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Geology of Carmacks and Laberge map areas, central Yukon:
Incomplete draft manuscript on stratigraphy, structure and its early interpretation (ca. 1986)

Dirk J. Tempelman-Kluit

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Preface

This open file was written in the mid-1980s for the Geological Survey of Canada 'Memoir' series but was not completed to publication. It details the activities and findings of a regional mapping project in central Yukon that took place between 1974 and 1982. This open file version of the manuscript is released as a background resource.

At the time of its writing, the era of large reconnaissance-style field parties was waning, and it is unlikely that the coverage obtained by many foot traverses will occur again. The field parties led by Tempelman-Kluit in the 1970s became legendary for the distances covered, their camp adventures, and the solid training provided to assistants, some of whom led Yukon geology for most of their own careers. The diversity of rocks they encountered, at the time when ideas of tectonic evolution were being applied to ancient orogenic rocks, inspired a bold interpretation of Yukon's geological evolution (Tempelman-Kluit, 1979). This open file manuscript presents more detailed evidence used to formulate this model.

Subsequent studies of bedrock and structure in this region have used and reinterpreted the mapping and nomenclature initiated by this project. Subsequent revision of the stratigraphic units requires reference of the full former description of units, not merely their summary in a map legend. To acknowledge the use of previous information requires that it be publicly available; this is the main purpose of this open file. This manuscript also contains details of fault relationships and an early synthesis of regional faults.

After this manuscript was written, new field mapping (Colpron et al., 2003, 2005, 2007; Simard and Devine, 2003), investigations of units in the Whitehorse Trough and their hydrocarbon potential (Lowey, 2008 and references therein) built upon the former work. A seismic reflection survey investigated the shallow structure (White et al., 2006) and a future energy assessment of the Whitehorse trough is anticipated. In addition, the Minto mine was opened in 2006 and several other occurrences in the region have reached the advanced exploration stage.

The manuscript is presented 'as-is'. It contains a modest number of grammatical errors, passages of informal language and speculative statements. Unfortunately the accompanying figures could not be found. To assist the reader this preface is followed by a table of contents and four page-size figures (labelled P-1 to P-4). For geographic place names the reader should consult topographic maps (NTS 105E and 115I). Most place names are also labelled on the relevant maps in Yukon MINFILE, available for free download from the Yukon Geological Survey. Geological features are labelled on the original maps (Tempelman-Kluit, 1984). Scanned copies of these are available from the Geological Survey of Canada MIRAGE website.

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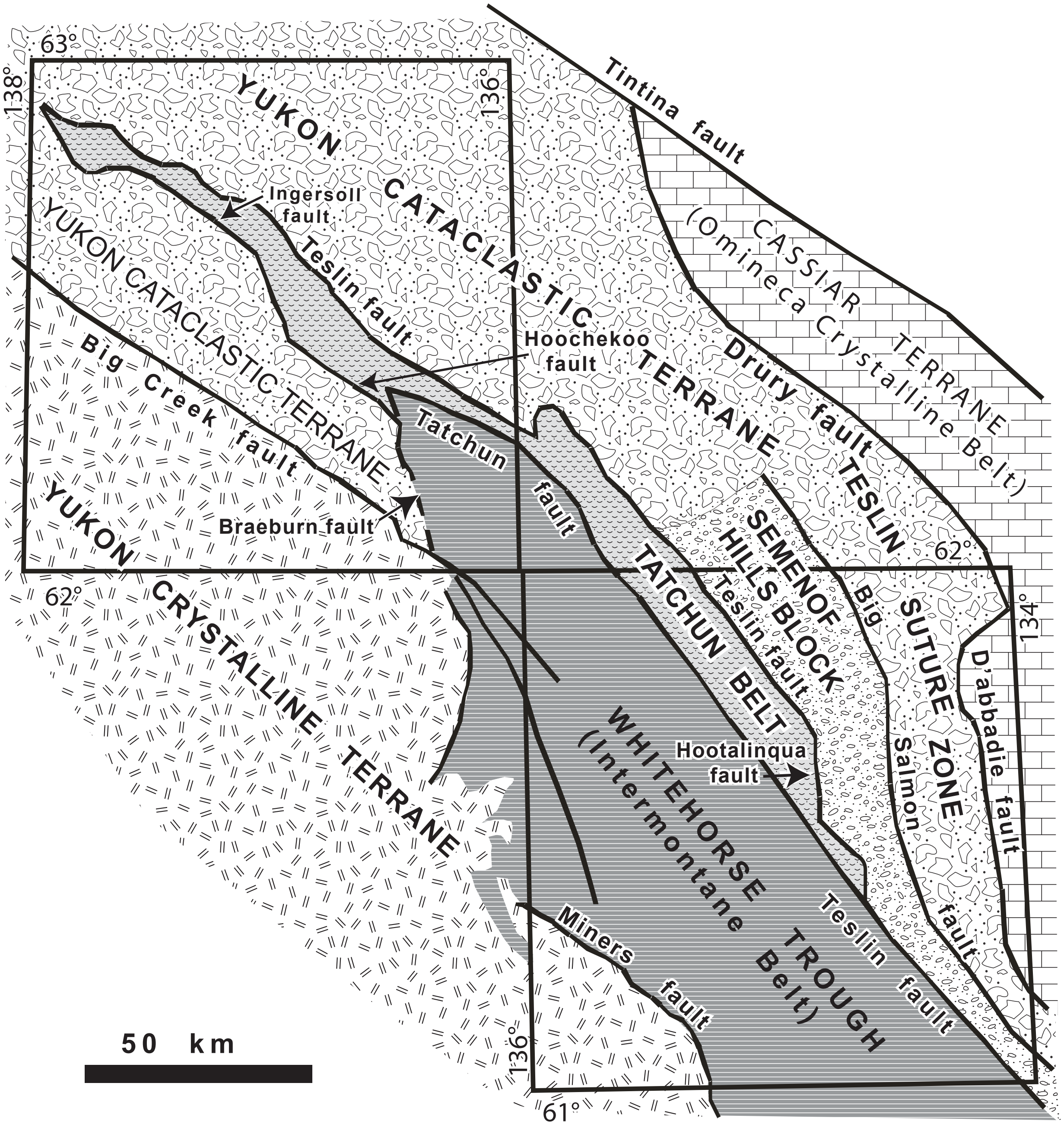


Figure P-1. Main geological units in Carmacks and Laberge map areas, from Tempelman-Kluit (1984; attached to map legend). This figure approximates missing Figure 9 cited in the manuscript.

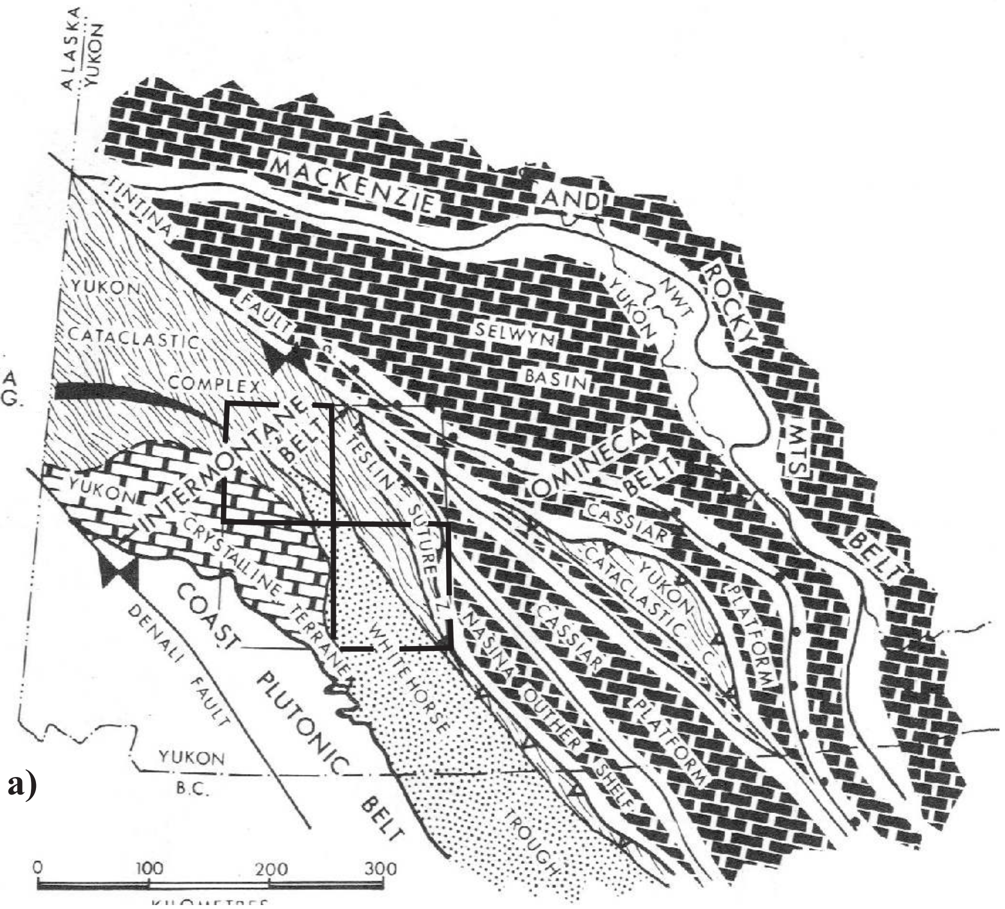
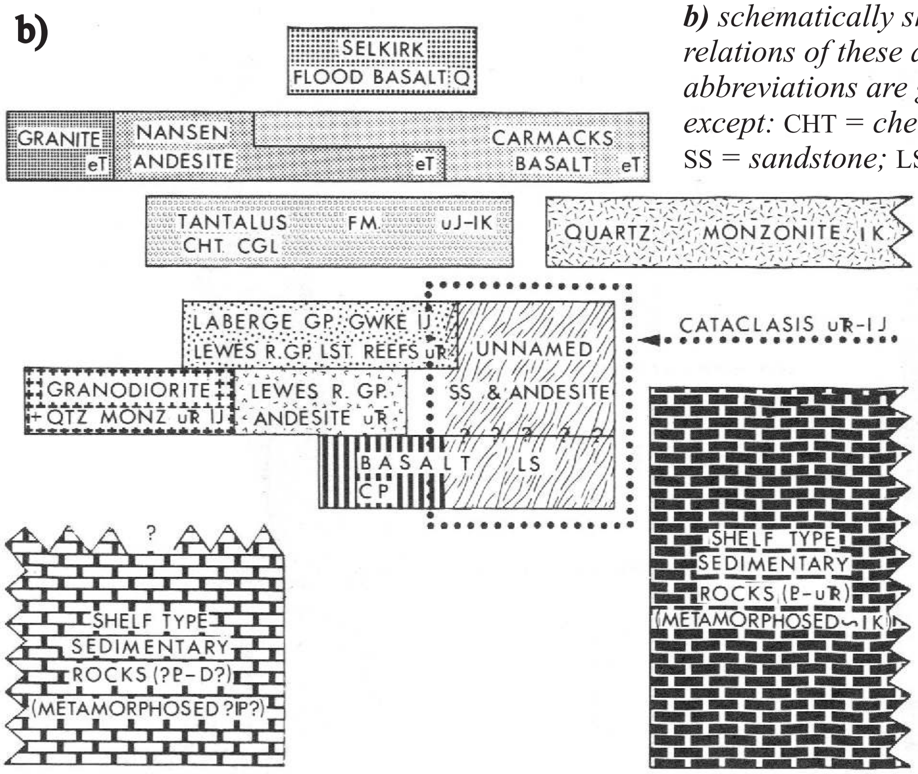


Figure P-2. *Main stratigraphic assemblages of central Yukon, from Tempelman-Kluit (1980):*
a) *shows location of the map areas in relation to Cordillera-wide subdivisions;*
b) *schematically shows the stratigraphic relations of these assemblages (letter abbreviations are geologic time periods, except:* CHT = *chert;* CGL = *conglomerate;* SS = *sandstone;* LS, LST = *limestone*

(Note: these diagrams pre-date writing of the manuscript).



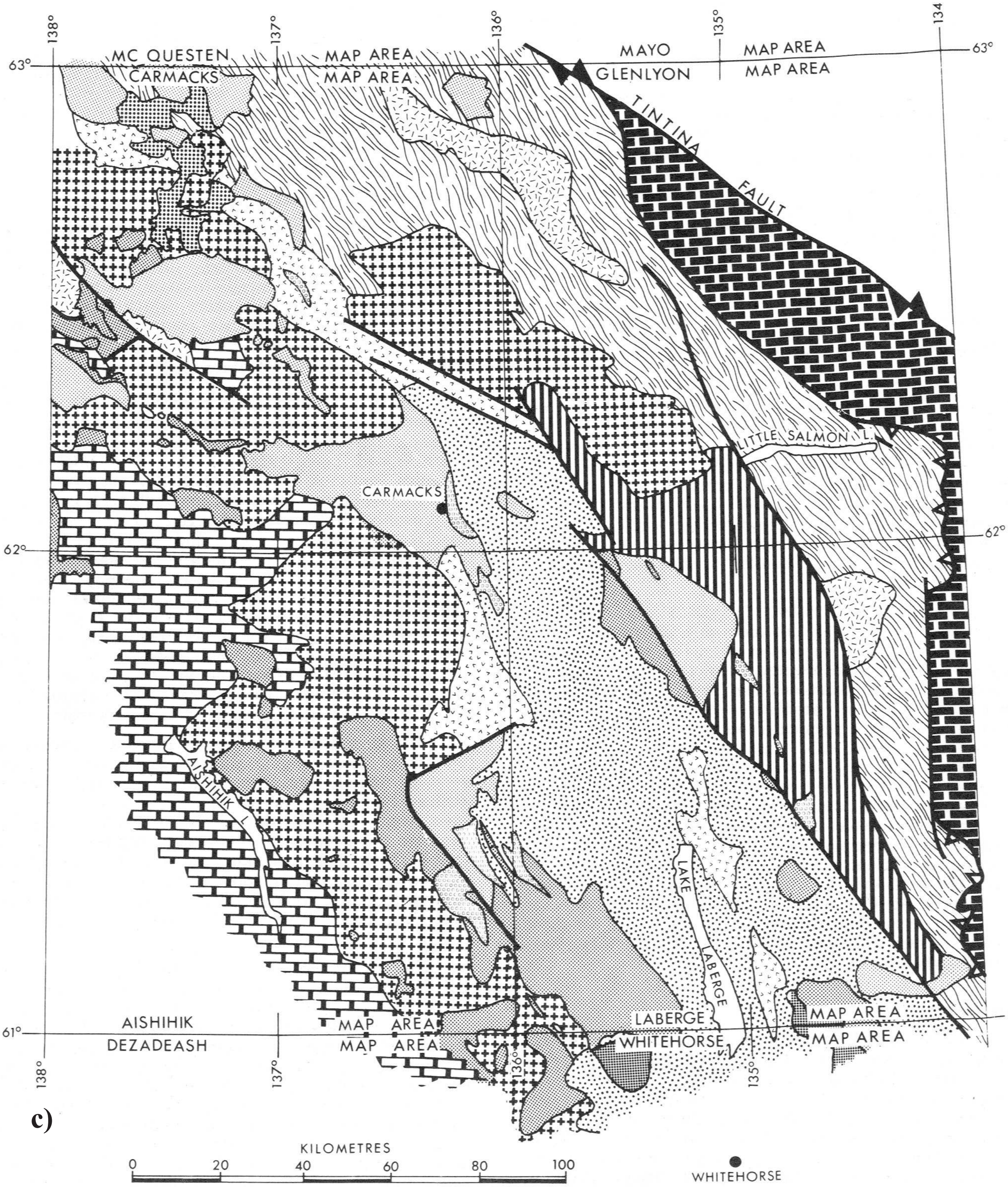


Figure P-2 (con't). *Main rock packages in Carmacks (northwest) and Lebarge (southeast) map areas, showing proposed correlations to adjacent areas. Patterns are the same as in Fig. P-2, b). From Tempelman-Kluit (1980); this figure approximates missing Figure 10, cited in the manuscript.*

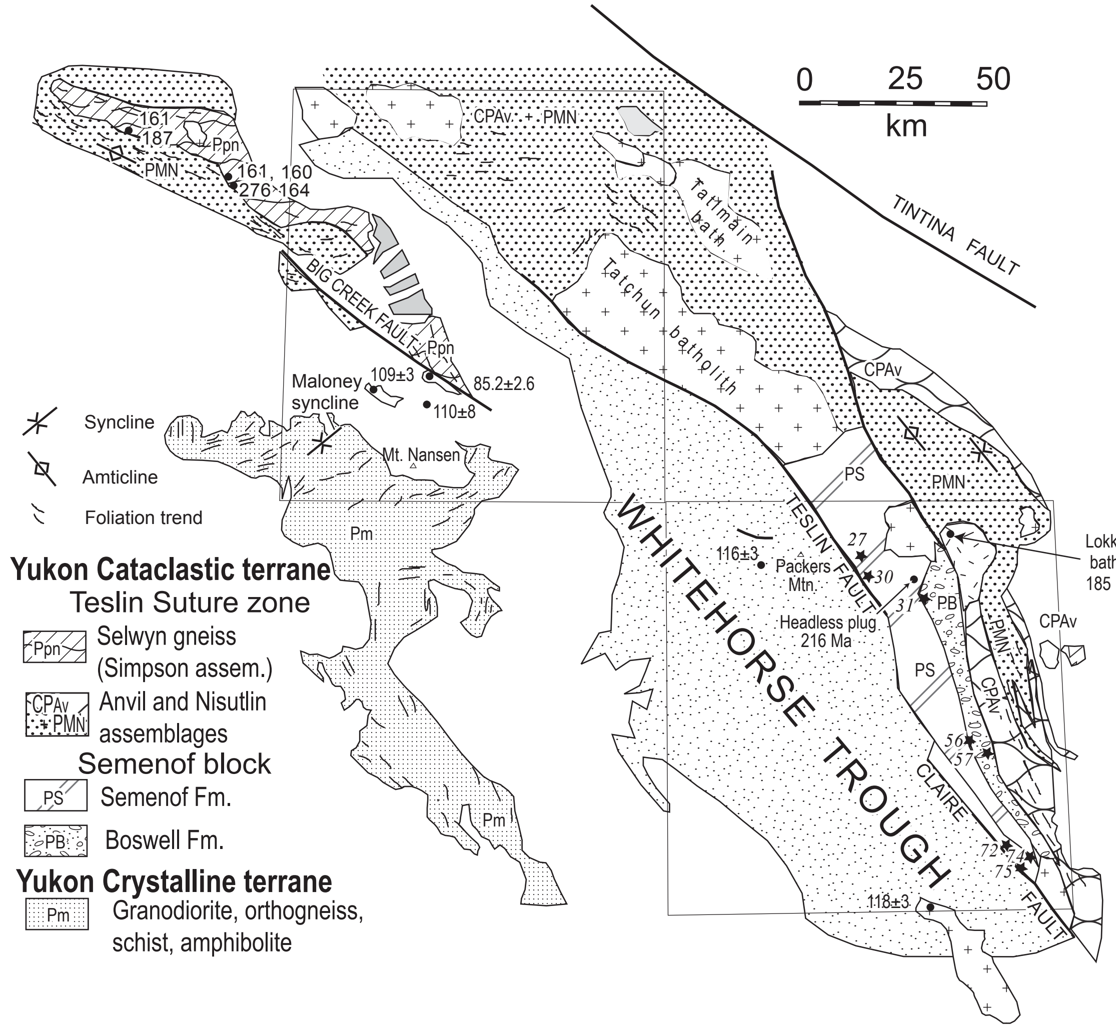


Figure P-3. *Map of the project area showing structural trends in the Yukon Cataclastic and Yukon Crystalline terranes. This figure may correspond to missing Figure 11 cited in the manuscript. Dots indicate sites of K-Ar dates in Ma. Stars indicate fossil localities with numbers that correspond to entries in the Appendix.*

GEOLOGY OF CARMACKS AND LABERGE MAP AREAS, YUKON TERRITORY

by Dirk J. Tempelman-Kluit

ABSTRACT

Laberge and Carmacks map areas in south central Yukon have three structurally superposed elements. From the base an autochthon, a ductilely deformed complex and a sheet cut by strike-slips. The autochthon on the northeast and southwest of the area differs. That on the northeast, Cassiar Platform, includes ancestral North American rocks which are repeated by northeast directed thrusts. That on the southwest, Yukon Crystalline Terrane, includes probable Paleozoic schist and gneiss that are metamorphosed and folded. The ductilely deformed complex in the middle of the structural succession is called Yukon Cataclastic Terrane. It comprises Paleozoic(?) sedimentary, volcanic and granitic rocks partly sheared to mylonite as well as large Mesozoic batholiths and Late Paleozoic basalt. And the strike-slip sheet, Whitehorse Trough, is of Mesozoic volcanic and sedimentary rocks broken by dextral faults. Boundaries between the elements are faults; steep-dipping dextral strike-slips at the top and ductile faults lower down.

Cassiar Platform contains late Proterozoic and Paleozoic miogeoclinal strata of North America's ancient margin, repeated on thrusts, folded and metamorphosed during the Jura-Cretaceous.

Yukon Crystalline Terrane is underlain by Early Paleozoic? biotite muscovite quartz feldspar gneiss and mica schist with interfoliated amphibolite, marble and serpentinite metamorphosed and deformed during the Late Paleozoic. The rocks, perhaps metamorphic equivalents of those in Cassiar Platform, have a coarse schistosity oriented discordantly to that of adjoining elements.

The second element, Yukon Cataclastic Terrane, has a ductilely deformed base and a less strained top, each discontinuous, several kilometres thick and separated by faults. The base has a structural succession of three mylonitic units: Paleozoic? immature clastic rocks called Nisutlin Assemblage, Late Paleozoic ophiolite called the Anvil Assemblage and Paleozoic and Mesozoic granite, the Simpson Assemblage. The top includes weakly metamorphosed ophiolite, Atlin Terrane, and a newly named Pennsylvanian basalt called the Semenof Formation. As well it has large, semiconcordant granodiorites, the Tatchun, Granite, Carmacks and Aishihik batholiths.

The penetrative flaser of the ductilely deformed rocks dips under Whitehorse Trough from all sides; northeast of the Trough it dips southwest, on the southwest it dips northeast. Metamorphic micas in mylonite last cooled through the argon retention isotherm in the Jurassic indicating ductile strain during the Jurassic. Model K/Ar ages range from 200 to 160 Ma.

