Granger	Coarse-grained, sl. altered(chl) hb. granodiorite.
J31-1	mKm1	Copper Cliff	Medium- to coarse-grained granodiorite, 15-20% euhedral hb
CH28-1	mKm	Mt. McIntyre	Fine-grained, pink, hb monzonite
P88-62	mKm1	Mt. Granger	Medium-grained biotite(10-15%)-hornblende granite, hb (5-10%), plag (55-60%), in red aph mx (15-30%)
CH 43-2	mKy	Coal Ridge	Coarse grained, grey anorthosite with occ. biotite
CH 71	mKm	Mt. McIntyre	Coarse-grained hornblende diorite with fine-grained mafic mtz
MF 64-2	mKm	Copper Belt	Fine- to medium-grained pink granophyric granite with 25% acicular hb, 45-50% plag
MG 1	mKm	Mt. Granger	Plag. porphyritic monzonite. 15-20% plag phenos(.25-1cm) 10% hb in red fine-grained matrix
J22-2	Kgd	Ibex River Area	Dark grey to green biotite-hb. granodiorite.
P88-38	Kgd	W. of Fish Lake	Coarse-grained hb diorite.
CH 62-1	Kdg	Ibex Valley	Fresh med-grained accicular hb granite-granodiorite. Hb 15%, qtz in large blebs to 12% of rock, rare pink k-spar
CH58-6	Pdgn	Ibex Basin	Slightly altered foliated hb diorite to qtz diorite
CH 21-1	Egr	Fire Tower Hill area	White porphyritic k-spar granite with 5% micro-biotite, 20-25% grey qtz-eyes.
MF18-4	Egr	Jackson Creek	Coarse-grained biotite-rich granite with large plag and k-spar. Large (20%) grey qtz, k-spar white. Similar to 21-1 and P88-72 with 5% bio.
P88-72	Egr	Mt. Golden Horn	Similar to CH 21-1 with k-spar megacrysts and larger (3%) biotite and (25%) grey qtz.
P88-8	TrA	South of Jackson Creek	Andesite; pyx (5-10%), plag(20-25%) in red, aphanitic matrix calcite filled amygdules
CH 2-3	JLan	Ridge east of Fish Lake	Feldspar-phyric andesite, (30%, up to 8mm) tabular with irregular hb
P88-61	PPmc	Mt. Granger	Olivine basalt