Radiometric ages from the granodiorite batholiths in upper Yukon Cataclastic Terrane define two intrusive events, one Permian the other Early Jurassic. The older is dated by a K/Ar date of 268 Ma on Aishihik Batholith and by a discordant U/Pb age of 276 Ma on zircon from Selwyn Gneiss, both just outside the project area. The younger is given by a single concordant U/Pb age of 192 Ma on zircon from the Minto Pluton. Most K/Ar ages on the granites range between 165 and 140 Ma. They are thermally reset through tectonic uplift during the ductile strain and dextral strike-slip.

Whitehorse Trough, the strike-slip sheet, includes two conformable stratigraphic units: the Upper Triassic Lewes River Group and the Lower Jurassic Laberge Group. They are an andesitic basalt with limestone and an immature volcanic and clastic unit interpreted as volcanic arc basin deposits. The Takla, Hazelton and Bowser groups of northern British Columbia are time and lithologic equivalents with parallels to Whitehorse Trough strata. Whitehorse Trough strata are not internally strained or metamorphosed.

The Lewes River Group is redefined and formally subdivided into a lower basaltic andesite called the Povoas Formation and an upper unit, the Aksala Formation~~, with~~ carbonate and clastic ~~members.~~ The rocks are Carnian and Norian. The Laberge Group is similarly formalized. It has four formations. The lower unit, a few hundred metres thick, of marine shale and slate, is the Hettangian and Sinemurian Richthofen Formation. The middle division has two, laterally equivalent, Pliensbachian units, the Nordenskiold Dacite and Conglomerate Formation, which are 1 or 2 km thick. The upper unit is arkose, the Tanglefoot Formation; it is Toarcian to Bajocian. Nordenskiold Dacite has extensive, thick ash flows, some subaerial, others submarine. The Conglomerate Formation is a set of debris flows of locally derived, detrital alluvium.

Several young stratigraphic units overlap boundaries between elements or lie across more than one. The oldest is a Jura-Cretaceous chert pebble conglomerate, the Tantalus Formation, which fills extension basins along the dextral faults around Whitehorse Trough. Two suites of Cretaceous volcanic rocks overlap Yukon Crystalline Terrane and Whitehorse Trough strata. The mid-Cretaceous Mount Nansen Group has areally restricted, dacitic subvolcanic plugs, pipes and dykes. The Late Cretaceous Carmacks Group has a lower thick andesite and an upper flood basalt. The Pliocene Walsh Creek beds and the Pleistocene and recent Selkirk volcanics are local overlap units.

Yukon Cataclastic Terrane is interpreted as the detachment zone between the autochthon and the Mesozoic volcanic arc strata. During the Jurassic Whitehorse Trough slipped northwest over the detachment while the autochthon slipped southwest under it.

Whitehorse Trough is bounded by dextral faults; on the northeast is the Teslin, Mason, Boswell, Hootalinqua, Semenof set and on the southwest are the Carmacks, Hoochekoo, Ingersoll and Selkirk faults. Internally the Trough is also cut by connected dextral faults. The strike-slips are part of the Teslin Fault system, which may have 1000 km of dextral displacement.

In Laberge map area the Teslin Fault's displacement is largely transferred to two branches, a northeastern one, which follows the edge of Whitehorse Trough, marked by extension basins, and a southwestern one with compressional structures. The northeast branch, Semenof system, incorporates the Mason, Boswell and Hootalinqua faults, which together define two releasing double bends. The southwestern branch, the Chain system follows the Chain, Braeburn and Big Creek faults. Displacement is transferred through the Open and Fairview faults, which are interpreted as restraining bends in the strike-slip system. Strike-slips along the southwest side of Whitehorse Trough include the Selkirk, Hoochekoo and Carmacks faults, interpreted as dextral faults with Tantalus filled basins at releasing double bends.

Other structures in Whitehorse Trough, mainly tight synclines and tighter anticlines are part of the transcurrent slip. The faults and folds are interpreted as products of simple shear, but their orientations are not as expected from such deformation suggesting that stress orientation varied with time.

The faults trend northwest and dip steeply, but cannot be traced into the surrounding ductilely deformed rocks. In cross-section they presumably end downward in, or on, the detachment zone and the dextral displacement is gathered along the contact between the top and bottom of the detachment, which must then be a gently dipping strike-slip.

Dextral slip was underway by the early Late Jurassic when 164 Ma porphyry dykes were intruded; it continued through 140 Ma when granites in the top of the detachment zone were raised. It had ceased when 118 Ma Mount Nansen volcanics were laid across some faults.

Several faults are probably Late Cretaceous "overlap" structures related to the Mount Nansen Group. The Big Creek Fault, the largest of them, apparently dropped a block of the Big Creek Syenite from the detachment zone into the autochthon.

Four classes of mineral showings are recognized. Two are hosted by, and genetically related to, the Mount Nansen Group the mid-Cretaceous volcanics that "overlap" Whitehorse Trough's southwest edge. They are gold-silver veins such as those on Mount Nansen and porphyry copper-molybdenite deposits such as those on upper Big Creek. The Mount Nansen Group accounts for the largest number and most interesting showings of the region. The third showing type, coal occurrences, are part of a second "overlap" unit, the Tantalus Formation of the extension basins along the dextral strike-slips. Only one type, metamorphosed copper deposits in schlieren in granodiorite - the Minto and Williams Creek occurrences, is fundamentally related to the older rocks. They occur in the top of the detachment zone and were deformed and metamorphosed when these rocks were sheared.

Mineral exploration possibilities connected with the Mount Nansen Group are not exhausted. In particular the postulated genetic connection between the Mount Nansen Group and the Big Creek Fault warrants prospecting for unrecognized mineralization. Nordenskiold Dacite is the time equivalent of the Toodoggone volcanics, which hosts epithermal gold showings, and is worth considering in this light. Where the Tantalus-filled extension basins bottom on the detachment zone are possible stratigraphic traps for epithermal gold occurrences which have not been looked for. Whitehorse Trough also warrants study for its hydrocarbon possibilities. The strata fall squarely in the "oil window" and they include potential hydrocarbon source and trap rocks.

1. INTRODUCTION

Laberge and Carmacks map areas are in southern Yukon Territory (Fig. 1). Laberge map area (105E) is between 61 and 62 north and between 134 and 136 west, and Carmacks map area (115H), to the northwest, between 62 and 63 north and 136 and 138 west. They encompass 12,091 and 11,752 km^2.

This report contains descriptions and interpretations based on new field work, but it is built on earlier mapping (Fig. 2). Remapping was prompted by mineral exploration interest in the region and the lack of up to date interpretations. Field work was done during June of 1974, and the entire 1977 and 1979 seasons, with follow up in 1982. Summaries of results were reported as the work progressed (Tempelman-Kluit, 1975, 1978, 1980). Carmacks map area was first mapped and reported by Bostock (1936), and Laberge area by Bostock and Lees (1938). The early studies are remarkable in their accuracy and insight, particularly with the limited regional geological understanding when the work was done and the difficult logistics. The early work provides the starting point for the present investigation; it identified problems and helped direct the remapping.

This study follows remapping in adjacent areas during the last decade and results of that work are incorporated or applied here. The Pelly Mountains east of the project area are reported in Tempelman-Kluit (in press), and the geology of Aishihik Lake and Snag map areas, to the west, is detailed in Tempelman-Kluit (1974). Mapping south and north of the project area is older (Fig. 3); these areas need restudy in the light of newer work.

1.1CURRENT WORK

Field work in 1974 concentrated on Carmacks map area. The work was done during June from a camp near Carmacks, about 8 km up the Freegold Road. Most traverses were from roads, but limited helicopter flying was done to set out and retrieve traverse teams. Rocks near the Pelly and Yukon rivers were examined on a canoe trip later that season. In 1974 the senior assistants were J.G. Abbott, S.P. Gordey and B.C. Read; D. Harper, G. O'Neill, R. Turna and D. van Appelen were junior assistants. During 1977 field work was concentrated in Laberge map area and was done from fly camps. Most work was from roads and from some rivers with minor helicopter support. The writer worked mostly alone, but he was assisted by M. Waterreus and A. Steele for two weeks each.

The most concerted mapping effort was during the summer of 1979, when work was done with five assistants and a helicopter on contract. Two base camps, the first near the north end of Fox Lake and the second at Carmacks, served as operation centres. The senior assistants were P. Erdmer and P. Reid; S. Churchill, T. England and H. Grond were the junior assistants. M. Duff was the helicopter pilot on contract from Yukon Airways and J. Souther cooked for the party.

Most of the summer the assistants worked on the overall remapping, but each was also responsible for independent work. Thus Erdmer began field work for his doctoral dissertation at Queen's University. He studied the ductilely deformed rocks' metamorphic mineral assemblages and fabrics in the Yukon

Cataclastic Complex (Erdmer, 1981, 1982) and documented the extreme strain and temperature and pressure conditions of metamorphism to which these rocks were subjected. Reid began studying the organisms and structure of Upper Triassic reefs in the Lewes River Group: the basis of her doctoral thesis at the University of Miami (Reid, 1981). Churchill, England and Grond's bachelor's theses at University of B.C. also concentrated on certain aspects of the project. Churchill (1980) provided the first K/Ar dates for the Carmacks Group, showing that this unit is Latest Cretaceous, not Eocene as had been thought. England (1980) focussed of conodonts in Lewes River Group carbonates. He demonstrated their dissimilarity from those in the correlative Hoole Formation; further evidence that the Intermontane Belt is allochthonous next to the Omineca Belt. Grond (1980) mapped and sampled an area in the Miners Range and dated the volcanics there, showing that they are Late Cretaceous and coeval with the Carmacks Group.

No field work was done during 1980 and 1981 and the project was idle while the writer was seconded to the Department of Indian and Northern Affairs in Whitehorse. In 1982 follow up was completed when the writer worked alone in Laberge map area in May and June and in Carmacks map area during July and August. Locations of traverses and spot observations are summarized in Figures 4 and 5.

1.2ACCESS AND LOGISTICS

The project area is just north of Whitehorse, Yukon's capital city. It is accessible by air and road and is traversed from north to south by the Klondike Highway, an all weather road from Whitehorse to Dawson and Mayo (Fig. 6). The Campbell Highway, another all weather road which joins the Klondike Highway at Carmacks, provides access from Faro, Ross River and Watson Lake to the east.

Laberge map area has no other maintained roads, but the old Dawson Wagon Road, which diverges from the Klondike Highway near Braeburn can be followed for long distances in dry weather. A winter trail reaches Livingstone Creek from the east shore of Lake Laberge.

The Freegold and Mount Nansen roads, which run westward from Carmacks are passable in summer. The Freegold Road gets the most use and can usually be driven to Big Creek; the Mount Nansen Road is generally passable to Mount Nansen. The spur of the Freegold Road along the southwest side of Yukon River runs to the Minto property, but is not used much and is generally impassable. The road along the north side of Pelly River, from Pelly Crossing to Pelly Farm, gets regular use and is mostly in good shape, like the track between Minto and Pelly Farm.

Carmacks with a population of 327 (1980) has been the main trading centre in this area since early this century (Bostock, 1979). It has several stores, two hotels and bars, and can provide most necessities for exploration. Carmacks also has an airstrip about 5 km east of town, and a helicopter was based there year round during the late seventies and early eighties. An RCMP post and forestry station completes the list of amenities. Pelly Crossing has a small store, garage and restaurant. McCabe Creek and Braeburn have operating roadhouses, the latter famous for its giant cinnamon buns. Braeburn also has an airstrip; beware of stray horses before landing. Pelly Farm continues to be operated by the Bradley brothers and their family.

Fort Selkirk, Minto, Big Salmon, Livingstone and Hootalinqua are abandoned; ruined buildings remain. Minto is a public campground where boats can be "put in" to the Yukon River. Fort Selkirk and Minto each have an airstrip.

The northwestward flowing Yukon River and its tributaries drain the project area (Fig. 6). Teslin River enters from the southeast at Hootalinqua, and the Pelly River from the east at Fort Selkirk. Secondary streams on the Yukon's right limit are Big and Little Salmon rivers, and Tatchun Creek. Similar left limit streams are the Nordenskiold River and Big Creek. Yukon River is navigable through the project area, with Five Finger and Rink rapids the only places where care is needed. Pelly River is also an easy stream with no obstacles to moderate sized boats downstream from Granite Canyon. The canyon is navigable, but care must be taken to avoid the large boulders in the channel. Teslin River is a wide, sluggish, muddy stream with no navigation hazards. Big Salmon River is a smaller, fast, clear stream that can be negotiated by canoe; it has many riffles and sweepers, but these can be avoided. Nordenskiold River and Big Creek are of comparable size to the Big Salmon River. Lake Laberge, near the Yukon River's head, drains northward through the Thirtymile River, the name given to the Yukon between Lake Laberge and Hootalinqua. This is the river's fastest stretch, with beautiful green water in a narrow confined channel. Lake Laberge water is divided with dark clear water on the lake's west half and blue green silty water, which derives from Takhini River, on the east side. The name Lewes River, now rarely used, was applied to the Yukon upstream of Fort Selkirk.

1.3ACKNOWLEDGEMENTS

This work has benefited from the physical and creative input of many people who worked on it at various stages in the field and the office. I owe debts to the many assistants who worked on the project in the field and to others who helped with field logistics; I am also indebted to those who worked on office study and compilations as the map making and reporting progressed. Beside the people named in the section on present work J.G. Abbott, S.P. Gordey, B.C. Read, D. Harper, G. O'Neill, D. van Appelen and R. Turna worked in the field during the summer of 1974. Various Archer-Cathro and Associates personnel, especially Doug Eaton, helped with parts of the field work.

J. Rhodes and A. Brookfield helped compile the data and produced drafts of the maps and drawings during 1984 and 1985; many of their good ideas about the geology and how to present it have found their way into this report. Bev Vanlier and Wendy Chiu helped beyond their duty by editing, checking spelling and manuscript layout and format.

My colleagues in the Vancouver office of the Geological Survey of Canada helped bring the work to this end by discussing ideas, reading drafts and commenting critically. I particularly thank B. Struik for his suggestions which forced me to reexamine ideas and improve the report's organization.

2.PHYSIOGRAPHY

Bostock's (1948) physiographic classification scheme for the northern Canadian Cordillera places the project area in the Interior System, which is the central upland between the more mountainous Eastern and Western systems. In southern Yukon this System is represented by Yukon Plateau, which is itself divided into the Pelly, Macmillan, Lewes, Klondike and Kluane Plateaux and the Pelly Mountains and Dawson Range (Fig. 7). Western Laberge and eastern Carmacks map areas are in Lewes Plateau, and eastern Laberge map area is in the Pelly Mountains. Western Carmacks map area is in the Klondike Plateau and Dawson Range. In Laberge map area the Lewes Plateau includes the Miners Range and Semenof Hills. Most of Lewes Plateau is a gently rolling upland with long, rounded ridges 1200 to 1500 m above the sea, separated by broad glaciated valleys.

Laberge map area is dominated by the generally low country between the Miners and Big Salmon ranges (Fig. 7). Much of this low ground has reasonable outcrop, not much brush, easy walking and stimulating geology, particularly the eastern shore of Lake Laberge, including the Hancock Hills. However the Semenof Hills are uninspiring, brushy low hills with few geological contrasts. The Big Salmon and Miners ranges are fine mountains with interesting rocks and good views.

The Semenof Hills are a ridge of connected, rounded, low mountains below 1500 m, between Big Salmon River and the Teslin-Yukon Valley. Mount Peters (+1500 m), Moose Mountain (1597 m) and Boswell Mountain (+1500 m) are three high points. Exposure is fair on ridges, but little outcrop occurs on the slopes or along streams. Ridges are vegetated to the top, with only the three named peaks above tree line. The maximum relief above Teslin River is less than 700 m.

Big Salmon River occupies a 5 to 10 km wide valley below the confluence of South Big Salmon River, but narrows abruptly where it enters the Big Salmon Range. The valley is the boundary between the Big Salmon Range and Lewes Plateau.

The Yukon-Teslin Valley is narrow north of Hootalinqua, and wider south of there. Where the river emerges from the Semenof Hills and is joined by the Big Salmon the valley widens abruptly. The Yukon River has few exposures and 30 to 50 m high gravel outwash banks are common in this stretch.

Lake Laberge occupies a northwest trending depression termed Ogilvie Valley (Cairnes, 1910), about 750 m above the sea. It extends to Coghlan Lake and Mandanna Valley. Between it and the Yukon-Teslin Valley the hills are generally below 1200 m elevation. Povoas Mountain (ca 1150 m), Lime Peak (+1500 m), Mount Laurier (1779 m) and Teslin Mountain (1953 m) are southern high points and Packers Mountain (1446 m) is the highest spot in the north. Outcrop here is surprisingly good on the ridges and along many streams. On both sides of Lake Laberge, outcrop is excellent.

Ogilvie Valley and the valleys of Klusha Creek and Nordenskiold River are underfit. They are occupied by streams that are small in comparison to their valleys. Evidently larger rivers than those that now flow there carved the depressions. These early, larger streams were displaced and replaced by the present drainage during Pleistocene deglaciation. The deranged drainage is hypothesized to be part of a system that flowed generally southward and emptied into the Pacific Ocean through the grossly misfit Takhini-Dezadeash Valley (Tempelman-Kluit, 1980).

Frenchman and Tatchun lakes occupy a valley about 100 m above the Yukon River, which was probably also abandoned during deglaciation.

Big Creek occupies an underfit valley below Dark Creek. It has carved a 5 km long canyon just above its mouth. Big Creek and Dark Creek probably emptied directly into the Yukon through the gap east of Dark Creek, before being deranged by ice upon deglaciation (Bostock, 1936; p. 8).

Richthofen Valley, occupied by Fox Lake and Klusha Creek, is wide and open, about 800 m above the sea and the northeast boundary of the Miners Range. Outcrop is plentiful, not only along streams incised into it, but also between them. Pilot Mountain, in the southern Miners Range, is 2054 m high. The rest of the range approaches 1900 m. The Miners Range has rounded peaks and long connected ridges, mostly above tree line. Exposure is excellent and even the lower slopes have fair outcrop.

Big Salmon Range slopes gently up to the east reaching 1300 m above the Teslin-Yukon Valley. Near the east edge of Laberge map area its peaks are about 2000 m high, with Mount Black 2157 m above the sea. The range has the highest local relief and outcrop is generally excellent, particularly along ridges.

Carmacks map area, northeast of Yukon River is dull country, with few vistas, unvaried geology, much swampy ground and large burns. Ptarmigan Mountain, the highest point, 1487 m above the sea is the only peak above tree line. Other peaks are below 1350 m. With the Yukon River 550 m above sea level here the maximum relief is roughly 900 m, but local relief is closer to half that figure.

Some 50 km southwest of the Yukon River in Carmacks map area is the Dawson Range. Mount Nansen (1705 m), Victoria Mountain (1870 m), Klaza Mountain (1937 m), Tritop (2034 m) and Prospector Mountain (ca 1850 m), the highest points, are rounded peaks above the general upland, and above tree line. Between Yukon River and the Dawson Range is a 1500 m high plateau, incised 500 m and more by Big Creek and other Yukon River tributaries. Granite Mountain and Mount Pitts (each ca 1500 m) are high points at the general plateau level.

Bostock (1948) placed the boundary between Lewes and Klondike Plateaux near the Yukon-Pelly rivers confluence. The boundary is arbitrary and follows no well defined physiographic feature. The boundary between the Dawson Range and the Klondike Plateau also follows no clear barrier.

Yukon River flows through the project area in a series of inherited valleys (Tempelman-Kluit, 1980). The stretch known as the Thirtymile River, between Lake Laberge and Hootalinqua, is a new channel, with rocky channels and fast current, not yet in balance. The river probably first occupied this reach during last deglaciation. From Hootalinqua to Cassiar Bar is a more mature valley with slacker water. The short stretch of valley from Cassiar Bar to Big Salmon is narrow, but from there to Tatchun Creek the valley broadens again. Between Tatchun and Fort Selkirk the valley is 5 to 8 km wide and flat bottomed. It narrows abruptly to a V-shaped cross-section northwest of there. In its wide stretch below Tatchun Creek and in the reach between Carmacks and Little Salmon the valley has prominent gravel benches many tens of metres above the river. Evidently the various valley segments below Hootalinqua derive from different streams. The river captured segments during deglaciation.

Laberge and eastern Carmacks map areas were covered by ice during the the McConnell and Reid glacial advances (Hughes et al., 1969) (Fig. 8). Ice of the Cassiar Lobe of the Cordilleran sheets flowed generally northwest out of the Pelly Mountains covering the generally low ground of Laberge map area generally to the valley ~~of~~ Yukon River in Carmacks map area. The region has beautifully preserved glacial and deglaciation features which have been studied by O.L. Hughes and R.W. Klassen.

3.GENERAL GEOLOGY

The project area is divided into four northwest trending elements; from northeast to southwest the Cassiar Platform, Yukon Cataclastic Terrane, Whitehorse Trough and Yukon Crystalline Terrane (Fig. 9). The four elements form a structural succession in which Cassiar Platform and Yukon Crystalline Terrane represent autochthon. It is overlain structurally by Yukon Cataclastic Terrane and by Whitehorse Trough in order. Each element has distinctive stratigraphy and structure and because important faults separate them stratigraphic ties between blocks are absent or tenuous. The stratigraphy is described element by element, the autochthonous rocks first followed by successively higher structural slices. "Overlap" units that bridge boundaries between elements are described last.

Cassiar Platform, the northeastern autochthonous element, contains Paleozoic miogeoclinal strata deposited on the ancient western margin of North America. They were folded and displaced on widely spaced thrust faults during the Jurassic and intruded by granites and metamorphosed in the Cretaceous.

Yukon Crystalline Terrane, the autochthon on the southwest, is underlain by Paleozoic? schist, marble and graphitic quartzite. Foliation is discordant to that in the adjacent Yukon Cataclastic Terrane and to the strike of Whitehorse Trough faults and folds and its deformation is thought to be independent of that in the other elements. Stratigraphic relations between Cassiar Platform and Yukon Crystalline Terrane are unknown, but some rock units are lithologically alike.

Yukon Cataclastic Terrane has a strongly sheared base and a less sheared top; the two are separated by ductile faults. The base has three lithologic assemblages whose stratigraphy and stratigraphic relations are unknown. They are immature clastic rocks with intermediate volcanics, Late Paleozoic amphibolite and serpentinite and granites. Yukon Cataclastic Terrane's top has large Jurassic granitic batholiths and Late Paleozoic oceanic volcanic rocks. The boundary beneath Yukon Cataclastic Terrane is the D'Abbadie Fault, a Late Jurassic thrust; that at the top is a set of large displacement strike-slips. Yukon Cataclastic Terrane rocks were sheared and metamorphosed during the Jurassic during strike-slip on Whitehorse Trough's large faults.

Whitehorse Trough, structurally the highest element, represents what are interpreted as the products of an Early Mesozoic volcanic arc. Its rocks were folded and displaced by strike-slips during the Jura-Cretaceous and the Trough is separated from Yukon Cataclastic Terrane by the Teslin and Carmacks Fault systems, breaks with about 1000 km dextral slip.

Certain young sedimentary and volcanic rocks occupy more than one element. They are deposited across, or intruded into, two or more elements. Most of them overlap Yukon Crystalline Terrane and Whitehorse Trough strata. The overlap units generally occur by themselves and not as a sequence; from oldest to youngest they are the Early Cretaceous Tantalus Formation, the mid-Cretaceous Mount Nansen Group and its plutonic relatives, the Casino Granodiorite and Coffee Creek Granite, the Late Cretaceous Open Creek volcanics and Carmacks Group, and the Plio-Pleistocene Walsh Creek beds and Selkirk volcanics.

4.CASSIAR PLATFORM

Cassiar Platform strata occupy eastern Laberge map area (Figs. 9, 10) and are separated from Teslin Suture Zone by the D'Abbadie Fault, a thrust across which few stratigraphic ties are made. Two main metasedimentary units, a Proterozoic and Cambrian mica schist, marble and gneiss, the Big Salmon Complex and a Cambrian to Devonian graphitic quartzite and slate, the Nasina Formation, are recognized. They are Members 1 and 2 respectively of Bostock and Lees' (1938, p. 7-8) Yukon Group. The main exposures are in Quiet Lake map area, where they occupy broad culminations around Cretaceous granite batholiths.

4.1BIG SALMON COMPLEX

Strata included in the Big Salmon Complex (1Cbs) occupy a small area where Big Salmon River crosses the east edge of Laberge map area. Ridges south of the river have good exposures. The name Big Salmon Complex is used in the sense of Tempelman-Kluit (in press) to include the metamorphosed Eocambrian and Early Paleozoic autochthonous strata in the Big Salmon Ranges. Readers are referred to that work for descriptions and discussion. The Complex includes biotite quartz and quartz mica schist and gneiss, overlain by a marble correlated with the Lower Cambrian Ketza Group. The rocks are tightly folded and fold limbs sheared out, so that the marble is repeated, locally several times. The rocks were metamorphosed to upper greenschist and lower amphibolite grades during the Cretaceous. Foliation in the metamorphic rocks generally parallels bedding and dips moderately west and southwest in the project area. The section of the Yukon Group given by Bostock and Lees (1938, p. 7-10) is considered to be a structural sequence.

4.2NASINA FORMATION

The Nasina Formation is an Ordovician to Devonian dark grey to black graphitic quartzite with graphitic slate. It includes interbedded orthoquartzite lenses correlated with the Hogg Formation (Sh) and dolomite pods equivalent to the Porcupine Formation (SDp). The rocks are sheared and probably repeated on bedding parallel faults; Bostock and Lees' (1938) section for Member 2 is a structural sequence in the Nasina Formation.

The Nasina Formation occupies a belt, about 5 km wide, in easternmost Laberge map area. Ten kilometres northeast of Last Peak and on upper reaches of Dycer and Mendocina creeks are good exposures. The rocks weather resistantly, the carbonates to light colours and the clastic beds to black. Readers are referred to Tempelman-Kluit (in press) for descriptions and correlations.

5.YUKON CRYSTALLINE TERRANE

5.1DISTRIBUTION

Yukon Crystalline Terrane in southwestern Carmacks map area (Fig. 9) lies southwest of Whitehorse Trough and is separated from it by the Granite, Carmacks and Aishihik batholiths and by the Hoochekoo and Carmacks faults (Fig. 10). It is underlain by biotite muscovite quartzo-feldspathic gneiss and mica schist with interfoliated amphibolite, marble and serpentinite, all of unknown age.

The rocks resemble those in Cassiar Platform and may be correlatives. They are distinguished because only certain units have equivalents and because the structural succession differs. For example the southwestern gneiss and mica schist with interfoliated marble resembles the Lower Cambrian Big Salmon Complex. And graphitic quartzite of Yukon Crystalline Terrane just outside Carmacks map area (in northeastern Aishihik Lake map area) may match the Nasina Formation of Cassiar Platform. Although some Yukon Crystalline Terrane strata may also have a match in Yukon Cataclastic Terrane most are missing. Amphibolite and serpentinite of southwestern Carmacks map area, for example, may match Anvil Assemblage rocks of Teslin Suture Zone. But Nisutlin and Simpson Assemblage equivalents are absent in Yukon Crystalline Terrane. Yukon Crystalline Terrane rocks are characterized by a coarse schistosity grown across a ductile flow fabric; Cassiar Platform strata are generally less metamorphosed and Yukon Crystalline Terrane rocks are dominated by ductile fabrics. Bostock (1936, p. 15) described the rocks briefly and summarized the sequence. He equated the southwestern metamorphic rocks with those of northeastern Carmacks map area and mapped them all as Yukon Group.

The rocks occupy southwestern Carmacks map area, where they form a 25 km wide, northeast trending, synform called Maloney Syncline and a parallel anticline to the southeast. Isolated exposures occur south of Big Creek (Fig. 11). Metamorphic fabric in the schist and gneiss strike northeast, across the general northwest trend of fabrics, folds and faults in Yukon Cataclastic Terrane and Whitehorse Trough (Fig. 11).

5.2INTERNAL RELATIONS

Exposures of the Maloney Syncline in southwestern Carmacks map area represent the lithology and structures of Yukon Crystalline Terrane (Fig. 11). Opposite limbs of the syncline expose different structural sequences. The southwest limb has a lowest unit of about 1 km of schist (with perhaps 20% micaceous quartzite and granodiorite gneiss) overlain by 300 m of serpentinite and amphibolite, capped by 3 km of gneiss (with about 20% interfoliated mica schist). The gneiss is overlain by about 200 m of amphibolite and it is covered by yet another 300 m of granodiorite gneiss with amphibolite lenses. It grades upward to coarse grained, foliated biotite granite and granodiorite, locally with amphibolite schlieren and lenses, but without marble. The foliated granite and the gneiss are interfoliated over a thick zone. The contact is transitional and appears intrusive-metamorphic, not structural. Gneiss with K-feldspar augen is common in the upper gneissess, but absent in the lower, schist dominated, succession. Marble lenses up to 20 m thick are interfoliated with the schist and gneiss near the amphibolite and serpentinite; they are more common in the schist than in the gneiss.

Maloney Syncline's northwest limb also has quartz mica schist and micaceous quartzite at the base, but the thick amphibolite and serpentinite low in the southwest limb is missing. A prominent marble, nearly 100 m thick, which occurs low in this schist, a few kilometres west of the mouth of False Teeth Creek may match marbles low in the southwest limb. Above are about 2 km of granodiorite gneiss and schist with minor interfoliated amphibolite equivalent to the upper units on the fold's opposite limb. As in the southern limb the top is foliated biotite granite apparently conformable with the gneiss.

5.3LITHOLOGY

The schist and gneiss are moderately resistant, blocky and weather to pale buff colours. Outcrop is poor; even ridge tops have only a few castellated exposures and are covered mainly by loose blocks. The rocks are uniform and the main variation is in the proportions of mica, quartz and feldspar. The mica schist and gneiss are gradational variants of one another. The quartzite contains more quartz and less feldspar and mica than the gneiss. Foliation is a well developed, coarse schistosity defined by preferred orientation of micas crystallized over, and generally along, a flaser fabric into which original bedding and compositional layers are transposed. Micas and quartz generally define the fabric, but some are grown across showing they last crystallized after the strain. Marbles are sugary, their colour banding is a remnant ductile flow fabric. Foliation dips gently or moderately and is folded broadly to define large open structures like Maloney Syncline. Minor folds are rare, those seen are subisoclinal folds, which bend the foliation and trend northeast with subhorizontal axes. Rodding, common and well developed in gneiss and quartzites, is subhorizontal and trends northeast. In adjacent Aishihik Lake map area lineation also trends northeast (Tempelman-Kluit, 1974, p. 58). In micaceous units a crinkle lineation is superposed on, and subparallel to, rodding.

The rocks represent the Barrovian metamorphic facies series in the greenschist and amphibolite facies. Aside from quartz, muscovite, biotite and garnet, sillimanite (fibrolite) and kyanite are seen locally. Grade varies slightly and gradually. Metamorphic isograds were not mapped, but isograd surfaces are presumed to dip gently.

The amphibolite is dark greenish black and made up of actinolite, epidote, oligoclase and quartz. It grades to black amphibolitic gneiss and grey quartzo-feldspathic amphibole biotite gneiss. Amphiboles are aligned and lend the rocks a strong grain and good foliation. Serpentinite is massive, weathers dun brown and contains greenish black serpentine minerals. It is an alpine peridotite or pyroxenite. The serpentinite and amphibolite are interfoliated, but their contact with the schist above and below is an abrupt fault(?) parallel to foliation.

The gneiss and schist may be continental shelf deposits and the amphibolite and serpentinite could be overthrust oceanic crust. They may be analogous to, but not necessarily the equivalent of, the Big Salmon Complex-Anvil Assemblage. The whole must have been deformed, metamorphosed and granitized before the mid-Cretaceous, the age of the Mount Nansen suite and Casino Granodiorite which cut them.

The upper gneiss of Maloney Syncline is a more granitized equivalent of the schist and gneiss below the serpentinite. The transition between them is gradual and occurs above the amphibolite and serpentinite. Because the more granitized gneisses rest above less mobilized equivalents at the top of a 5 km thick structural stack the entire succession may be overturned. The upper gneiss may occupy the core of a large anticlinal nappe that is refolded by Maloney Syncline. If so the amphibolite and serpentinite may mark the core of a corresponding isoclinal syncline below it. An alternative explanation for having more mobilized rocks above less granitized equivalents is that the upper gneiss is thrust over the lower. The gradational relations favour the "upside down" interpretation.

Pendants, inliers and screens of gneiss in the Early Jurassic Big Creek Syenite on the Dawson Range's north flank may be equivalents of the Maloney Syncline gneisses or of the "Selwyn Gneiss" north of Big Creek. They are engulfed in the syenite and cut by Mount Nansen Group dykes and plugs. Their diffuse, irregular boundaries and gradational relations to younger plutonic types obscure original relations.

5.4AGE AND CORRELATION

No fossils, in or outside the project area, date the schist, gneiss and amphibolite directly, but U/Pb data on zircons from the southwest corner of Carmacks map area give a Permian upper limit. One sample each of the schist and gneiss from peak 5191 between Maloney Creek and Klaza River gave strongly discordant, but similar results. Two zircon fractions from each sample fall on one discord with intercepts at 248.1 and 2199 Ma. One interpretation of this is that detrital zircon in the sedimentary protolith of the schist and gneiss was derived from an Early Proterozoic source and that the rocks were metamorphosed or otherwise lost a significant part of their lead about the mid-Permian. The lower intercept age can be interpreted to mean that the rocks are Paleozoic or older and that they were metamorphosed by the mid-Permian. A younger limit to the deposition, metamorphism and deformation is given by the cross-cutting mid-Cretaceous Casino Granodiorite.

In southern Yukon the only lithologic match for the schist and gneiss is in the Eocambrian or Lower Cambrian strata of Big Salmon Complex. Graphitic quartzite above the schist in adjacent Snag map area, lithologically matches the Ordovician to Devonian Nasina Formation. In Cassiar Platform this unit rests on the Big Salmon schists. Finally the amphibolite and serpentinite compare closely to the Anvil Assemblage. That unit rests structurally on the Nasina Formation east of the D'Abbadie Fault.

McConnell's (1905a) Pelly Gneiss as redefined by Tempelman-Kluit and Wanless (1980), resembles the gneiss of Maloney

Syncline in lithology and relations. Pelly Gneiss of the Fiftymile Batholith has yielded a U/Pb discordia age of 375 Ma (Tempelman-Kluit and Wanless, 1980). If equivalent the plutonism and at least some of the metamorphism and deformation in Yukon Crystalline Terrane are Devonian. This does not conflict with the ages suggested by the lithologic correlations suggested above.

Apparently Yukon Crystalline Terrane contains Eocambrian schist, Lower Cambrian marble and Ordovician to Devonian graphitic quartzite possibly connected to ancient North America during deposition. All were metamorphosed, folded and granitized during the Late Paleozoic (375 to/and/or 248.1 Ma.

Gneiss, schist and marble of southwest Carmacks map area are continuous with, and included in,the Biotite Schist unit of central Aishihik Lake map area (Tempelman-Kluit, 1974, p. 23-24). They are also equivalent to Muller's (1967, p. 17-25) Yukon Complex of Kluane Lake map area. Minor structures in the Biotite Schist are the same as those described above. The folds near southern Sekulmun Lake (Tempelman-Kluit, 1974) are considered to be late metamorphic. They may predate the Maloney Syncline and the anticline southeast of it, which both deform the latest schistosity.

6.YUKON CATACLASTIC TERRANE

Yukon Cataclastic Terrane (Fig. 9) is the block between Cassiar Platform and Whitehorse Trough and between Yukon Crystalline Terrane and Whitehorse Trough. Northeast of Whitehorse Trough it is bounded by the D'Abbadie Fault (and its northwestern extension along Drury Lake) and the Teslin Fault system including the Teslin, Mason, Boswell and Hootalinqua faults. Southwest of Whitehorse Trough its upper boundaries are the Selkirk, Hoochekoo and Carmacks faults; the lower boundary is largely overprinted by "overlap" granites.

Yukon Cataclastic Terrane includes metamorphosed and sheared, sedimentary, volcanic and igneous rocks at the base and unsheared rocks, mainly Jurassic batholiths, at the top. The sheared base has three groups: the Nisutlin, Anvil and Simpson assemblages. The first is dominated by sheared immature clastic rocks and volcanics of intermediate composition, mostly of Paleozoic depositional age. Anvil Assemblage has sheared Late Paleozoic ophiolite and Simpson Assemblage sheared granitic rocks intruded in the Permian and Jurassic.

Large semiconcordant batholiths of granodiorite and granite on both sides of Whitehorse Trough (Fig. 10) are grouped in upper Yukon Crystalline Terrane. They may intrude or rest structurally on the ductilely deformed rocks and occupy the top of the detachment zone between Whitehorse Trough and the autochthonous Cassiar Platform and Yukon Crystalline Terrane. Three broadly Jurassic suites are recognized. Oldest is a generally foliated biotite hornblende granodiorite that has given Jurassic radiometric ages, but which is likely Latest Triassic. This is the Klotassin suite of the Aishihik and Klotassin batholiths west of the project area; it forms the Lokken, Tatchun and Granite batholiths. Next youngest is the Big Creek Syenite. It is likely Early Jurassic and may be related to the Klotassin suite or to a pink granite, the third suite. Early Jurassic pink granite is the youngest suite; it forms the Carmacks and Long Lake batholiths, which intrude and agmatize parts of Aishihik Batholith.

The granodiorite's radiometric ages have a confusing range. Some are interpreted to reflect the intrusive age, others later thermal events. Intrusion of some granodiorite is dated by a concordant U/Pb age of 192 Ma on zircon from the Minto Pluton and corroborated by K/Ar dates of 185 and 184 Ma on hornblendes from Lokken Batholith and Big Creek Syenite. The younger K/Ar dates in the range 165 to 140 reflect cooling following post-intrusive uplift or cooling after the strain that produced the foliation. The Permian intrusive age of the older granodiorite is given by a concordant U/Pb date of 276 Ma on zircon from just west of the project area. It is supported by a single K/Ar determination of 268 Ma on hornblende from southern Aishihik Batholith. Thus two intrusive events are distinguished: Permian granodiorite intruded before the Jurassic ductile strain and Jurassic granodiorite intruded during the strain. The first may be genetically related to the Anvil Assemblage, the second could be the plutonic root of Whitehorse Trough volcanics.

6.1SHEARED BASE OF YUKON CATACLASTIC TERRANE

The three lithologic groups of Yukon Cataclastic Terrane form a structural sequence with the Nisutlin Assemblage below the Anvil Assemblage, and it in turn below the Simpson Assemblage. The assemblages are juxtaposed on ductile faults. The degree of strain varies laterally and across the structural succession. In places the entire stack is represented by mylonite and mylonitic schist a few kilometres thick; elsewhere less sheared precursors, are included.

The metamorphic rocks are tectonically interleaved; internal stratigraphy and depositional relations are known only locally where the ductile strain has not destroyed them. Structural mixing occurs on scales ranging from centimetres to kilometres, and no stratigraphic order was recognized. Between North and South Big Salmon rivers, and from structurally lowest to highest (east to west), the zone contains amphibolite, structurally interleaved thick slices of graphitic quartzite and mylonitic quartz-muscovite schist and amphibolite with sheets of serpentinite. North of Big Salmon River amphibolite and quartz-muscovite schist continue, but the slices are not differentiated. The main muscovite schist slice narrows and interfingers with the Nasina Formation between Big Salmon River and Mendocina Creek. Hornblende diorite augen gneiss forms slices in Teslin Suture Zone, but also grades laterally into the amphibolite, for example across lower Mendocina Creek.

Teslin Suture Zone, in eastern Laberge map area (Fig, 9), is a subdivision of Yukon Cataclastic Terrane distinguished only by its steep dips. It has the same rocks. The transition from steep to gentle dips occurs in northern Laberge map area and the boundary between Teslin Suture and Yukon Cataclastic Terrane is arbitrarily placed there. The Semenof Hills Block is considered a subdivision of the Teslin Suture Zone separated by the Big Salmon Fault. Its stratigraphy is not demonstrably related to that of Teslin Suture Zone.

6.1.1YUKON CRYSTALLINE TERRANE IN CARMACKS MAP AREA

Yukon Crystalline Terrane in northeastern Carmacks map area (Fig. 11) is represented by a structural sequence of interfoliated, ductilely deformed, probably Carboniferous or Permian metamorphic rocks. Main rock types are gabbro, amphibolite, micaceous quartzite, muscovite quartzite, marble and biotite hornblende granodiorite gneiss. Foliation dips moderately in most places. Exposures are poor, but fairly good outcrops are on Ptarmigan Mountain, on the ridge north of Mica Creek and in places along Pelly River.

6.1.1.1ULTRAMAFIC ROCKS

On the lower Pelly River (Figs. 6, 11) are dense amphibolitic gabbro and related ultramafic rocks with minor interfoliated marble, quartzite and schist. They are dark green, and resistant weathering and lack fabric so that their general orientation is obscure. Many are coarsely crystalline aggregates of pyroxene partly replaced by actinolite, red garnet and serpentine minerals. Biotite is common. The pyroxene is a relict original constituent and some shows excellent crystal form, but the remainder of the rock is a metamorphic product.

Serpentinite occurs as irregular shaped lenses several metres thick and tens of metres long in the amphibolitic gabbro and may constitute 5% of the volume. It is dark green, massive and dense and made up of dark green and black serpentine with some relict olivine and pyroxene and was probably formed from pyroxenite. The marble is a white, resistant weathering aggregate of coarsely crystalline calcite and tremolite with some grossular garnet and wollastonite. It has a good metamorphic fluxion structure which is intricately folded in places.

6.1.1.2MARBLE AND METAQUARTZITE

Grey biotite muscovite quartzite and garnet quartz mica schist are the commonest rocks interfoliated with the gabbro; they make up a quarter of the unit. They may represent metamorphosed argillaceous chert or quartz sandstone. Unlike the enclosing gabbro the schist is superbly foliated with an excellent flaser that is locally tightly refolded and transposed. Muscovite quartzite, resembling the Klondike Schist, is common on western Ptarmigan Mountain and in exposures between upper Selkirk and Hayes creeks. Marble lenses, as much as 150 m thick, and ranging to strings of disconnected remnants a metre or two long are enclosed by gabbro. Some marble has structures resembling crinoid columnals, but the rocks are coarsely recrystallized and it is often difficult to be sure. Careful search has not turned up diagnostic fossils. Well foliated grey micaceous metaquartzite, which may represent recrystallized chert or quartz sandstone is interleaved with the marble.

Rocks correlated with the Nisutlin Assemblage occur south of Selkirk Creek at the west edge of Carmacks map area. Muscovite quartz mylonite schist and mylonitic micaceous quartzite predominate. Both have an excellent flaser and strong rodding lineation. Quartzite is locally graphitic and weathers resistantly into large slabby blocks controlled by foliation. Muscovite is the dominant mica, but chlorite is seen. Between Hayes and Selkirk creeks foliation generally dips southeast and lineation plunges eastward. The rocks resemble the Klondike Schist near Dawson (Green, 1972) and the Nisutlin Assemblage of Laberge map area.

6.1.1.3GNEISS

While gabbro with amphibolite and marble predominate on the lower Pelly River, quartzite, micaceous quartzite, marble, amphibolite and granodiorite gneiss are more common east of Pelly Crossing. Micaceous quartzite and amphibolite are commonest, but marble sheets, locally a hundred metres thick, and gneisses of similar dimension are interfoliated. Generally the gneiss is homogeneous and lacks interfoliated schist. It is equigranular, medium grained and homogeneous, without original igneous textures, but with a superb flaser foliation. The gneiss is medium grey and mesocratic: its main minerals are quartz, plagioclase and biotite. It resembles the Selwyn Gneiss, which occurs nearby as large bodies.

6.1.1.4INTERNAL RELATIONS

The structural pattern by which the quartzite, amphibolite, marble and gneiss are interfoliated in Yukon Cataclastic Terrane and Teslin Suture Zone is difficult to explain by the simple stacking of klippen as seen in Finlayson Lake map area (Tempelman -Kluit, 1979). In the klippen the Nisutlin, Anvil and Simpson assemblages occur in consistent order and although some units may be missing, inverse order has not been seen. This does not apply outside the klippen and the lithologic units must be repeated structurally on faults of several generations or on several faults of one episode. It has not been possible to distinguish different generations of faults, but such distinction may be possible by assuming that the units were originally structurally ordered according to the klippen's scheme.

6.1.1.5AGE AND CORRELATION

The quartzite and schist resemble strata grouped with the Nisutlin Assemblage in adjacent Quiet Lake and Finlayson Lake map areas (Tempelman-Kluit, in press) and are correlated with it and assigned the same Late Paleozoic or Early Mesozoic age. Similarly the marble is probably equivalent to the Pennsylvanian marble in upper Nisutlin Assemblage, near Finlayson Lake for example. Gabbro and the related ultramafics and amphibolite are grouped with the Anvil Assemblage and presumed to be Late Paleozoic.

The gneiss resembles that of Simpson Assemblage and the Selwyn Gneiss; the latter is Permian. It is unlike the Pelly Gneiss of Fiftymile Batholith and the Mink Creek dome: those are granitic augen gneiss full of orthoclase megacrysts. It is also unlike the augen gneiss at the head of Mendocina Creek in Laberge map area, which is more mafic and also contains large feldspars.

Bostock (1936) included the metamorphic rocks in northern Carmacks map area in the Yukon Group, which was considered Precambrian when he did his work. He recognized that the marbles are Paleozoic by the crinoid columnals.

Campbell (1967) included equivalents of the metamorphic rocks in his units 6 and 7 and described the lithologic members (p. 39-43). He recognized their probable Paleozoic age and was the first to speculate that the Yukon Group might be largely younger than Precambrian. Campbell included the muscovite quartzite, amphibolite and marble in his units 6a, 6c and 6f respectively; some of his other subdivisions may be gradational between these end members. Northeastern Carmacks map area ultramafic rocks are equivalents of Campbell's unit 7. Campbell was uncertain about the internal and external relations of metamorphic rocks; he recognized that they are probably structurally repeated and internally deformed and speculated that they are faulted against other rocks.

6.1.2TESLIN SUTURE ZONE

Teslin Suture Zone between Cassiar Platform and the Semenof Block is bounded by the D'Abbadie and Big Salmon faults (Figs. 9, 10, 11). It includes penetratively sheared rocks grouped in the Nisutlin and Anvil assemblages.

6.1.2.1NISUTLIN ASSEMBLAGE

Nisutlin Assemblage includes allochthonous, tectonically interleaved slices of four rock units, quartz muscovite schist, chlorite schist, carbonate and quartzite. The rocks are strongly and pervasively sheared and their flaser fabric or schistosity masks or obliterates bedding and other depositional features. Stratigraphic relations and internal stratigraphy are unknown.

6.1.2.1.1QUARTZ MUSCOVITE SCHIST

Quartz muscovite schist, by far the commonest rock type in the Nisutlin Assemblage, includes pale rusty weathering, moderately resistant, light greenish sericite-quartz mylonitic schist that grades to muscovite-quartz blastomylonite schist. Chlorite is a common minor constituent. The quartz-muscovite schist invariably has a well developed fluxion fabric, enhanced by neocrystallization. Quartz grain size varies from 0.01 mm to 0.2 mm and micas are correspondingly larger, so the rocks range from coarse schist to fine mylonite. Quartz and micas have strong preferred form and crystallographic orientation. The quartz muscovite schists were included in the Yukon Group as Member 3 by Bostock and Lees (1938, p. 8-9). They recognized that the rocks are strongly sheared and noted "gneisses exhibiting augen and mylonite in some places in this member."

Good exposures occur on and around Last Peak. The main slice there is nearly 5 km at its thickest, but the depositional thickness is unknown. Poorly bedded, gritty, feldspathic quartzite with a few thin shaly partings, is preserved locally in the muscovite schist. It has bluish and clear detrital quartz grains and fresh white K-feldspar, up to 3 or 4 mm across, in a fine grained, detrital quartzofeldspathic matrix.

6.1.2.1.2CHLORITE SCHIST

Chlorite schist with a well developed foliation or flaser fabric occurs as discontinuous structural slices, a few to hundreds of metres thick, in the quartz muscovite schist. It also forms a large lens on the ridge between Dycer and Mendocina creeks. There the schist locally retains pillow and fragmental structures indicating that the protolith was submarine andesite-basalt. The rocks are not as massive as, and less mafic than, Anvil Assemblage amphibolite. The chlorite schist grades laterally and across the foliation to quartz muscovite schist. Though structurally modified this interfingering may be depositional and the chlorite and quartz muscovite schist may be the sheared metamorphosed remnants of a stratigraphic sequence of feldspathic sandstone and andesite.

6.1.2.1.3MARBLE

Carbonate in Nisutlin Assemblage is a resistant, medium grey to buff weathering marble, generally with well developed, closely spaced, laminar fluxion structure. In thin section the calcite displays preferred form and crystallographic orientation. The stratigraphic affiliation is unknown as the marble occurs in structurally disconnected remnants. Some is enclosed by slices correlated with the Nasina Formation, others by quartz-muscovite, or quartz chlorite schist correlated with the Nisutlin Assemblage. Marbles in the quartzite tend to be medium grey, darker than those in the muscovite schist.

6.1.2.1.4QUARTZITE

Quartzite in the Teslin Suture Zone is a dark grey to black rock with an excellent fluxion structure and no depositional texture or fabric. Graphite is common, but not voluminous and the competence varies with the quartz and graphite content. The rocks contain form-oriented quartz grains up to a millimetre long, with intergranular graphite. The quartzite resembles that in the Nasina Formation, and locally includes lenses of carbonate also like those in the Nasina. It probably represents structurally imbricated Nasina slices in Teslin Suture Zone. It has sharp contacts with the quartz-muscovite schist and is not interlayered with other Teslin Suture Zone rocks as the quartz-muscovite and chlorite schist are with each other.

6.1.2.1.5AGE

The age of the quartz-muscovite and chlorite schist are uncertain. Muscovite from Nisutlin Assemblage schist in Quiet Lake and Finlayson Lake map areas has given K/Ar dates as old as 230 and 226 Ma (Tempelman-Kluit, in press) and younger dates ranging to 180 Ma. At least a part is therefore Earliest Triassic or older.

The carbonate's age is not known; that included as structural lenses in the Nasina Formation may be Siluro-Devonian and equivalent for example to carbonate lenses immediately southwest of Quiet Lake, in which middle Devonian crinoids are known. Marble enclosed in quartz mica schist may be equivalent to that in the top or the Nisutlin Assemblage near Finlayson Lake (Finlayson Lake map area). Pennsylvanian conodonts were recovered from it and it may be correlated with the Boswell Formation.

The quartzite is so much like that in the Nasina Formation that it is correlated and assigned an Ordovician to Devonian age.

6.1.2.2ANVIL ASSEMBLAGE

In Teslin Suture Zone the Anvil Assemblage (Fig. 11) is represented by resistant, dark weathering, dark green, amphibolitic gneiss, fine grained amphibolitic schist and chlorite-epidote-actinolite greenstone. Serpentinite forms lenses in the amphibolite at several places and occupies a klippe above Cassiar Platform strata at the east central edge of Laberge map area.

6.1.2.2.1AMPHIBOLITIC GREENSTONE

Bostock and Lees' (1938, p. 9-10) Member 5 of the Yukon Group, recognized near the mouth of Teraktu Creek and on "the lower slopes of the mountains fronting on Big Salmon River..", represents the Anvil Assemblage amphibolitic greenstone.

The amphibolite is bounded on the west by the Semenof Hills block. Generally the boundary follows south Big Salmon River and is not exposed, but there is outcrop across the valley of Fish

Creek and on the east side of Boswell Mountain. Amphibolitic greenstone lenses, several kilometres wide and 30 or 40 km long, mark the east and west sides of Teslin Suture Zone.

The rocks grade from greenstone to coarse grained, locally garnet bearing, amphibolite and amphibolitic gneiss. The main minerals are actinolite, epidote, chlorite, plagioclase and quartz. Fluxion structure is generally present, but varies in perfection. Neocrystallization of amphiboles locally emphasizes it, but elsewhere masks and locally obliterates the fabric. Grain size varies from 0.05 mm to several millimetres and the rocks locally have well developed alternate amphibolitic and feldspathic laminae, a few millimetres to centimetres thick, which give it a gneissic fabric. Such compositional layering parallels the flaser.

Although separated by the Big Salmon Fault the amphibolitic greenstone may be the metamorphic equivalent of the Semenof Formation; both are probably Late Paleozoic basalt. Some Teslin Suture Zone marbles may similarly be the unsheared precursors of Boswell Formation limestones.

6.1.2.2.2AUGEN AMPHIBOLE GNEISS

The western amphibolite lens of Teslin Suture Zone grades to melanocratic diorite gneiss about where it crosses Mendocina Creek. Similar gneiss is found at several other places in Teslin Suture Zone notably where Big Salmon River crosses the zone. Bostock and Lees (1938) separated the gneiss lens on Mendocina Creek and mapped it as unit 2, a subdivision of the Yukon Group.

The rocks are massive, resistant, grey weathering, homogeneous, coarse grained amphibole augen gneiss; the composition is dioritic to quartz dioritic. Beside hornblende the main minerals are andesine, microcline and quartz with sphene the main accessory and epidote a common secondary product. K-feldspar augen, several centimetres across, make up as much as a quarter of the rock's volume.

The gradational relations between the gneiss and amphibolite and the high amphibole and low quartz of the gneiss suggest that it may be the amphibolite's metasomatised equivalent. Its feldspars may not derive from preexisting megacrysts, but from phenocrysts which grew in the rock during the ductile strain from mobile K ions.

The augen gneiss' relations and lithology differ from those of the Selwyn Gneiss and the Simpson Assemblage of Finlayson Lake map area. Both are biotite hornblende granodiorite gneiss that rest structurally on Nisutlin or Anvil Assemblage strata. Neither is it like the Pelly Gneiss of Fiftymile Batholith (Tempelman-Kluit and Wanless, 1980); it is foliated muscovite biotite granite structurally under the Nisutlin and Anvil assemblages.

6.1.2.2.3SERPENTINITE

Serpentinized peridotite and pyroxenite occur at several places in Teslin Suture Zone and as lenses in the Dunite Mountain klippen (Erdmer, 1982). Two lenses about a kilometre wide, occur on upper Livingstone Creek and smaller bodies are just east of the south Big Salmon River's mouth and on the low ridge between D'Abbadie Creek and North Big Salmon River. Amphibolite is structurally interleaved in the lenses.

Most of the rocks are resistant, orange and brown weathering, massive dunite, peridotite and pyroxenite. They are partly or wholly serpentinized and lack layering or fabric. Foliated talc schist lenses, and massive, irregular shaped, coarsely crystalline quartz carbonate bodies occur locally. They are commonly veined by serpentinite and locally by chrysolite.

6.1.2.2.4AGE

The age of the amphibolitic greenstone and serpentinite are only inferred by correlation with the Anvil Assemblage in Finlayson Lake map area, where Carboniferous or Permian conodonts occur in limestone at the Assemblage's structural base (Tempelman-Kluit, in press). If the amphibolite is equivalent to the Semenof Formation, as argued elsewhere, it is Carboniferous. The serpentinite is assumed to be Late Paleozoic from its association with other Anvil Assemblage rocks.

6.1.3SIMPSON ASSEMBLAGE-SELWYN GNEISS

Granite to granodiorite orthogneiss in western and central Carmacks map area (Figs. 10, 11) was formerly included in McConnell's (1905a) Pelly Gneiss by Tempelman-Kluit (1974b). New work shows that as previously mapped the Pelly Gneiss includes at least two orthogneisses of different affinities (Tempelman-Kluit and Wanless, 1980). One, dominated by Permian hornblende biotite chlorite granodiorite gneiss, and now considered equivalent to the Simpson Assemblage, is renamed the Selwyn Gneiss (Tempelman-Kluit and Wanless, 1980, p. 298). It is found in Carmacks map area and is traced there from the type area. The second Pelly Gneiss is Devonian granitic orthogneiss for which the original name is retained. Its possible equivalent in the project area is the gneiss of southwestern Carmacks map area.

Selwyn Gneiss crops out in west central Carmacks map area and on trend to the southeast (Figs. 10, 11). It occupies two areas, one between Yukon River and Selkirk Creek, referred to here as the Selkirk body, and another at the bend of Big Creek, informally called the Big Creek body. The two outliers presumably join beneath the cover of Cretaceous Carmacks Group lavas. Probable Selwyn Gneiss equivalents, not distinguished on the map, are the granodioritic gneisses interfoliated with other metamorphic rocks of Yukon Cataclastic Terrane.

Outcrop is generally poor, and relations are not well displayed in the Selkirk or Big Creek bodies. However in adjacent Snag map area, to where the Selkirk body is traced, Selwyn Gneiss rests structurally above siliceous mylonite that is correlated with the Nisutlin Assemblage. The contact is a gently dipping, foliation-parallel fault that is folded into a northwest trending, open syncline (Tempelman-Kluit and Wanless, 1980). Similar relations are postulated for the southern Selwyn Gneiss contact in the Selkirk body. A foliation-parallel fault beneath the gneiss probably follows the valley of upper Selkirk Creek to Wolverine Creek in Carmacks map area (along the southwest contact of the gneiss band north of Big Creek of Fig. 11). Judging from fabric orientation the fault dips northeast as in Snag map area. Just north of Wolverine Creek's bend, on the Selkirk body's south side and on peak 3627, is a granitic gneiss lens distinguished from the more mafic Selwyn Gneiss. It is interpreted as the lowest Simpson Assemblage sheet above Nisutlin strata. At its upper contact with the biotite amphibole granodiorite the two are interfoliated over a narrow zone. The granite gneiss is discontinuous and presumably faulted above and below. Ultramafic rocks or amphibolite, representatives of the Anvil Assemblage, are expected, but not seen, between the Selwyn Gneiss and Nisutlin Assemblage on the Selkirk body's south side. Their absence is interpreted to mean that the Anvil Assemblage is sheared out. In the Pelly Mountains the Anvil Assemblage is commonly structurally discontinuous. The Big Creek body's southwestern contact is uninstructive about its original relations. It is intruded by, or faulted against, Coffee Creek Granite.

The northeast Selwyn Gneiss contact is clearer near Big Creek than at the Selkirk outlier. Selwyn Gneiss and granodiorite (of Granite Batholith) are interleaved over a 2 or 3 km wide zone. Foliation in the gneiss and granodiorite is parallel and dips steeply controlling the orientation of granodiorite sheets. The granodiorite is foliated less strongly than the gneiss. Mafic schlieren in the granodiorite may be incompletely digested Selwyn Gneiss remnants. On the north the Selkirk body is interfoliated with hornblende granodiorite, probably the extension of Minto Pluton. The contact is not exposed on the ridges south of Yukon

River, but where it crosses the river in Snag map area, the granodiorite apparently intrudes Selwyn Gneiss. As near Big Creek the contact dips steeply parallel to the penetrative foliation in the gneiss and the weaker protoclastic granodiorite fabric.

6.1.3.1LITHOLOGY

Selwyn Gneiss has two orthogneisses, a dark biotite amphibole granodiorite gneiss and lighter biotite granite gneiss. Homogeneous, mesocratic, amphibole biotite chlorite granodiorite gneiss, grading to biotite muscovite granodiorite blastomylonitic gneiss is commonest. It is moderately resistant, weathers grey and is greyish brown on fresh surfaces. It has a strong, closely spaced, planar flaser foliation and parallel compositional layering. The flaser is uniformly oriented and dips northeastward over large areas. The fabric is rarely folded, but small, east plunging, north verging, subisoclinal folds deform foliation locally. Some gneiss resembles the foliated granite of Granite Batholith and the two are locally difficult to distinguish. The foliation is defined by parallel oriented micas and by form oriented plagioclase, quartz and amphibole. Its spacing is generally under 2 mm. Fabric varies from blastomylonitic or mylonitic schist to gneissic. Micas are recrystallized along the foliation and mask the flaser to various degrees. Alternate light and dark layers are only a centimetre or two thick and about equal in proportion. Light layers are largely plagioclase and quartz with less than 5% mafics while dark laminae are largely amphibole and biotite with under 10% feldspar. The rocks are medium to fine grained and equigranular; augen are absent. Micas and some amphibole postdate, or are coeval with, the flaser, but some amphibole may be original hornblende.

Homogeneous, mesocratic to leucocratic, medium grained biotite granite to granodiorite gneiss, the second type of Selwyn Gneiss, has the same fabric and fabric variation and grain size range as its more mafic counterpart.

6.1.3.2AGE AND CORRELATION

Selwyn Gneiss is not dated in Carmacks map area, but several samples from Snag map area, just to the west were dated by K/Ar and U/Pb isotopes (Tempelman-Kluit, 1974; Tempelman-Kluit and Wanless, 1980). As expected the K/Ar dates are younger than those given by U/Pb. K/Ar dates of 160 and 161 Ma were obtained on muscovite and biotite in one sample and 164 Ma on biotite in a second sample (Figs. 10, 11). Dates of 181 and 187 Ma were obtained on hornblende and biotite in a second sample farther west. Zircon from the sample with the 164 Ma K/Ar date gave a nearly concordant 276 Ma U/Pb date. The K/Ar dates show that Selwyn Gneiss last passed through the argon retention temperature during the Early or Middle Jurassic and likely date cooling after the penetrative strain. Alternatively they may date the time of last tectonic uplift. The U/Pb date is interpreted as the crystallization age for the gneiss' granodiorite parent. It was therefore probably intruded in the Early Permian and then strained twice, first penetratively before intrusion of the Minto granodiorite and more weakly later. Because K/Ar dates on the gneiss and granodiorite dates coincide between 180 and 160 Ma they probably date cooling following the second, weaker event. It must then be Middle Jurassic. The older penetrative strain of the gneiss predates Granite Batholith intrusion in the Earliest Jurassic and must be Permian or Triassic.

A single K/Ar date of 268 Ma on hornblende from massive, medium grained, equigranular biotite hornblende granodiorite from southern Aishihik Batholith (in Asihihik Lake map area) corroborates the Selwyn Gneiss zircon date. It suggests that Aishihik Batholith may include two granodiorites, the Permian protolith for the Selwyn Gneiss and the Triassic Klotassin granodiorite, previously thought to be its only constituent.

Selwyn Gneiss is correlated with the Simpson Assemblage, also a penetratively deformed granodiorite ranging to mylonitic schist and gneiss with the same fabrics and structural relations as Selwyn Gneiss. In its type area the Simpson Assemblage has given K/Ar dates of 251, 316 and 344 Ma (Early Mississippian to Late Permian).

6.2WEAKLY SHEARED TOP OF YUKON CATACLASTIC TERRANE

Yukon Cataclastic Terrane includes lightly sheared and metamorphosed volcanic and sedimentary strata and granites at the top (Figs. 9, 10). Semenof Block represents the volcanic and sedimentary rocks; the Tatchun, Tatlmain, Granite, Carmacks and Lokken batholiths are the main granites. The lightly sheared rocks rest structurally on the more strained ones; depositional or intrusive relations are not seen.

6.2.1SEMENOF BLOCK

The Semenof Block is a subdivision of Teslin Suture Zone with Carboniferous basalt and limestone, partly correlative with the Taku and Cache Creek groups. The boundary between it and the remainder of Teslin Suture Zone is the Big Salmon Fault. Semenof Hills rocks may be the protolith for Anvil Assemblage strata elsewhere in Teslin Suture Zone. Specifically the basalt and limestone may be protolith for some amphibolite and marble in Yukon Cataclastic Complex.

The Semenof Block is underlain by the Boswell and Semenof formations, sedimentary and volcanic units respectively. The Boswell Formation includes about 1100 m of volcaniclastic rocks with limestone at the top, and the overlying Semenof Formation is a massive, largely volcaniclastic greenstone, perhaps 800 m thick. These two formations are exposed in a large, open asymmetrical, northwest trending, faulted trough. The southwestern limb exposes the lowest strata and the opposite limb the highest; limestone in the upper Boswell Formation is common to both limbs. The trough's northeastern and southwestern limbs are separated by Teslin Fault system strands, the Boswell, Semenof and Hootalinqua faults. The northeastern limb is an apparently gently southwest dipping succession of two units; a lower, thin, discontinuous limestone, and an upper thick massive greenstone. Fossils from the limestone are Pennsylvanian. The southwestern limb has a more varied, steeply northeast dipping, succession of which a limestone, also with Pennsylvanian fossils, is the upper unit.

6.2.1.1BOSWELL FORMATION

6.2.1.1.1NAME AND DISTRIBUTION

The Boswell Formation is named here for Boswell Mountain, whose southwestern slopes provide reference exposures. Most of its carbonate was formerly grouped with the Lewes River Series (Bostock and Lees, 1938), although one outcrop near Big Salmon was separated by them and recognized as Carboniferous or Permian. The formation's other rocks were grouped with greenstones, which are here called the Semenof Formation, in the Hutshi Group. The Boswell Formation includes interlayered slate, phyllite, chert, greenstone and limestone. The main exposures are on southwestern Boswell Mountain and the Semenof Block's northeast flank (Fig. 11); no type section is identified, but the outcrops on Boswell Mountain are characteristic.

6.2.1.1.2STRATIGRAPHY

The Boswell Formation includes four members; from the base up a slate, greywacke, greenstone and limestone. On Boswell Mountain the lowest strata are thin bedded, dark grey slate and phyllite with thin, massive greywacke interbeds. This recessive unit is exposed in the low hills immediately northeast of Teslin River; best outcrop is near Teslin Crossing. The slate may be 100 m thick, but this is uncertain because the rocks are tightly folded into small upright folds and have a steep dipping, axial plane cleavage.

Slate grades upward into the second member, about 500 m of greywacke and chert pebble conglomerate or grit with minor interbedded red mudstone and slate. Some greywacke is calcareous and bioclastic limestone pods, as much as 30 m thick, occur commonly near the slate-greywacke transition. The chert conglomerate, red mudstone and greywacke weather to distinctive rusty and orange colours making this the only colourful member among the otherwise drab weathering Semenof Hills succession. Within the greywacke-conglomerate are discontinuous, massive greenstone sills or flows like those of the Semenof Formation. Clasts in the conglomerate range to 10 cm across and are moderately rounded with poor sphericity. Beside the prominent greenish, grey and red chert fragments, probably derived from chert within the unit the conglomerate contains greenstone clasts evidently derived from the greenstone flows or sills. Volcanic clasts dominate in places and the rocks grade to volcanic breccia or redeposited volcanic tuff. Red mudstone interbedded with the conglomerate locally contains green tuff lapilli and may be a subaerial volcanic tuff. It grades laterally and up section to the coarser grained rocks.

The third member of massive, resistant greenstone, about 200 m thick, rests above the volcaniclastic rocks, probably conformably. The contact is gradational, and lenses of the volcaniclastics occur in the massive volcanics. The greenstone is a fine grained mixture of epidote and chlorite with faint outlines of original minerals in some thin sections. A few outcrops show pillow forms and some are breccia, but most lack such hints of origin. Some outcrops are purplish or reddish, suggesting that the rocks weathered subaerially, but most greenstones are submarine basalt flows. Water depths were probably moderate considering the interbedded limestone and red colour.

Buff to cream white weathering, massive to thickbedded, micritic limestone, the highest member of the Boswell Formation, rests above the greenstone, perhaps conformably. It commonly contains fusulines, but macrofossils are rare. The limestone is about 300 m thick, and is traced discontinuously along Boswell Mountain's southeast side, above Loon Lakes, for 25 km. The large, irregular shaped, limestone lens on the south end of Boswell Mountain, just north of the Indian River mouth, contains the same age fossils as the continuous unit, but is separated from these lenses by the Boswell Fault. The relations of the Boswell Mountain carbonate lenses show that the carbonate intertongues with the other rocks. Upper limestone lenses grade laterally to green and purple massive volcanics and lower lenses trend into the greywacke-conglomerate.

The large limestone near the north edge of Laberge map area, between Walsh and Illusion creeks (Fig. 11), is correlated with the Boswell Formation. At least 600 m are exposed in steeply dipping ribs sliced diagonally by a northeast trending fault. No fossils were found and the greenstone and clastic rocks seen elsewhere with the Boswell Formation are absent. Large areas of red weathered limestone are prominent in these northern exposures. Their colour derives from a hematitic ochre residue from chemical weathering of the carbonate. It probably represents karst formation about the time of Walsh Creek Formation deposition i.e. the Pliocene.

Boswell Formation strata in the northeastern Semenof Hills are poorly exposed and their stratigraphy is uncertain. Here the Formation is recognized by its limestones. Two small northeast draining streams, about opposite the mouth of the North Big Salmon River, have good exposures. Most rocks are massive to thickbedded, light grey micritic, partly dolomitized and silicified limestone. Thinbedded chert and slate, reddish cherty limestone and red sandy tuff are interbedded, but the commonest other rocks are greenstones as in the Semenof Formation. No sequence like that on Boswell Mountain has been seen. Outcrops opposite the mouth of Illusion Creek, mapped as Laberge Series by Bostock and Lees (1938), are turbiditic volcanic sandstone, with cyclic AE Bouma layering. They are included in the Boswell Formation.

On the lower Big Salmon River, 8 m up from the mouth, is a good outcrop of Boswell Formation thinbedded, turbiditic, volcanic greywacke in graded beds with clear Bouma sequences. Angular to poorly rounded, green and red volcanic rock fragments from sand to granule size are the main debris. Grey to green chert or siliceous tuff layers a few centimetres thick are interbedded with the turbiditic greywacke and constitute about a quarter of the exposure.

Boswell Formation outcrops on Teslin River, about 10 km downstream from Mason Landing, are massive to well graded volcanic greywacke with interbedded chert.

6.2.1.2SEMENOF FORMATION

6.2.1.2.1NAME, DISTRIBUTION AND LITHOLOGY

The massive volcanics in the highest Semenof Hills, stratigraphically above the Boswell Formation, are here called the Semenof Formation (Fig. 11). The name is taken from the low mountain range to which their outcrop is restricted. Formerly these rocks were included with the Hutshi Group (Bostock and Lees, 1938). Assuming a general moderate westward dip the volcanics may be 800 m thick. The Semenof Formation resembles other volcanic units in the project area, namely the Povoas Formation and parts of the Carmacks Group; it is distinguished by association with the lithologically distinctive and fossiliferous Boswell Formation.

Like the greenstone intercalated with the Boswell Formation the volcanics are remarkable mainly for their homogeneity and cryptic textures. In some exposures the greenstone is clearly a volcanic flow rock, because it has abundant calcite filled amygdules and faint pillow outlines. In a few places it contains augite phenocrysts. The massive appearing greenstone is a sand-sized basaltic tuff with intercalated volcanic breccia, locally with faint stratification. It contains angular, green and purplish or red clasts from sand to cobble size. The breccia is unstratified except on the grandest scale and may represent catastrophically deposited volcanic detritus. The rocks lack cleavage or other fabrics, but are commonly extensively altered to epidote-chlorite assemblages and veined by epidote.

Brown weathering, resistant hornblendite-gabbro lenses, probably intrusive equivalents of the Semenof volcanics, occur in the Semenof and Boswell formations. The large lens on southwestern Boswell Mountain has good exposures. Stubby, subophitic hornblende crystals up to 3 cm long, dominate the rocks and make up more than half the volume. Plagioclase occurs interstitially and magnetite is the important accessory. The rocks are fresh and unsheared.

6.2.1.2.2DEPOSITIONAL ENVIRONMENT OF THE BOSWELL AND SEMENOF FORMATIONS

Semenof Formation volcanics are probably andesitic basalt and may represent the products of a marine volcanic arc deposited in moderately deep water. The Boswell Formation includes slightly older to partly coeval, shallow water carbonate buildups. Lower Boswell Formation chert and slate may represent older ocean bottom sediment onto which the arc encroached. The Semenof Formation may be marine volcanics whose breccia may represent flows fractured during extrusion under water or upon entering water. Alternatively they may be volcanic debris sheets washed into a marine regime from land. Little reworking occurred before deposition and the volcanic material flooded the depositional system. The red volcanic fragments suggest subaerial weathering before deposition, which in turn implies relatively shallow water depths at deposition. The Boswell Formation's well layered sandy tuff and turbidite may represent submarine turbid flow deposits, particularly because some of these are interbedded with chert or siliceous tuff. The limestone on the other hand suggests relatively shoal conditions.

6.2.1.2.3AGE AND CORRELATION

Brachiopods from Boswell Formation limestones were examined by E.W. Bamber, who determined that the forms are not diagnostic and the age assignment is broad, namely to the Carboniferous or Permian.

Conodonts recovered from the carbonate at two localities are considered as Early Pennsylvanian by M.J. Orchard. One collection (#74 of Appendix I, Fig. 16) is from the large irregular shaped limestone on the south end of Boswell Mountain; the other is from limestone about opposite the mouth of Headless Creek west of Big Salmon River (Fig. 11). It is probably lower Morrowan (collection 31).

Fusulinacean foraminifera occur commonly in Boswell Formation limestone, but only three collections, one from a limestone in the Semenof and two from the Boswell Formation, (#27, 56, 57, Appendix I, Figs. 11, 16) are of diagnostic material. None are from the same outcrops where conodonts were recovered. C.A. Ross of the University of Texas assigned the fusulines to the Moscovian stage (Middle Carboniferous). This is roughly equivalent to the Middle Pennsylvanian, so that the fusulines apparently indicate a somewhat younger age than the conodonts do. Ross considers that the fusulines show some range in age; those in collection 27, from the Semenof Formation, are younger than those in collection 56, which is slightly younger than collection 57 (lower to middle Moscovian against upper Moscovian).

The fossils indicate that Boswell Formation carbonates are Early to Middle Pennsylvanian. Because the clastic beds, including the greywacke-conglomerate and the slate are the limestone's lateral equivalents they are assumed to be the same age. No depositional break is envisaged between the Boswell and Semenof formations, but a Middle Pennsylvanian age is postulated for the Semenof Formation on the basis of the one collection of fusulines in the limestone lens enclosed by volcanics (collection 27). There is no evidence that the Semenof and Boswell formations range into the Permian.

Bostock and Lees (1938, p. 11) found fossils and recognized a "Carboniferous or Permian Limestone" and mapped a single lens 6 km south of Big Salmon. Neither the limestone nor the fossils were found when the locality was revisited during the present work. On the basis of the fossiliferous limestones they suspected (p. 11, op. cit.) that "some or all of them (the limestones east of Teslin-Lewes Valley) may be of Paleozoic age", but on their map they included the Boswell and Semenof formations in the Lewes River Group. The carbonate-greenstone pair of Lewes River is similar to those of the Boswell-Semenof. Without fossils only some associated volcaniclastic rocks and the chert distinguish the Paleozoic rocks from the Triassic.

The Boswell and Semenof formations are rough equivalents of the Permian and possibly partly Pennsylvanian Taku Group of Whitehorse map area (Wheeler, 1961). Because the Teslin Fault separates the Taku and Boswell-Semenof formations and because their ages overlap, but are not the same, equivalence cannot be proven. Both units resemble the Cache Creek Group and the Anvil Assemblage generally. The southeastward extension of the Semenof and Boswell formations into Teslin map area is not separated by Mulligan (1963), who includes probable equivalents in his unit 10 on the northeast side of Teslin River.

North of Laberge map area Campbell (1967) grouped the extension of the Semenof and Boswell formations with the Lewes River Group.

6.2.1.3HEADLESS PLUG

About 5 km west of the mouth of Headless Creek is a small hornblende quartz diorite, which invades Semenof Formation greenstone (Fig. 11). The rock is grey, medium grained, equigranular and fresh, locally with schlieren of partly digested mafic material and dark angular xenoliths a few centimetres across. It is unsheared, lacks foliation or relict fabric and contains about 20% euhedral fresh hornblende, partly as the dominant grains and partly interstitial to euhedral tabular plagioclase. Quartz makes up 10% or more and occurs interstitially; sphene is the common accessory mineral. An age determination (K/Ar on hornblende) gave a model age of 216 Ma, about ~~Upper~~ Late Triassic. Because evidence for subsequent resetting is lacking, the date may indicate the time of cooling following intrusion. No like intrusions are known in the project area and correlations with other plutons are uncertain. Undated bodies of similar rocks, with the same age hosts occur at Hayes Peak and Mount Bryde in Teslin map area to the southeast. An Late ~~Upper~~ Triassic age for the Headless Plug indicates that the Semenof Formation is older than the Lewes River Group and is compatible with the Semenof Formation's postulated Pennsylvanian age.

6.2.2LOKKEN BATHOLITH

Lokken Batholith, in northeastern Laberge map area (Figs. 11, 12), is named for the stream that crosses the intrusion's northern side. Spectacular granodiorite exposures are seen in the shallow bedrock canyon in its lower section. Generally the intrusion is poorly exposed and weathers recessively. Massive, fresh, coarse grained, equigranular, mesocratic, hornblende granodiorite to quartz diorite is the common rock. A weak planar fabric, defined by aligned hornblendes, is common. Hornblendes are greenish black, stubby euhedral crystals, several millimetres across, with enclosed biotites. Sphene is a prominent accessory mineral. Phenocrysts of pink potash feldspar make up about a quarter of the volume in places. The diorite grades to hornblendite in exposures on the southern side of the batholith. Mafic xenoliths are common and schlieren of amphibolite, likely derived from the Anvil Assemblage, occur near the margins. Bostock and Lees (1938, p. 19) gave a summary description.

On its southwest edge the Lokken Batholith may be faulted against the Boswell Formation across the Big Salmon Fault (Fig. 11). No thermal metamorphic halo was recognized around the batholith and in common with the other intrusions in the cataclastic rocks intrusive relations are rare. Judging by the map pattern and by the xenoliths and schlieren, the granodiorite may intrude metamorphic rocks of Teslin Suture Zone. Alternatively the batholith may rest on Anvil Assemblage strata structurally and represent a tectonic slice of the Simpson Assemblage.

Stratigraphic data do not limit the time of Lokken Batholith intrusion, but the single K/Ar date of 185 ± 8 Ma (Fig. 11) indicates that the pluton last cooled about the earliest Middle Jurassic (Aalenian) and the date may represent the time of last uplift. Whether intrusive or a tectonic slice the date is younger than the fabric of the surrounding rocks and shows that ductile strain had ceased (at least in this part of Teslin Suture Zone) by this time).

6.2.3TATLMAIN BATHOLITH

Tatlmain Batholith in northeastern Carmacks map area (Figs. 11, 12) is generally poorly exposed. Outcrops are dominated by coarse grained, grey, megacrystic, unfoliated, recessive weathering, leucocratic granite to granodiorite. Anhedral grey quartz and white oligoclase with subhedral, pinkish K-feldspar phenocrysts to 5 cm across with biotite are the main minerals. Hornblende occurs in places. The rocks contain a few round xenoliths about 10 cm across. They are generally fresh, but the grains are poorly held and the rock weathers to grus at many places. Locally the rocks are strongly saussuritized and chloritized, so that original constituents are unrecognizable. The batholith is inhomogeneous and its main variation results from differences in the proportions of mafics, phenocrysts and alteration. Bostock (1936, p. 36-37) includes a description of the batholith.

Relations with the surrounding metamorphic rocks were not seen and no thermal metamorphic halo was noted. The granites may intrude the metamorphic rocks of Yukon Cataclastic Terrane or may rest on them structurally. An analogous contact is that between the Selwyn Gneiss and the Granite Batholith north of Big Creek; there the rocks are interfoliated and it appears that the granite intruded the gneiss during the strain.

Campbell (1967, p. 75) noted that the Tatlmain and Tatchun batholiths are similar in Glenlyon map area. Their extensions into Carmacks map area differ. Tatlmain, the northern intrusion is dominated by unfoliated coarse grained granite and Tatchun, the more southern body, has strongly foliated hornblende granodiorite.

One K/Ar age determination of 204 ± 4 Ma on biotite from central Tatlmain Batholith (Figs. 10, 12) shows that the rocks last cooled through the "argon retention isotherm of biotite" about the latest Triassic-earliest Jurassic. They were either intruded or raised tectonically at that time. The rocks resemble the Coffee Creek Granite of northern Snag map area, but that granite gave mid-Cretaceous (intrusive?) ages and its relations differ (Tempelman-Kluit and Wanless, 1975). Tatlmain Batholith may be coeval with the Carmacks Batholith, which gave uplift ages in the range 160 to 165 Ma, but which is assumed to have been emplaced about 195 or 200 Ma on its relationship to the Nordenskiold Dacite.

6.2.4TATCHUN BATHOLITH

Exposures of Tatchun Batholith, in eastern Carmacks map area (Figs. 10, 11, 12) are generally poor and the body was not studied carefully. Foliated biotite hornblende granodiorite is the main rock. Though compositionally fairly uniform the degree of strain differs markedly so that the rocks range from granodiorite gneiss to weakly foliated granodiorite. They are mesocratic with granitic texture and variable proportions of pinkish K-feldspar phenocrysts (to 20%) several centimetres across. Quartz, oligoclase and K-feldspar occur in roughly equal proportions and biotite and hornblende, which make up 15%, are both present. The minerals are fresh and considering the rock's strain they must have recrystallized after the shearing. Foliation generally dips north or northeastward at moderate angles. Bostock (1936, p. 38) includes a brief description.

Contacts of Tatchun Batholith with the surrounding metamorphic rocks were not seen and the granodiorite may intrude them or rest on, or against, them structurally. An analogous contact, that between the Selwyn Gneiss and the Granite Batholith north of Big Creek suggests that the granite intruded the gneiss during the strain and that the contacts should be interfoliated. The northeast contact along Tatlmain Lake and Towhata Creek may therefore be interfoliated, with granites above the metamorphic rocks. A newer fault may displace the contact because the schist northeast of Mica Creek is structurally above the granite now. The northwestern contact of the Tatchun Batholith, also poorly exposed, is probably interfoliated with the granites resting structurally on the schists. At the southeast the Tatchun Batholith abuts the Semenof block, along Little Salmon River in Glenlyon map area. The relations are not exposed; they may be intrusive with Tatchun Batholith related to the Headless Plug. On the southwest the Tatchun Batholith abuts the Povoas Formation of the Lewes River Group across the Semenof Fault.

Three K/Ar age determinations on two samples of Tatchun Batholith gave ages of 144 ± 3, 160 ± 3 and 162 ± 8 Ma (Figs. 10, 12). They are probably better clues to the time of strike slip and associated uplift on the Teslin Fault than indicators of the time of intrusion. Perhaps the older dates (ca 160 Ma) give the time of shearing, which may coincide with strike slip, and the younger, the time of uplift. In any case they show that the rocks had been intruded and sheared by the Late Jurassic. Tatchun Batholith may have been sheared (and tectonically juxtaposed next to the metamorphic rocks on its north side?) about the Oxfordian and uplifted about the Berriasian. If so strike slip occupied 20 Ma during the latest Jurassic.

Tatchun Batholith resembles the Aishihik, Granite and Klotassin batholiths. They have also given Late Jurassic K/Ar uplift ages, but are most likely Middle to Late Triassic or Early

Jurassic. If they are the subvolcanic root of the Povoas Formation, as argued elsewhere, they are Ladinian. If they are coeval with Minto Pluton they are Earliest Jurassic. Tatchun Batholith was therefore probably intruded in the Late Triassic or Earliest Jurassic.

6.2.5GRANITE BATHOLITH

The Granite Batholith in central Carmacks map area (Figs. 10, 12) is made up of medium grained, mesocratic, heterogeneous, strongly to slightly foliated, biotite hornblende granodiorite. The rocks contain about 15% hornblende, 5% anhedral biotite, 20% grey quartz, 15% perthitic K-feldspar and 45% oligoclase. The minerals tend to be aligned and define a well developed to weak foliation; where the rocks are not foliated the texture is granitic with subhedral hornblendes and interstitial quartz and feldspar. Foliation generally trends northwest and dips steeply.

The rocks are variably altered. Wholesale replacement by pink K-feldspar phenocrysts a few centimetres across, has locally transformed them to porphyritic granite. Megacrysts are grown across foliation and may be related in time to the next younger igneous phase, the Big Creek Syenite. Feldspars are generally fresh, but chlorite and epidote are common around the mafics. Most heterogeneity results from variation in the proportion of phenocrysts, metamorphic screens and aplitic dykes. On the northern side of Hoochekoo Creek, hornblende is absent and biotite muscovite granite is found. This grades to fine grained aplite or felsite locally; the same rock which elsewhere intrudes the granodiorite as veins and dykes.

Bostock (1936, p. 37) described the rocks as follows:

> "In a belt extending from Rowlinson Creek to Yukon River the granitic rocks are commonly porphyritic and exhibit some degree of foliation. Foliation is particularly noticeable in the neighbourhood of contacts with the Yukon Group. It is markedly developed in the vicinity of Yukon River, in areas between the head of Seymour Creek and the mouth of Williams Creek and south of Rowlinson Creek. The typical porphyritic granite is light grey or pinkish, of coarse grain, and carries scattered, white or pinkish phenocrysts of orthoclase, commonly three-quarters inch long and in places considerably larger. The remainder of the rock is composed of quartz and orthoclase in about equal amounts, plagioclase feldspar, and biotite. Titanite, titaniferous magnetite, epidote, and apatite are present, and patches of clear green epidote are common. Pegmatites were noted to be particulary abundant on the north side of upper Merrice Creek. Elsewhere the rock is traversed by narrow pegmatite and aplite dykes and, in places, by veinlets of epidote.
>
> Westward along the ridge north of Crossing Creek, and in the vicinity of Big Creek, the rock is not porphyritic and is a granodiorite. White feldspar, quartz, biotite, hornblende, and titanite are readily apparent to the unaided eye. Under the microscope it is seen that slightly more oligoclase is present than orthoclase."

Contact relations of the Granite Batholith are ambiguous. Locally the rocks contain biotite gneiss screens and schlieren, perhaps of their undigested metamorphic host, the Selwyn Gneiss, found to the west. At the margins the rocks grade to gneissic granodiorite, which resembles the gneissic host. Along the ridge north of Big Creek's large bend, at the western edge of the batholith, foliated granodiorite lies along the orthogneiss foliation. Here the Selwyn Gneiss and granodiorite are difficult to distinguish. Presumably the granodiorite was intruded along the gneiss fabric and both rocks were later sheared to produce the granodiorite fabric. Or again the gneiss may be the granodiorite's more sheared equivalent and the two may be gradational.

An age determination on a Granite Batholith sample (Fig. 12) shows that its hornblende last began retaining argon about the earliest Cretaceous (142 Ma). Judging from the rock fabric this date is a younger limit to the time of strain and is more a clue to the age of post-intrusive strike slip and uplift than to the emplacement. The rocks resemble the Klotassin suite, which is probably Late Triassic or Early Jurassic. The Granite Batholith is likely the same age as the Minto Pluton, which gave a Lower Jurassic, concordant U/Pb isotopic age of 192 Ma.

6.2.6MINTO PLUTON

The Minto Pluton in central Carmacks map area (Figs. 10, 12) is separately named for convenience, but is considered continuous with the Granite Batholith beneath a Carmacks Group cover. The rocks resemble each other and have similar relations. Sinclair

(1977, p. 70-73) gave modal and chemical analyses of Minto Pluton, which show that the rocks are granodiorite to quartz diorite. He described the rocks as follows.

> "The granodiorite is medium- to coarse-grained, massive to weakly foliated and varies from equigranular to porphyritic.
>
> Strongly foliated to gneissic zones of similar composition (Unit 3b) occur within massive granodiorite in the west-central part of the area and along the eastern contact with Triassic volcanics. Aplitic and pegmatitic phases of the granodiorite occur as west- to northwest-trending dykes ranging from a few centimetres up to one metre across.
>
> Modal analyses of the granodiorite indicate a compositional range from quartz diorite to quartz monzonite. Oligoclase (An_{24-27}) is the main constituent and makes up 40 to 65% of the rock. Quartz content varies from 10 to 25% and potash feldspar content from 5 to 20%. In the porphyritic granodiorite, potash feldspar occurs as pink orthoclase phenocrysts up to 2 cm long. Mafic minerals, mainly biotite with varying amounts of hornblende and epidote, constitute 5 to 15% of the rock. Hornblende occurs as stubby, subhedral crystals commonly replaced by biotite and epidote. Sphene, apatite and zircon are common accessories; allanite is rare.

> Foliated zones in the Klotassin granodiorite are caused by the alignment of mafics, particularly biotite. A subtle tendency of orthoclase phenocrysts to be aligned with the foliation occurs locally. The degree of foliation varies from weak foliation characterized by subparallel recrystallization of biotite to strong foliation marked by strong alignment of the mafics and gneissic compositional banding. The strongly foliated zones are generally similar to the massive granodiorite in modal composition although high concentrations of mafics, mainly biotite, occur locally. There are also siliceous sections with a very low mafic content. Almandine commonly occurs in strongly foliated, biotite-rich zones. Magnetite is common, occurring as disseminated grains and in bands up to 2 cm wide. Ilmenite is associated with magnetite locally."

Intrusive relations of Minto Pluton with older rocks are unexposed. Presumably they are the same as those of the Granite Batholith. On the northeast Minto Pluton is truncated by the Ingersoll Fault. Several age determinations on Minto Pluton samples (Figs. 10, 12) show that it is Lower Jurassic. Three K/Ar determinations of 174, 177 and 180 Ma (early Middle Jurassic) (Tempelman-Kluit and Wanless, 1975; Pearson and Clark, 1979) are close to the intrusive age of 192 Ma (late Early Jurassic) given by a concordant U/Pb age on zircon (Tempelman-Kluit and Wanless 1980). The Minto Pluton is therefore the time equivalent of the Carmacks and Long Lake batholiths if interpretations of their relationships to the Nordenskiold Dacite are correct. Minto Pluton is correlated with parts of the Aishihik, Granite, Tatchun and Lokken batholiths; it is also the same age as Big Creek Syenite.

6.2.7BIG CREEK SYENITE

Distinctive, coarse grained, porphyritic, hornblende syenite occupies an irregular area on the Dawson Range's north flank (Figs. 10, 12). It occurs as one large body south of Big Creek and as several plugs or dykes in Selwyn Gneiss north of the creek (Fig. 10). Though surrounded by "overlap" units and the Selwyn Gneiss, it is interpreted as a down faulted intrusion in the top of Yukon Cataclastic Terrane; hence it is treated here. The syenite invades Selwyn Gneiss along its foliation and makes agmatite with it and is itself cut by innumerable feldspar porphyry dykes and granodiorite of the Mount Nansen suite.

Euhedral pink orthoclase in thick tablets, 2 to 5 cm long, dominate the rocks and make up about one-third their volume. Hornblende (25%), oligoclase-andesine (25%), orthoclase (20%) and quartz (5%) occur interstitially; the first is commonly euhedral, but the others anhedral. Quartz and albite form graphic intergrowths around the K-feldspars. The proportion of quartz varies to about 15% so that the rocks grade to granite. The proportion of hornblende also varies and is locally so high that the rocks are coarsely crystalline hornblendite. Apatite, sphene and magnetite, common and plentiful accessories, make up 5 to 10% by volume. Texture varies from coarse grained equigranular to very coarsely megacrystic. The rocks are moderately resistant and weather to blocky dark talus.

The syenite generally looks foliated; its orthoclase tablets and hornblendes are weakly aligned. Generally the fabric dips gently or is subhorizontal. Syenite dykes and sheets follow the foliation of the gneissic host and in places the syenite's fabric appears inherited. Though it is locally fresh the syenite is more commonly strongly altered. Hornblendes are replaced by chlorite and epidote and feldspars are clouded by sericite. The rocks are commonly crushed and broken along irregularly oriented fractures. Bostock (1936, p. 34-35) described variations in the syenite at different places in Carmacks map area. Johnston (1937, p. 5-6) described the syenite on the northern side of Seymour Creek and detailed its relations to other granitic rocks and to felsite and porphyry dykes.

At its margins the Big Creek Syenite is faulted or intruded by younger rocks and intrusive relations to older rocks are seen only around roof pendants or syenite outliers on Freegold Mountain. On the northeast the syenite is faulted against Coffee Creek Granite across the Big Creek Fault. On the southwest is the Casino Granodiorite, a younger intrusive and on the northwest it is faulted against the Prospector Mountain block. At its southeast side the syenite is overlain by the Carmacks Group. Near pendant edges the syenite invades the orthogneiss as sills, a few metres thick, along the foliation. In places the syenite sheets have sharp boundaries, elsewhere the syenite grades to the gneiss and has evidently altered it along the margins. Within the syenite are orthogneiss schlieren and xenoliths. The syenite is weakly foliated compared to its host and the two may have been sheared together following syenite injection. The small syenite bodies on Freegold Mountain intrude the Selwyn Gneiss, but none occur in the Granite Batholith.

6.2.7.1AGE AND CORRELATION

Three K/Ar dates of 142 ± 10, 152 ± 7 and 184 ± 7 Ma on hornblendes from the syenite (Figs. 10, 12) suggest that the rocks were intruded about the Early Jurassic and uplifted about the Latest Jurassic. The younger syenite ages are close to those on the Granite and Tatchun batholiths. Those ages are considered evidence of uplift related to Teslin Fault strike-slip. Less probably the younger ages reflect incomplete thermal resetting during mid-Cretaceous Mount Nansen intrusion. The older syenite age compares with ages determined for the Minto Plug and Lokken Batholith; all three may be coeval.

Stratigraphic data do not constrain the syenite's age determined from the radiometric data. Older rocks intruded by it are the Early Permian Selwyn Gneiss: younger rocks that cut it are the mid-Cretaceous Mount Nansen suite. No time and lithologic equivalents of the syenite are known in southern Yukon, but in west central British Columbia the Francois Lake Intrusions (Carter, 1982; p. 44) are such equivalents.

6.2.8CARMACKS BATHOLITH

The northern edge of the Carmacks Batholith occupies a small area in south central Carmacks map area (Figs. 10, 12). As in the Granite Batholith most rocks are coarse grained, porphyritic granite with conspicuous pinkish K-feldspars some 5 cm across. The groundmass contains roughly equal proportions of quartz, microperthitic potash feldspar and albite-oligoclase all intricately intergrown. Biotite occurs interstitially as small ragged grains (ca 3%). Hornblende occurs as subhedral grains in less porphyritic varieties. The rocks grade from prominently porphyritic to coarse grained equigranular. Foliation is developed locally. The rocks are described in greater detail by Tempelman-Kluit, 1974.

Four K/Ar age determinations on biotite from Carmacks Batholith samples south of the project area (Figs. 10, 12, 13) fall in the range of 160-165 Ma and coincide with Long Lake Batholith ages. They are interpreted as uplift ages which show that the rocks were last warmer than the argon blocking temperature of biotite about the early Late Jurassic. The intrusive age is considered to be Pliensbachian because the rocks are considered to be subvolcanic to the Nordenskiold Dacite or extrusives like them elsewhere. If the granites and Whitehorse Trough are indeed displaced far with respect to each other, on faults of the Carmacks system, the Carmacks Batholith may be the root of volcanics like the Nordenskiold Dacite farther southeast in the Intermontane Belt.

Carmacks Batholith intrudes Aishihik Batholith on its southern side. It forms dykes and plugs in the granodiorite and grades into it so that the two rocks show agmatitic relations in which the granodiorite is host. On its north side the Carmacks Batholith invades amphibolite and schist, but the relations are poorly exposed.

7.WHITEHORSE TROUGH

The northern Intermontane Belt of Yukon was referred to as Whitehorse Trough, by Wheeler (1961). In the project area the Trough occupies a zone which trends northwest across Laberge, and into Carmacks, map area (Figs. 1, 10). On the northeast Whitehorse Trough is bounded by the Teslin, Mason, Boswell and Hootalinqua faults, which separate it from Teslin Suture Zone. On the southwest Whitehorse Trough is faulted against granodiorite of the Granite, Carmacks and Aishihik batholiths along the Hoochekoo and Carmacks faults. The contact between them is covered in many places by Carmacks Group basalt, one of the overlap units. The Tatchun Belt, a subdivision of the Whitehorse Trough, is separated by the Claire and Open faults.

Whitehorse Trough includes two established stratigraphic units: the Upper Triassic Lewes River Group and the Lower Jurassic Laberge Group. They are a submarine andesitic basalt with limestone and a marine and subaerial volcaniclastic and immature clastic unit. The Laberge rests on the Lewes River Group conformably. The Takla and Hazelton groups of northern British Columbia are time and lithologic equivalents of the two units with many parallels to Whitehorse Trough strata.

The Lewes River Group is redefined and formally subdivided into a lower basaltic andesite called the Povoas Formation and upper carbonate and clastic members of the Aksala Formation. The rocks are Karnian and Norian. The Laberge Group is similarly formalized. It has a lower unit, a few hundred metres thick, of marine shale and slate, the Richthofen Formation, which is

Hettangian and Sinemurian; a middle division of two laterally equivalent units, the Nordenskiold Dacite and Conglomerate Formation, 1 or 2 km thick, which are Pliensbachian; and an upper arkose, the Tanglefoot Formation, which is Toarcian to Bajocian. Nordenskiold Dacite has extensive, thick ash flows, some subaerial, others submarine. The Conglomerate Formation is a set of debris flows of locally derived alluvium.

Whitehorse Trough strata rest structurally against those of the Semenof Block on the northeast; together they lie structurally above Yukon Cataclastic Terrane. No stratigraphic ties are seen between Whitehorse Trough and Yukon Cataclastic Terrane. Trough strata are folded and broken by brittle Jura-Cretaceous transpressional faults; Yukon Cataclastic Terrane rocks are penetratively strained, metamorphosed, and broken by ductile faults.

Whitehorse Trough rocks are interpreted as the products of a volcanic arc deposited in fore-arc, back-arc or interarc basins. The hypothetical arc is here called the Lewes River Arc. The volcanic rocks, Povoas Formation and Nordenskiold Dacite, may be the arc's eroded volcanic edifices, but are more likely volcanic detritus deposited in basins. The trench above which the arc was presumably built lay northeast of Whitehorse Trough. There the detachment zone under the arc is interpreted as the reactivated subduction complex. If so the volcanic centres lay to the southwest and the basins are in the fore-arc. The Late Paleozoic Atlin Terrane and Semenof Block under Whitehorse Trough may be remnants of the oceanic crust on, or next to, which the arc was built. And granites under the Trough, Tatchun Batholith for example, are thought of as the arc's plutonic roots. Oceanic crust and batholiths are now structurally detached from, and displaced with respect to, Whitehorse Trough.

7.1TATCHUN BELT

The Tatchun Belt between Whitehorse Trough and the Semenof Block (Fig. 9), is bounded on the northeast by the Teslin, Mason, Boswell and Hootalinqua faults and on the southwest by the Claire and Open faults. Tatchun Belt has two blocks, one in north central Laberge map area and a second between Open Creek and Teslin River in southeastern laberge map area. Both have Triassic strata which differ from those in Whitehorse Trough, but which are taken to be remotely related depositionally. The two areas are described separately. The Tatchun Belt lacks the limestones, which are common in the Lewes River Group of Whitehorse Trough, and it is separated from the Whitehorse Trough by the Claire and Tatchun faults. It is therefore considered to be fault block that was remote from Whitehorse Trough during the Early Mesozoic. Tatchun Belt strata are provisionally included in the Povoas Formation.

Between the Teslin and Semenof faults in Laberge map area are massive, boulder to cobble conglomerate-agglomerate, volcanic breccia and greenstone. The rocks extend northwestward through Glenlyon to Carmacks map area (Fig. 9). They are a distinct, near-source volcanic facies correlated with Lewes River Group and presumed equivalent to the Povoas Formation. They are described separately because the correlation is uncertain. Generally they are massive to crudely stratified volcaniclastic rocks with subrounded pebbles and cobbles of green altered andesite in a fine grained volcanic matrix. Many massive appearing green, altered andesites retain faint volcaniclastic texture and are sand sized, basaltic tuffs. Augite crystal tuff was noted at some localities. Volcanic rocks are massive and green and range from andesite to basalt. Many are porphyritic with dark subhedral pyroxenes up to 2 mm long and smaller partly altered, greenish plagioclases. Some are amygdaloidal with calcite filled vesicles. The groundmass is very fine grained, greenish saussurite. Fragments are also strongly epidotized and chloritized, but the rocks are not sheared. Volcanic and volcaniclastic members are mixed and no ordered relationship was discerned.

In Carmacks map area massive green basalt dominates; the augite porphyry, basaltic tuff and conglomerate-agglomerate are less common. Bostock (1936, p. 29-30) gave good descriptions of the rocks in Carmacks map area.

7.1.1RELATIONS, AGE AND CORRELATION

Tatchun Belt strata are faulted against several units, but depositional relations are unknown. An Upper Triassic to Lower Jurassic age is postulated on the similarity to the Povoas Formation and to Laberge Group conglomerate, but the distinctive strata of Whitehorse Trough are lacking and the assignment is tentative. A single radiometric age determination of 199 Ma (Sinemurian-Lower Jurassic) by the K/Ar method on hornblende from fresh fragmental basaltic andesite (Fig. 10) supports this assignment. Tatchun Belt rocks may be proximal Povoas Formation pyroclastic flow breccias or lahars deposited as mass flows. A few, notably the outcrops at Claire Lake, may be fossil alluvial fans.

In Laberge map area the conglomerate-agglomerate was included in the Hutshi Group by Bostock and Lees (1938); their Hutshi Group comprised what are now known to be three widely different volcanic units: the Pennsylvanian Semenof Formation, the Upper Triassic Povoas Formation and parts of the Late Cretaceous Carmacks Group.

Bostock (1936) included Tatchun belt rocks in Carmacks map area in the Mount Nansen Group incorrectly. Campbell (1967) was uncertain about the correlation of these rocks in Glenlyon map area, but he speculated an Upper Triassic or older age and considered them probably part of the Lewes River Group.

Differences between Tatchun Belt strata and the rest of the Lewes River Group suggest that the rocks formed remote from each other and implies possible large displacement on the Tatchun, Claire and Teslin faults. Tatchun Belt strata may have originated southeast (or northwest) of their present position. Their best match southwest of the Teslin-Kutcho-Finlay-Swannell Fault system is with the Takla Group and the Nazcha and Shonektaw formations of central and northern British Columbia, at least 500 km to the southeast.

7.1.2OPEN CREEK-TESLIN RIVER STRATA

Exposures on the ridge between Open Creek and Teslin River (Figs. 6, 10) differ from those discussed above: clast types have more variety and the rocks are better layered, and have interbedded shale and sandstone. The conglomerate contains granodiorite and limestone clasts beside the volcanic pebbles. Though volumetrically unimportant, limestone commonly makes up the largest boulders. Dark grey chert pebbles, not seen in the Lewes River or Laberge groups elsewhere in the project area, make up 5 to 10% by volume in many outcrops. Volcanic sandstone and dark greyish brown argillite is interbedded with the pebbly rocks in beds many metres thick. The unit is resistant and weathers red brown.

Limestone is interbedded with the clastic rocks at one place on the ridge. It resembles that of the Hancock Member of the Lewes River Group and contains fish teeth that are probably Upper Triassic (collection 73). The clastic rocks resemble the Conglomerate Formation of the Laberge Group and parts of the Lewes River. Open Creek-Teslin River strata occupy a discrete block between the Teslin and Open Creek faults. They are on trend with the Tatchun belt, but are separated by faults and their relations to Laberge and Lewes Group strata are unknown. An ammonite from these rocks about 2 km southwest of Swift Lake (at Peak 5003), just south of the project area was not diagnostic. The rocks may be a distinct facies of the Lewes River Group close to the Povoas Formation. Bostock and Lees (1938) included the Open Creek strata in the Laberge Group, but Wheeler

(1961) grouped their extension in northeast Whitehorse map area in the Lewes River Group noting that Laberge equivalents may be present. His correlation is preferred and followed.

7.2LEWES RIVER GROUP

7.2.1NAME AND DISTRIBUTION

The name Lewes River Series was first applied by Lees (1934) to the Upper Triassic volcanic and sedimentary rocks of Laberge map area. The name was changed to Lewes River Group by Bostock (1936) and this usage was continued by Bostock and Lees (1938), Tozer (1958) and Wheeler (1961). The type area, between Casca and Aksala creeks just east of Yukon River, was studied in detail by Tozer (1958), who showed that the rocks range through the Carnian and Norian.

Lewes River Group strata occupy central Whitehorse Trough in Laberge map area, largely between the Chain Fault and the Fairview and Goddard faults. In Carmacks map area they are restricted to the southeast corner (Fig. 10).

7.2.2STRATIGRAPHY

The Lewes River Group includes four generally superposed, laterally interfingered facies deposited during the Carnian and Norian. From the base up are basalt-andesite breccia, reefal limestone, calcareous shale and greywacke and red greywacke (Fig. 14).

Lees (1934) and Bostock and Lees (1938, p. 13) recognized three subdivisions, "a lower, limestone member; a middle, clastic member; and an upper, limestone member." Tozer (1958) subdivided the Lewes River Group into seven formations distinguished by the letters A through G. Formations A, C, E, and G are carbonates and the intervening units are volcaniclastic and clastic rocks. Tozer's upper and lower carbonates correspond to Bostock and Lees' two carbonates and Tozer's other formations (i.e. Formations B, C, D, E and F) were grouped in Bostock and Lees' middle Member (Fig. 14).

In Whitehorse map area Wheeler (1961) distinguished three areas of the Lewes River Group with dramatic facies differences: the western, central and northeastern belts. Wheeler's western belt succession resembles that of Laberge map area and its divisions match those of Bostock and Lees (1938) (Fig. 14). The five divisions (A to E) are, a lower volcanic unit, a carbonate, a volcanic breccia, a greywacke and a second carbonate. Wheeler's central and northeastern belts include a lower greywacke-argillite with minor interbedded limestone and and upper carbonate. In Laberge map area the northeastern belt is represented by the Open Creek-Teslin River block. Bostock and Lees (1938) and Tozer (1958) excluded the volcanic rocks from the Lewes River Group, and Wheeler (1961) was the first to recognize the volcanics as integral to the Group.

Tozer's formations are laterally discontinuous tongues, not traceable beyond the type area, and Wheeler's western belt divisions can be formalized. A modified version of their divisions of the Lewes River Group is proposed.

In the project area the Lewes River Group includes four lithologic units grouped in two newly named formations (Fig. 14). The Povoas Formation includes the volcanic rocks at the base and the Aksala Formation encompasses three laterally equivalent, interfingered higher members: a limestone, a green greywacke-shale and a red greywacke. The Povoas Formation was not included in the Group by Bostock and Lees; Tozer suspected that it lay conformably below the Group and Wheeler was the first to include it in the Lewes River Group (his division A). The Aksala Formation is a greywacke-shale with thick limestone lenses. In places it is entirely limestone, elsewhere clastic rocks dominate. The carbonates, here grouped in the Hancock Member are equivalents of Wheeler's division B and F, Tozer's formations A, C, E and G and the lower and upper members of Bostock and Lees. The Aksala Formation's clastic rocks include a green greywacke and calcareous shale with conglomerate, called the Casca Member and a red and green greywacke and conglomerate, called the Mandanna Member. Though the Aksala Formation lies above the Povoas Formation the two are upward and laterally gradational and the contact between them is diachronous. The Casca Member includes Tozer's formations B and D and Bostock and Lees' middle Member. The Mandanna Member corresponds to Wheeler's division D and to Tozer's Formation F. Bostock and Lees included them in their middle member. Wheeler's division C, a thick volcanic breccia above the lowest carbonate, was not seen, but thin volcaniclastics in the Aksala Formation are probably equivalents.

Tozer and Wheeler showed that the lower and upper limestones contain Carnian and Norian fossils respectively and that the boundary between these stages is in the clastic rocks between them. Tozer placed the boundary in his Formation D, the Casca Member. The Lewes River Group is Upper Triassic, but the Povoas Formation may range downward into the Middle Triassic.

The Lewes River Group is correlated with the Takla and Nicola groups of northern and southern B.C. respectively. All three are Upper Triassic, have similar fossils and include the same lithofacies: andesitic volcanics, volcaniclastic rocks and subaerial sedimentary strata with limestone and calcareous clastics. Relations of the facies within each group are similar: facies are laterally discontinuous and interfingered and no general stratigraphic sequence is recognized. Nevertheless volcanics with intercalated submarine volcaniclastics dominate lower parts of each and limestone with subaerial clastic rocks are more common near the tops.

7.2.3POVOAS FORMATION

7.2.3.1DISTRIBUTION AND NAME

Most of the Povoas Formation crops out in the core of Aksala anticline, an open fold east of Lake Laberge. Other exposures are northeast of Mandanna-Chain Lakes west of Conglomerate Mountain and between Mandanna Creek and Birch Mountain (Fig. 10). Goddard Point, on lower Lake Laberge has excellent wave washed exposures. The formation name is taken from Povoas Mountain (Fig. 6), where large outcrops occur and the reference area is between Goddard Point and Povoas Mountain.

7.2.3.2LITHOLOGY

Massive volcanic breccia, agglomerate and altered flow rocks dominate the Povoas Formation. The rocks are resistant, weather dark purplish, but are generally dark green on fresh surfaces. Volcanic breccia or agglomerate of angular, altered, green and purplish aphanitic volcanic clasts, with fairly common feldspar porphyry pebbles and a few limestone boulders and cobbles dominates. The aphanitic volcanic clasts may derive from the volcanic flows and the porphyries from subvolcanic vents. Limestone clasts presumably came from Hancock Member lenses that were laterally equivalent to the volcanics or from small limestones within the Povoas Formation. Mostly the rocks lack layering, but crude stratification, with units tens of metres thick, is seen locally. Clast size ranges to a metre, but most fragments are pebbles or lapilli 5 to 20 cm in diameter. Generally the rocks are clast supported, with very little matrix, but with smaller pebbles between the larger. Clast sphericity and angularity vary from place to place, presumably reflecting the distance of transport. Clast size is independent of roundness.

Massive greenstone, mostly altered andesitic basalt, makes up about a tenth of the Povoas Formation. It is difficult to distinguish from the breccia and is not separated on the maps. The rocks are locally porphyritic with augite and plagioclase. The groundmass is a mixture of chlorite, epidote, quartz and calcite. Commonly the rocks are saussuritized so that epidote replaces feldspar and chlorite or actinolite replaces augite. Minor greywacke, dominated by volcanic rock detritus, is interbedded with the breccia and agglomerate.

On and near Conglomerate Mountain and Birch Mountain the Povoas Formation is massive pink, red and mauve weathering andesite-dacite and fragmental volcanic rock that resembles the Nordenskiold Dacite. They are grouped with the Povoas Formation because it contains small limestone lenses, known only in the Lewes River Group.

7.2.3.3LATERAL RELATIONS

North of the Casca Fault and on the south side of Povoas Mountain the Povoas Formation is overlain by, and intertongued with, carbonate of the Hancock Member without evidence of a depositional break (Fig. 15 and column 12 of Fig. 17). The relationship is exposed just east of US bend (Fig. 6) where massive volcanic breccia lies directly beneath limestone. On the southern side of Lime Peak and on the east flank of Peak 4308, orangy weathering calcareous greywacke is intertongued with the lowest sheets of Hancock Member carbonates (Fig. 15). No strata are seen depositionally below those of the Povoas Formation. The unit may have been deposited on the Boswell and Semenof formations or on Cache Creek Group strata, but they are now structurally disconnected from them. In adjacent map areas depositional relations below Povoas Formation equivalents are no clearer.

Povoas Formation breccias northeast of the Chain Lakes contain intertongued carbonate lenses, but lack overlying limestone (column 3, Fig. 17). The carbonate lenses are Norian and the volcanics are therefore younger than in the type area.

The thickness of the Povoas Formation is difficult to gauge because it is massive. On Povoas Mountain a minimum of 500 m must occur if the strata dip gently and if they are not repeated.

7.2.3.4DEPOSITIONAL ENVIRONMENT

The Povoas Formation is inferred to be the depositional record of a relatively few, short lived, catastrophic volcanic events, each separated by short intervals in relation to the time represented by the unit. Depositional episodes of a few weeks interspersed with hundreds or thousands of years over a total depositional span of perhaps several million years for the unit are envisioned. The greenstone likely represents autoclastic volcanic breccia with minor intercalated subaerial flows. Most represent pyroclastic flow deposits and alluvial debris transported as massive sheet flows on land and under water, but deposited in water. No pillow basalt or flow breccia was seen. The agglomerate approaches an epiclastic rock. Its clasts were transported and reworked more than those of the breccias, but it too was probably deposited as massive sheet flows judging from the lack of stratification, sorting, grading and the matrix support. The same volcanic debris as in the breccias was carried and worked in streams, and first deposited as coarse alluvial fans. These were later transported as sheet flows, during storms or other catastrophic events.

Deposition was in shallow water, and perhaps locally on land judging from the purple weathering colour of some clasts and from the intertongued carbonate buildups.

The Povoas Formation is interpreted as the volcanic component of a Lewes River island arc. It is more basaltic than the Norden-skiold Dacite, but its gradation from breccia to agglomerate parallels the range between the Dacite and the Conglomerate Formation. Distinction between pyroclastic flow rocks and sheet or debris flow deposits is difficult in the Povoas, perhaps because most of the exposed rocks are near the transition.

The Povoas Formation may be the extrusive product of intrusions such as the Aishihik Batholith. That intrusion lies just west of, but is faulted against, Whitehorse Trough. If the Aishihik Batholith is the plutonic root of the Povoas or its Takla Group correlatives this defines the age of the intrusions better than the radiometric ages do. The radiometric ages range from 268 to 144 Ma (Fig. 13).

7.2.3.5AGE AND CORRELATION

The Povoas Formation ranges through the Carnian; parts are Norian and it may range into the Ladinian (Figs. 17, 18, 20, 21). Conodonts from the Hancock Member directly above the Povoas Formation (collections 12, 17, 26) and bivalves and ammonites collected by Tozer (collections 102, 104 107) are Norian or Carnian. Three conodont collections (20, 21, 22) were made from limestone intercalated with volcanic breccia of the Povoas Formation northeast of Chain Lakes. Two range through the Upper

Triassic, but the third (21) is Norian. Northeast of Chain Lakes valley volcaniclastics assigned to the Povoas Formation are intercalated with limestone which contains Norian conodonts (collections 20, 21, 22). This shows that the unit must be younger there.

The volcanic breccia resembles breccias in Wheeler's (1961) divisions C and D. Equivalents of the Povoas Formation in Aishihik Lake map area, west of Nordenskiold River, are included in map unit TRvb (Tempelman-Kluit, 1974).

The Povoas Formation is lithologically like, and time equivalent to, volcanic rocks of the Stuhini Group (Souther, 1971) and to the Savage Mountain Formation of the Takla Group (Monger, 1977). The first occurs in northern British Columbia in Tulsequah map area on the southern side of Whitehorse Trough; the second in the McConnell Creek area farther south. The Stuhini volcanics are andesitic flows and pyroclastic rocks with interbedded Upper Triassic boulder conglomerate. Interbedded with the Stuhini volcanics are clastic rocks (King Salmon Formation) that resemble the Aksala Member. Whereas the volcanic rocks occur dominantly at the base of the Lewes River Group, they make up the bulk of the Stuhini Group (see Fig. 14). Unlike the Lewes River Group, the Stuhini rests unconformably on older rocks.

The Savage Mountain Formation consists of basic flows and volcaniclastic rocks, intertongued with volcanic greywacke (Dewar Formation) and overlain by pyroclastics, the Moosevale Formation. The Savage Mountain Formation is dominated by basaltic proximal volcaniclastic and pyroclastic rocks deposited in a shallow marine environment. Most of the Takla Group of central British Columbia (i.e. Main Unit of Tipper, 1959, p. 12-16) consists of Upper Triassic volcanic breccia and flow rocks. It is a time and lithologic equivalent to the Povoas Formation.

7.2.4AKSALA FORMATION

Clastic rocks and carbonates above the Povoas Formation are together called the Aksala Formation and that unit is equivalent to Tozer's (1958) Lewes River Group (Fig. 14). The unit encompasses three laterally intergradational, lenticular, lithologically distinctive units, the Hancock, Casca and Mandanna members. Tozer's type section (near US bend, Fig. 6) includes the three lithologic members and is retained as the type for the Aksala Formation. Thicknesses at the type section are not representative of the Aksala Formation away from the type area. The name reflects the type locality; Aksala Creek is just north of Tozer's type section.

Aksala Formation limestones formed as reefs or buildups and the clastic rocks represent beach accumulations and subaerial sandstones near tidal flats. The Aksala Formation is the product of continual shifts in the balance between carbonate reef growth, beach development and tidal flat incursions in a shallow, energetic, marine environment. The Aksala and overlying Richthofen Formations are a record of a Carnian through Sinemurian lull in volcanism; they may also represent refugia protected from Lewes River Group volcanism. The intravolcanic lull followed Povoas volcanism and preceded extrusion of Nordenskiold Dacite.

7.2.4.1HANCOCK MEMBER

7.2.4.1.1DISTRIBUTION AND NAME

Lewes River Group limestones are named the Hancock Member (Fig. 14) after the Hancock Hills, where good exposures are seen. The rocks occur intermittently on the flanks of Povoas Anticline in a belt that runs northwestward along the east side of Lake Laberge toward Carmacks (Fig. 10).

The Hancock Member represents ephemeral carbonate buildups, discontinuous in space and time. The limestones are lenses from a few metres to hundreds of metres thick and from hundreds of metres to tens of kilometres long. They grade laterally to, and are intercalated with, Casca and Mandanna members clastic rocks and locally with Povoas Formation volcanics. Between Casca and Donville creeks the four main limestones are each thicker than 100 m, the lowest may be 500 m and they may aggregate about 1200 m. About 300 m are estimated on the southwest flank of Aksala Anticline southwest of Miller Lake. On Lime Peak about 400 m are preserved.

7.2.4.1.2LATERAL RELATIONS

The relations of the limestone to other Aksala Formation Members across Povoas Anticline between Laurier Creek and Povoas Mountain demonstrate its lateral variation (Fig. 15). In the north the lowest limestone rests directly on the Povoas Formation, but southward clastic beds assigned to the Casca Member intervene. Here the clastic rocks must predate the lowest carbonate. On the anticline's east flank upper and lower limestones are separated by Casca Member beds. Northward on the same flank of the fold the intervening strata disappear and the two limestones merge. Directly west of Miller Lake one carbonate, presumably the equivalent of the two separate sheets, is interposed between the Povoas Formation and Laberge Group. On Peak 4308 a series of disconnected limestones, enclosed by clastic strata, constitute the west flank of the Povoas Anticline. The lenses, all mapped as the Hancock Member, occur at stratigraphically different levels.

Across the Laurier Fault is a lateral change like that across Povoas Anticline. South of the fault, on Mount Laurier, the Aksala Formation includes about 50 m of limestone above several hundred metres of greywacke and calcareous shale and below the lowest shale of the Laberge Group, the Richthofen Formation. North of the fault, on Lime Peak, 500 m of Hancock Member limestone overlies calcareous greywacke of the Casca Member. Thus south of the Laurier Fault the Aksala Formation is represented largely by the Casca Member; north of it by the Hancock Member.

The discontinuity of the limestone is also illustrated by relations at the type locality between Casca and Aksala creeks on the east flank of Povoas Anticline. There the lowest carbonate above the Povoas Formation is lens intertongued with clastics on the north and south like several stratigraphically higher carbonates. The highest limestone is also discontinuous and laterally gradational to the Mandanna Member. Tozer (1958) considered the units more continuous and grouped them differently. He included the three lowest limestones in the southern part of the block in his formation A and defined the two limestones above as his formations C and E. In the north he considered the highest limestone part of his Formation G and included the three lower lenses in formations E and C.

The highest Aksala Formation limestones at any place, are generally overlain conformably by clastic rocks included in the Laberge Group. In the Hancock Hills and on Mount Laurier dark brown slate, the Richthofen Formation, rests directly on limestone. Southwest of Miller Lake and on the hills east of US bend sandstone and conglomerate, included in the Conglomerate Formation, overlies the highest Hancock Member lenses.

7.2.4.1.3LITHOLOGY

Most of the Hancock Member is represented by massive to thick bedded, white weathering, light grey limestone. In contrast to other rocks in the region the limestone generally lacks vegetative cover so that it is easily distinguished from afar. The rocks range from massive clean lime mudstone to thin bedded, argillaceous, bioclastic limestone. Massive limestone is commonest and forms the core of many carbonate lenses; thick bedded to thin bedded limestone occurs near lens margins.

Most massive limestone is micritic or finely crystalline, pelleted lime mudstone, with some floating coral or sponge fragments. Massive framestone or bindstone with calcisponges, tabulozoans, algae, corals and other fossils bound by algal coatings are also common. Voids are filled with lime mud and sparry cement giving some weathered surfaces spectacular textures. The thick bedded limestone is medium to coarse sand sized packstone or grainstone of broken skeletal fragments with a lime mud matrix. Some medium or dark grey, argillaceous, thinbedded limestone occurs around the more massive carbonates. It is a fine grained packstone of sponge spicules, echinoderm fragments, forams and bivalves with a considerable siliciclastic component.

7.2.4.1.4DEPOSITIONAL ENVIRONMENT

Carbonates of the Hancock Member are discontinuous, depositionally lenticular, reefal buildups (Tempelman-Kluit, 1978; Reid, 1981, 1982). Lees (1934; p. 15) was the first to recognize that some limestones in the Lewes River Group are reefs. Tozer (1958) considered the limestones as continuous sheets. Wheeler (1961) and Tozer (1958) followed Bostock and Lees' (1938) thinking that the thickness variations and lenticularity of the upper limestones reflects erosional bevelling under the Laberge Group.

7.2.4.1.5AGE AND CORRELATION

Hancock Member limestones contain corals, bivalves, ammonites and conodonts, which indicate Carnian or Norian ages; most of the diagnostic fossils are Norian. Among the megafossils those collected by Tozer (1958) (101, 102, and 103 of Appendix I, Fig. 18) are the best clue of a Carnian age; of the conodont collections 12 and 26 are Carnian. Collections 10, 21, 59, 64, 65, 69, 70 are examples of Norian fossils from the Hancock Member (Fig. 18). The unit evidently ranges through the Carnian and Norian (Figs. 17, 20, 21).

Tozer (1958) collected Norian bivalves from his Formation G, the equivalent of stratigraphically high lenses of the Hancock Member. Collections 109, 110, 111, and 112 were made and reported by him. During the present work several new conodont and macrofossil collections were made. Collection 12 is of Late Carnian or Early Norian conodonts and collections 25, 32, 36, 37 and 41 are of Late Triassic bivalves and corals. Collection 54 contains the Upper Norian Spondylospira Lewesensis.

England (1980) studied conodonts from samples of a measured section of the Casca Member on the east flank of Hill 4308, east of Lake Laberge (at fossil localities 64 to 68). He measured some 500 m of strata, mostly massive limestone, here included in the Hancock Member, and recovered conodonts from near the middle. Among others he identified Epigondolella postera and concluded that the rocks are Middle Norian. His collections were re-examined by M.J. Orchard, who considers the fossils Middle or Upper Norian (see collections 64 to 68). England also showed that the conodont colour alteration index, thought to be a measure of the degree of thermal maturation of the rocks, is between 2 and 3. It means that the rocks attained temperatures near 150°C and have about 70% fixed carbon. The colour alteration index of conodonts from elsewhere in Laberge map area generally falls in the same range. The highest determined index, 4, (M.J. Orchard, written comm., 1983) indicates that temperatures reached to between 190 and 300°C and that about 90% of the rock's carbon is fixed.

The youngest Hancock Member lenses are Upper Norian. The lower Richthofen Formation above them is probably Hettangian. Because no depositional break is recognized between the limestone and Richthofen beds the Hancock Member may range into the lowermost Jurassic.

The Takla Group of McConnell Creek map area in northern British Columbia lacks limestones like those of the Hancock Member, but the Nicola Group of southern British Columbia includes time and lithologic equivalents. Time and lithologic equivalents of the Hancock Member are called the Sinwa Formation in northern British Columbia (Souther, 1971). That unit is a Norian limestone at the top of the Stuhini Group which is overlain by the Inklin Formation, a facies of the Laberge Group. The difference between the Lewes River and Stuhini groups is in the relative volumes and ranges of carbonates and volcanics. Carbonate and related shallow water siliciclastics constitute the bulk of the Lewes River Group and represent most of Upper Triassic time, but represent only part of the Norian in the Stuhini Group.

7.2.4.2CASCA MEMBER

7.2.4.2.1DISTRIBUTION AND NAME

The Casca Member (Fig. 14) includes calcareous siltstone, shale, sandstone and conglomerate. The rocks are not generally distinctive by themselves and resemble those of the Laberge Group. Orangy brown weathering, brownish calcareous siltstone or shale, not found in other units, is diagnostic. The strata rest above the Povoas Formation and grade laterally to the Hancock Member. The name is taken from Casca Creek, near where a thick section is exposed.

Casca Member beds occur on both flanks of the Povoas Anticline east and north of Lake Laberge. Other outcrops are east of Mandanna Valley and in the Hancock Hills, but the best section is about 10 km north of Braeburn. This section, about 2 km east of the Klondike Highway at post 290 is taken as the reference section. The unit is generally several hundred metres to one kilometre thick, but thickness differs drastically from place to place.

7.2.4.2.2LITHOLOGY

The Casca Member weathers to pale orange colours and the beds are recessive compared with the carbonates around them. The commonest rock is medium bedded, greenish greywacke with roughly equal parts of angular plagioclase and volcanic rock fragments and about 25% quartz. This is richer in quartz than most Laberge Group greywacke. Hornblende and augite, common detrital minerals, probably derive from volcanics of the Povoas Formation.

The rocks range from granule grit to medium or fine sand and include pebble conglomerate similar to that in the Conglomerate Formation. Dark greenish grey, thinbedded calcareous siltstone and shale is interbedded with the coarser clastics. This, the diagnostic rock of the Formation, is commonly bioturbated and its lamination disturbed by fine horizontal burrows. Fine ripple marks and small scale cross-stratification are seen locally. Beds are medium to thick and planar.

Bioclastic limestone (packstone to grainstone) in beds several metres thick is interlayered with the siliciclastics at most places. Its detritus is largely calcareous, some is bioclastic, the remainder detrital. By decrease in lime and increase in detrital quartz it grades to limy sandstone in which the siliciclastic material outlines bedding. Near limy beds the greywacke commonly contains angular and rounded limestone clasts which are larger than the other fragments. Such clasts are commonly arranged in layers which outline bedding and may constitute half the rock's volume. Some thin shale beds contain abundant thinshelled bivalves and other bioclastic debris. In places the bioclastic material includes large sponges and coral heads. Orange weathering calcareous or dolomitic argillite is also common in the Casca Member. Lamination is brought out by alternate limy and argillaceous layers. In places the carbonate is ankeritic and this lends the rock its distinctive red weathering colour.

Some thin beds in the Casca Member are volcanic breccias that look like the Povoas Formation volcanics. They lack evidence that they were reworked by water and are probably waterlain tuffs.

7.2.4.2.3DEPOSITIONAL ENVIRONMENT

Casca Member sandstones lack large volumes of interbedded conglomerate and are slightly better sorted than the overlying coarse clastic rocks of the Laberge Group. Although the rocks are by no means mature they are cleaner than overlying Laberge Group beds and underlying Povoas Formation strata.

Casca Member beds are interpreted as siliciclastics deposited contemporaneously with Hancock Member limestone, generally after Povoas Formation volcanism. Judging from the interlayered carbonate they were probably deposited in shallow water. The clastic detritus was derived from volcanic rocks of the Povoas Formation and transported into the marine basin by streams. The greywacke probably represents material accumulated on the beach or shallow shelf around volcanic islands partly fringed by carbonate reefs. Possibly the reefs were periodically killed as these deposits washed across them following storms. When clastic input waned the reefs flourished, but when siliciclastic detritus flooded the beach and shelf the reefs died.

7.2.4.2.4AGE AND CORRELATION

Pelecypods, ammonites and conodonts from the Casca Member show that the unit is Carnian and Norian; most fossils are Norian. Tozer's (1958) collections from the type area of the Lewes River Group are Carnian and Norian (see collections 104, 105, 106, 107, 108, Appendix I, Fig. 18). Tozer's Formations B and D are mapped here as the Casca Member. Tozer thought the second spans the Carnian-Norian boundary.

Bivalves and ammonites collected during the present work and represented in collections 34, 35, and 66 are assigned to the Norian. Conodonts from limestones intercalated with clastics and included in the Hancock Member (collections 26, 66, 67, 68, 69) are assigned Carnian and Norian ages (Figs. 16, 17, 18, 20, 21).

Approximate time and lithologic equivalents of the Casca Member in the Takla and Stuhini groups are the Dewar and King Salmon formations respectively (Fig. 14). Unlike the Casca Member both are intercalated with volcanic rocks and neither is laterally gradational to limestone.

7.2.4.3MANDANNA MEMBER

7.2.4.3.1DISTRIBUTION AND NAME

The name Mandanna Member (Fig. 14) is introduced here for distinctive red and green weathering greywacke and volcanic sandstone in the upper Aksala Formation. These rocks occur mainly in northwestern and western Laberge map area, but also crop out near the outlet of Lake Laberge. Bostock and Lees (1938) included them in the upper or middle Member of the Lewes River Group and Tozer (1958) based his Formation F on these rocks. In Whitehorse map area Wheeler (1961) grouped these beds in Division D. Good reference exposures are on both sides of Mandanna Valley (Fig. 6) east of the Fairview Fault, their type area. Other outcrops are a few kilometres northwest of Braeburn and east of US bend.

7.2.4.3.2INTERNAL RELATIONS

The Mandanna Member is a lithologically distinctive, aerially restricted unit generally above, and laterally and upward gradational to, the Casca Member (Figs. 17, 20, 21). A limestone lens of the Hancock Member commonly rests above it, but east of Mandanna Valley the red sandstones are the top of the Aksala Formation and are overlain conformably by the Conglomerate Formation.

No sections were measured, but about 900 m occur on the east side of Mandanna Valley and 600 m are estimated west of Mandanna Lake (column 4, Fig. 17). Tozer (1958) measured some 300 m in the type section (his Formation F) (column 12, Fig. 17).

7.2.4.3.3LITHOLOGY

Red weathering red sandstone, the diagnostic and distinctive rock, is a medium bedded, volcanic sandstone or greywacke with angular coarse grit to medium sand grains. The rocks weather more resistantly than the calcareous Casca Member, but more recessively than Hancock Member carbonates. Argillaceous partings between sandy beds are thin and commonly weather red also. Some have mudcracks and rain drop impressions.

Brown and green weathering greywacke, like that of the Casca Member, is interbedded with the red clastics. In places it makes up the bulk of the unit. The rocks are medium bedded with beds to a half metre thick. Alternate beds range from coarse to medium or fine sand. Fine grained greywackes are parallel laminated with dark and light red layers which presumably reflect variations in magnetite-hematite.

Like Casca Member greywacke the main constituents are mafic volcanic rock fragments and plagioclase with about 10% quartz and some hornblende and biotite. Most constituents are fresh and unaltered. The matrix is fine grained feldspar and chlorite with minor calcite. Volcanic rock fragments resemble Povoas Formation greenstone and tuff.

Limestone lenses and beds, several metres thick and too small to map, occur in the red sandstone locally. They resemble the discontinuous carbonates in the Hancock Member and are mostly bioclastic grainstones with shell, sponge and coral debris.

Because of their colour, mudcracks and rain drop impressions the red greywackes are considered to have been deposited subaerially. They may be supratidal equivalents of the green greywackes in the Casca Member, which were laid down on tidal flats fringing deeper water. The red greywackes are mineralogically as immature as their green counterparts and lack evidence of having been extensively wave washed; the carbonate beds may be fossil shelly beach deposits or cheniers.

7.2.4.3.4AGE AND CORRELATION

The Mandanna is very fossiliferous: collections 17 and 18 (Appendix I, Fig. 18) from two limestone lenses in it are Upper Triassic (Norian). Collections 111-116 from the Mandanna Member are upper Norian (Tozer, 1958, collections 11 to 16). Because the rocks are overlain conformably by the Conglomerate Formation and because tongues of volcanics like the Nordenskiold Dacite are interbedded, the Mandanna Member may range into the Lower Jurassic. Parts may be as young as Hettangian (lowest Jurassic) (Figs. 17, 21).

Red sandstones are not known in the Stuhini Group (Souther, 1971), but coarse clastic rocks, some with red clasts, are time equivalents of the Mandanna Member (see Fig. 14). The coarse clastic unit of the Stuhini Group has interbedded volcanic sandstone, graded siltstone and impure limestone lenses. Like the Mandanna Member the Stuhini is overlain by a limestone, the Sinwa Formation.

Takla Group red sandstones are included in Tipper's (1959, p. 16-20) Red Bed Unit. It constitutes the upper Takla Group in central British Columbia and is Upper Triassic and Lower Jurassic. More recently Tipper and Richards (1976, p. 11-16) included the red units in the lower Hazelton Group's Howson and Babine Shelf Facies. They assigned a Sinemurian age which is younger than the Norian age of the Mandanna Member.

In McConnell Creek map area the Upper Triassic Moosevale Formation, red and green nonmarine and marine volcanic breccia and conglomerate (Monger, 1977), correlates with the Mandanna Member. Relations of the Moosevale Formation to underlying and overlying strata are similar to those of the Mandanna Member.

7.2.4.4TAKLA, STUHINI AND LEWES RIVER GROUPS

The Takla, Stuhini and Lewes River are coeval groups of the same rocks. They developed similarly and were probably connected when deposited. They change from volcanic dominated sequences in the south to carbonate dominated successions farther north with a general northward shoaling of the depositional environment. Thus the Takla Group is dominated by basaltic to andesitic volcaniclastic and volcanic rocks, with immature, coarse grained epiclastic rocks derived from the volcanics. It lacks limestone and is largely submarine. Volcanic and derived clastics also dominate the lower Stuhini Group, but a Norian limestone deposited in shallow water, makes up the top. By contrast shallow water limestone and laterally equivalent siliciclastic rocks dominate the Carnian and Norian of the Lewes River Group: volcanic rocks are comparatively restricted and confined to the base.

In all three groups basaltic rocks predominate low in the sequence while intermediate volcanics occur low in the next overlying unit. Thus augite porphyry predominates among the volcanic and volcaniclastic rocks low in each group, but andesitic to dacitic feldspar porphyries occur in the immediately overlying unit or even high in each group. In the Lewes River Group the Povoas Formation represents the mafic extrusive event and the Nordenskiold Dacite of the Laberge Group the intermediate. In the Stuhini Group the lower basaltic pyroclastics are unnamed and Nordenskiold Dacite equivalents, also unnamed, are interpreted in the directly overlying Laberge Group.

The volcanic quiet interval between basalt and andesite-dacite extrusion promoted carbonate deposition and accumulation of relatively mature siliciclastic rocks. At any time during the Norian three facies, carbonate, siliciclastic beach sands and red beds, formed side by side. Locally volcanic pyroclastics like those of the Povoas Formation were also extruded. From Laberge to Tulsequah discontinuous carbonate buildups formed in the Lewes River and Stuhini groups. They thrived during the Carnian and Norian in the north, but only flourished during the Norian farther south: Laberge area came closest to establishing a carbonate bank. Why the bank is discontinuous is unclear. Perhaps storms drowned the carbonate buildups intermittently with floods of siliciclastic debris. Aksala Formation carbonate deposition began in Whitehorse Trough during the Carnian and progressed southward with time. By the close of the Norian, carbonates extended 500 km from Laberge area to the Stikine. The shallow shelf on which the carbonates built has a volcaniclastic substrate of ash flows and alluvial fans erupted and shed from a volcanic arc to the west. About the Hettangian the shallow shelf from Lake Laberge to the Stikine was drowned beneath the level of carbonate compensation and shale (Richthofen Formation) transgressed it.

The intravolcanic interval in the Stuhini Group was shorter than that in the Lewes River Group; in the Takla Group it was still shorter. Red beds near the top of the three Groups (Mandanna Member, Coarse Clastic Unit and Moosevale Formation) record a time when carbonate was no longer the preferred mode, although shoal conditions remained. Clastic influx or the factor(s) that controlled the world wide demise of carbonate buildups at the beginning of Jurassic time probably influenced their disappearance.

The parallels between the Lewes River and Stuhini and Takla groups are similar to those that can be drawn between the Lewes River and Nicola groups. Generally the subaerial epiclastics with limestone reefs in Preto's (1979) eastern and central belts compare with strata of the Mandanna Member and his western belt andesites resemble the Povoas Formation.

7.3LABERGE GROUP

7.3.1NAME, DISTRIBUTION AND RELATIONS

The Laberge Group is a succession of shale, conglomerate, dacite, greywacke and arkose that ranges through the Lower and into the Middle Jurassic. The rocks were studied west of Lake Laberge and named the Laberge Series by Cairnes (1910, p. 30). They were subsequently studied and reported in Whitehorse map area by Cockfield and Bell (1926) and in Laberge map area by Lees (1934) and Bostock and Lees (1938). Bostock and Lees (1938, p. 13) considered that the Group consists of three Members "a lower member of sandstone and argillite; a middle member of conglomerate; and an upper member of sandstone and argillite."

Wheeler (1961) studied the Laberge Group in Whitehorse map area showing that the Group generally has a lower conglomerate and an upper argillite-greywacke. He divided the unit into Eastern and Western Belts, between and within which, he documented dramatic variation.

The Laberge Group is generally considered to rest unconformably or disconformably on the Lewes River and disconformably below the Tantalus Formation. Cairnes (1910), who studied the group in the Nordenskiold district southeast of Carmacks, considered that it rests unconformably on the Braeburn Limestone (the name he used for Lewes River carbonates). He thought that conglomerates in the lower Laberge represent a basal clastic unit above the unconformity. Bostock and Lees (1938, p. 15) thought the relations "apparently conformable", but did not rule out an erosional interval. Wheeler (1961, p. 62), influenced by thickness variations in the carbonate beneath the Laberge Group and by clasts of the Lewes River in it, thought the relations probably disconformable. Laberge beds may truncate Lewes River strata locally, but much of the lenticularity of Lewes River Group carbonate under the Laberge is the product of depositional discontinuity not erosional truncation. Fossils also show no evidence for a regional hiatus. Youngest Lewes River beds are Latest Norian and the oldest Laberge strata are Hettangian.

Relations at the top of the Laberge Group, below the Tantalus Formation were thought disconformable by Wheeler in Whitehorse map area and conformable by Bostock (1938) in Carmacks area. Lower Tantalus and upper Laberge Group beds are parallel, but an absence of fossils indicates an hiatus spanning the Bathonian, Callovian and at least part of the Upper Jurassic, between them.

The Nordenskiold Dacite, studied and named by Cairnes (1910), is here treated as a formation of the Laberge Group. In the original usage it was given formation status, but not considered integral to the group.

The Laberge Group occupies a large area that trends northwest from southern Laberge map area to beyond Carmacks (Fig. 10). It is the youngest and most extensive unit of Whitehorse Trough.

7.3.2STRATIGRAPHY

The Laberge Group includes four lithologically distinct, generally superposed and laterally interfingered units here given formation status. Upward from the base they are a shale, conglomerate, dacite and arkose named the Richthofen and Conglomerate formations, Nordenskiold Dacite and Tanglefoot Formation respectively (Fig. 19). Units are lens shaped, not blanketlike, and thickness varies, so that units more than a kilometre thick at one place are absent elsewhere (Figs. 20, 21). Nordenskiold Dacite is exposed only in the west and the Conglomerate Formation is found to the east.

The four formations represent a depositional record without long periods of universal nondeposition, but accumulation rates probably varied and short interruptions in deposition were probably common. The Nordenskiold Dacite and Conglomerate formations accumulated in about one-sixth the time that the same thickness of the Richthofen and Tanglefoot collected. Up to 1.5 km of dacite and conglomerate were laid down in 5 Ma, but less than 0.5 km of shale was deposited in an interval twice as long and a 0.5 km of arkose accumulated in 12 Ma. Numerous short local hiatuses, too small to discriminate with available fossil control, are probably included and the group was probably laid down in many short pulses separated by intervals of nondeposition. Though short by comparison to the span of fossil zones such nondeposition intervals may have outlasted the depositional events. The sum of nondepositional time spans may exceed that of the depositional events.

Laberge Group strata are generally marine and their environment generally shoaled with time. Thus the Richthofen Formation is a shallow marine shale, the Nordenskiold Dacite, a set of submarine and subaerial ash flows, the Conglomerate Formation, a series of submarine alluvial debris flows and the Tanglefoot Formation, a partly subaerial arkose. The Nordenskiold Dacite and Conglomerate Formation constitute about three-quarters of the Laberge Group and are direct products of one volcanic episode about midway through Laberge Group time.

Laberge Group strata reflect a balance between volcanism and sedimentation; between autoclastic and epiclastic deposition. The balance shifted in time and space so that facies varied rapidly. Although the detritus is exclusively volcanic the depositional setting ranged from sedimentary to volcanic dominated. Some rocks are detrital siliclastics, others are volcanic products laid down as unmodified extrusive products. A facies spectrum is envisaged from the Nordenskiold Dacite to the interbedded greywacke. The dacite represents proximal subaerial pyroclastic flows, the drab dacite is their marine equivalent and the greywacke was produced by marine reworking and sedimentary deposition of weathered dacite.

Faults which cut the Laberge Group have dominant post-depositional displacement, but some apparently also controlled depositional patterns. Within fault blocks stratigraphy is fairly constant, but units do not match well across some faults and facies changes may be localized near them. For examples the Laberge Group changes drastically across the Braeburn and Frank faults with different thicknesses and even different units on opposite sides. Some faults either formed during deposition and were reactivated in the Late Jurassic or they remained active.

The profound and rapid, possibly fault controlled, facies changes in the Laberge Group resemble those in the correlative Hazelton Group in northern British Columbia (Tipper and Richards, 1976). Rapid facies variation was not noted in Tulsequah and Atlin map areas; instead large areas are underlain by fairly consistent successions. If the difference is real Laberge Group depositional basins in northern British Columbia were larger than those in which coeval rocks to the north and south formed.

7.3.3AGE AND CORRELATION

Laberge Group strata are as fossiliferous as Lewes River Group beds (Figs. 17, 18). They contain ammonites and pelecypods of which the oldest are Hettangian, the youngest Bajocian and the commonest Pliensbachian and Toarcian. The Richthofen Formation is Hettangian to Pliensbachian, the Conglomerate Formation and Nordenskiold Dacite are Pliensbachian to Toarcian and the Tanglefoot Formation is Toarcian-Bajocian. Three radiometric age determinations of 187 ± 10, 200 ± 9 and 209 ± 9 Ma (Fig. 10) on minerals in Nordenskiold Dacite overlap almost within their error limits at 200 Ma. They indicate a Sinemurian age, roughly 10 Ma older than the fossil data suggest (using the time scale of Palmer, 1983).

Laberge Group strata are time and lithologic equivalents of the Hazelton Group in northern British Columbia. They correlate with the Ashcroft Formation of southern British Columbia.

7.3.4RICHTHOFEN FORMATION

7.3.4.1NAME, DISTRIBUTION, THICKNESS AND RELATIONS

The name Richthofen Formation is applied to the oldest unit of the Laberge Group, a dark brown shale beneath an extensive conglomerate and generally above Lewes River Group limestone (Fig. 19). Richthofen Island in southwest Lake Laberge is the source of the name; the reference locality for the unit is on the shore of Lake Laberge just west of the island. The Lake's east shore below the Hancock Hills also has good outcrops and the area between Fox Lake and Lake Laberge is a general outcrop area. The unit is missing in northwestern Laberge map area, but reappears in southeastern Carmacks map area in exposures just upstream of Five Finger Rapids on Yukon River. Other outcrops are near Teslin Crossing and 18 km southeast of Braeburn.

Along the west shore of Lake Laberge the Richthofen Formation attains an estimated thickness of 600 m (column 11, Fig. 17). Between Braeburn Mountain and Big Hill and on the lower reaches of Joe Creek the unit may be equally thick (columns 8, 9, Fig. 17). At Five Finger Rapids about 300 m are exposed (column 1, Fig. 17). About 200 m of the Richthofen Formation lie between the upper Lewes River carbonate and the Conglomerate Formation on Mount Laurier (column 14 of Fig. 17). East of the Hancock Hills the Richthofen Formation lies above the same carbonate and beneath Tanglefoot Formation arkose without intervening conglomerate (column 12 of Fig. 17). On Lake Laberge's west side (column 11 of Fig. 17) the Formation is overlain by the Conglomerate Formation. West of Fox Lake (column 8 of Fig. 17) the shale is overlain by Nordenskiold Dacite.

Along the east shore of central Lake Laberge the Richthofen Formation rests directly on the Hancock Member, the same relations as on Mount Laurier. Where exposed 7 km south-southeast of Ptarmigan Point, on the lake's east side, the contact is a sharp, steeply west dipping, planar boundary without interfingering or gradation and no evidence of slip. The relations are apparently conformable, but disconformity cannot be ruled out. Not enough of the contact is seen to know whether the Richthofen Formation truncates beds of the Aksala Formation regionally, in any case the underlying unit changes facies so rapidly that such changes would be difficult to attribute to an unconformity alone. Changes in the underlying unit may result from facies changes, truncation or both. The Richthofen Formation's interpreted relations are illustrated in Figures 20 and 21.

Fossil evidence and the nature of the rocks suggest that the Lewes River and Laberge Groups are conformable. The Aksala Formation ranges to the Late Norian and the Richthofen Formation probably is partly Hettangian. Only the Rhaetian, recognized in few places worldwide, is absent. The Richthofen Formation represents sudden deepening of the depositional environment following Aksala Formation time. Inundation resulted from dropping Whitehorse Trough as one, or as several, fault blocks. The Lewes River Group was suddenly inundated in the Earliest Jurassic and preserved under the Richthofen Formation.

7.3.4.2LITHOLOGY

The Richthofen Formation along western Lake Laberge is uniform dark brown to khaki-green, resistant, drab brown weathering shale and siltstone. It is thinly bedded and regularly and finely laminated with locally well developed ripple drift cross lamination. Small scale slumps are seen locally and may be more common than they seem. Beds are generally about 10 cm thick, but range to 3 m. Lamination, best seen where the rocks are weathered, is on the scale of a few millimetres. Silt laminae weather yellowish and are thinner than shale layers and are locally slightly calcareous.

Near Richthofen Island and Jackfish Bay on Lake Laberge, the rocks are commonly baked, but not hornfelsed and the rocks weather rusty. Hornfels forms narrow zones around satellitic plugs and dykes of the Carmacks volcanic suite.

Massive gritty "greywacke" is interbedded with the shale-siltstone, but conglomerate is rare. "Greywacke" beds are up to several metres thick, weather orangy brown, and are resistant. Some are pebbly with a few scattered, matrix supported volcanic clasts; normal grading is seen locally. Plagioclase, hornblende, volcanic rock fragments, biotite and quartz are the detrital constituents. The "greywacke" is interpreted as submarine Nordenskiold Dacite ash flow tongues in the Richthofen Formation. Ash flows are interlayered with the shale-siltstone in the canyon 4 km southeast of Braeburn Mountain.

A section of the Richthofen Formation just below the Conglomerate Formation at Five Finger Rapids is described by Bostock (1936, p. 22-23). About 90 m of thinbedded, dark shale are overlain by 150 m of medium bedded, buff arkosic sandstone. It is topped by 15 m of conglomerate and in turn overlain by 60 m of shale. Another 15 m buff sandstone above this shale probably represents the next overlying unit, the Conglomerate Formation.

7.3.4.3AGE AND CORRELATION

The Richthofen Formation ranges through the three lowest stages of the Lower Jurassic: it is largely late Sinemurian and early Pliensbachian, but includes Hettangian beds at least locally. It contains few fossils, but ammonites were collected near Five Finger Rapids (collections 3, 7 and 8, Appendix I, Fig. 18), south of Braeburn (collections 43, 44, 45 and 46) and near Teslin Crossing (collections 60 and 61). Most forms are assigned to the Sinemurian or Pliensbachian with preference for the latter (see Fig. 18). No fossils were found in the type area on either shore of Lake Laberge. Figure 18 summarizes the fossil ranges and Figures 20 and 21 show the interpreted rock unit-time line relations.

Lees (1934, p. 23) collected Psiloceras, a form restricted to the Hettangian, from sandstone and shale presumed to be in the Richthofen Formation because it is next to limestone mapped as the Hancock Member (his lot 10241, collection 203). The collection was reexamined by Frebold and Poulton (1977, p. 98) who concluded that the fossil was correctly identified by Lees and is indeed Hettangian. The location given by Frebold and Poulton differs from that of Lees: i.e. "four miles southeast of the southern end of Frank Lake, in sandstone west of contact with ls. belt". The latter is adopted here. Poulton stands by his identification of Lees' Hettangian collection and wrote "The Hettangian locality ....is probably also correctly dated." (written comm., 1984). That the Hettangian fossil is from the Richthofen Formation is inferred only from its age. Outcrop is insufficient to know to what unit the fossiliferous rocks belong, but the lithology is atypical of the Richthofen Formation. The locality is close to a Hancock Member limestone lens and if no fault intervenes, as postulated, it is stratigraphically close to the Norian.

The Nilkitkwa Formation of the Hazelton Group, a Pliensbachian and Toarcian shale and greywacke, is a rough time and lithologic equivalent of the Richthofen Formation (Tipper and Richards, 1976; p. 18-27). Richthofen beds also have equivalents in the Takwahoni Formation of Tulsequah map area. Some 600 m or more of shale-siltstone, the lower part of the Takwahoni (Souther, 1971) may be equivalent to the Richthofen Formation.

In Whitehorse map area the Laberge Group lacks a discrete shale at the base and instead conglomerate rests directly on the Lewes River Group (Wheeler, 1961). Wheeler's conglomerate in Whitehorse map area evidently ranges into the Sinemurian, time represented by the Richthofen Formation in southern Laberge map area.

In Northern British Columbia the Laberge Group is divided into two laterally equivalent units; a coarse clastic called the Takwahoni Formation and a shale-greywacke called the Inklin Formation (Souther, 1971; p. 23-28). Souther considered them proximal and distal equivalents juxtaposed across the King Salmon Thrust. The Richthofen Formation is a contemporary of, and resembles, the lowest 500 m or more of the Takwahoni Formation, but also correlates with the lower 300 m or so of the Inklin Formation. The succession of the Laberge Group between Lake Laberge and Fox Lake resembles the Inklin Formation closely.

7.3.5CONGLOMERATE FORMATION

7.3.5.1DISTRIBUTION AND NAME

Massive to extremely thick bedded conglomerate that is exposed discontinuously from the west shore of Lake Laberge to Mandanna Valley is here grouped in the Conglomerate Formation. The name is taken from the type area at Conglomerate Mountain just east of the Klondike Highway about km post 300, where the rocks form conspicuous outcrops (Fig. 6). Other large exposures occur between Long Lake and Miller Lake. The peak of Mount Laurier has good exposures.

7.3.5.2THICKNESS AND RELATIONS

The Conglomerate Formation's thickness is estimated from the map, because the rocks are massive or extremely thick bedded. Figure 17 shows stratigraphic successions, fossils and thicknesses for local areas; figures 20 and 21 are synthetic interpretations of this data. About 1200 m of section are present in the tight north trending Ptarmigan Syncline and about 800 m occur where the Surprise Syncline runs into Lake Laberge (column 11, Fig. 17). On Mistake Mountain 500 m are estimated and west of southern Coghlan Lake 1200 m are exposed in a steeply west dipping homocline (column 7, Fig. 17). Along the east side of Mandanna Valley 300 m are estimated and on its west side are two conglomerates: the lowest, about 600 m thick, thins to nothing near Cone Hill, and the highest thickens from 0 a few kilometres northwest of Cone Hill to 300 m farther north on southern Fairview Mountain, but thins rapidly still farther north on Tanglefoot Mountain (column 5, Fig. 17). In outcrops along Yukon River 1 km downstream from Eagle's Nest Bluff (Glenlyon map area) are about 200 m of conglomerate and at Five Finger Rapids in Carmacks map area is a similar thickness (column 1, Fig. 17).

Along Lake Laberge's west shore and on Surprise Mountain farther north the Conglomerate Formation rests on shale assigned to the Richthofen Formation. Critical outcrops were not seen, but the relationship is assumed to be conformable. No channelling in, or bevelling of, the shale was noted. At the southern end of the Surprise Syncline a second shale overlies the conglomerate. West of Coghlan Lake the conglomerate rests directly on Hancock Member limestone, without intervening shale. Further north on the west side of Mandanna valley between Cone Hill and Birch Mountain the conglomerate lies above red volcanics which resemble Nordenskiold Dacite, but which are included in the Lewes River Group because of their intercalated limestone.

East of Mandanna Valley on both limbs of Mandanna Syncline, the Conglomerate Formation rests below, and is intertongued with, the subaerial Nordenskiold Dacite. On the syncline's limbs and north of the Mandanna Fault the conglomerate rests on red sandstones included in the Aksala Formation's Mandanna Member. Relations are conformable and sharp, without channelling of the conglomerate into the greywackes.

On Yukon River just downstream from Eagle's Nest Bluff in the southwest corner of Glenlyon map area is a beautifully exposed section of the Conglomerate Formation. The base is not exposed, but the Conglomerate apparently rests directly on the stratigraphically highest limestone lens of the Hancock Member that forms the Eagle's Nest Bluff.

7.3.5.3LITHOLOGY

The Conglomerate Formation consists of a thick bedded to massive, boulder and pebble conglomerate. It weathers resistantly and forms large, dull coloured outcrops and locally weathers reddish. On clean surfaces the rocks are khaki green. Layering is generally lacking because no finer grained rocks are interbedded, but where greywacke occurs layering is clearly defined.

The conglomerate is generally clast supported; close packed, and has rounded boulders, cobbles and pebbles of volcanic, subvolcanic and plutonic rocks, which lie in a coarse sand to clay sized matrix of volcanic rock fragments, plagioclase, quartz and hornblende. Where the texture ranges to matrix supported the rocks are pebbly and bouldery sandstone in which a few pebbles and cobbles are scattered in a sand to clay sized matrix. Clasts are moderately well rounded, but their sphericity is generally low. Granitic clasts are generally the largest at any place, but occasionally limestone boulders fill this role. The largest boulders are a metre or more across, but in most places the largest clasts are 20 to 30 cm with 5 to 10 cm the general average. Grain size is distinctly bimodal between pebbles to boulders and coarse sand to clay sized material. Clasts are not imbricated and normal size-graded beds are rare. In places greywacke lenses are interbedded with the conglomerate. Such coarse grained, immature sandstones are exposed at Mistake Mountain, Coghlan Lake, Eagle's Nest Bluff and Five Finger Rapids.

The conglomerate is well indurated and breaks as readily across, as around clasts. Its cement is siliceous and locally calcareous. Clasts do not penetrate each other and are not fractured where they touch. In places the clasts break out of the rock preferentially so that the unit looks like modern alluvium. Clasts are fresh and generally not weathered, but on Conglomerate Mountain many boulders are coated with hematite, which may reflect subaerial weathering, possibly during deposition.

Depositional units in the conglomerate are generally many metres or tens of metres thick. Massive beds, as much as 20 m thick, are common along western Lake Laberge. In places one depositional unit of conglomerate is a hundred metres thick or more. The conglomerate is most massive where it occurs with Nordenskiold Dacite. Where sandstone lenses punctuate the sequence conglomerate beds are generally thinner; depositional units may each be a few metres thick.

Volcanic clasts generally predominate over the subvolcanic and plutonic types, but the proportions of the three range widely. On Conglomerate Mountain subvolcanic quartz-andesine porphyries with an aphanitic medium grey groundmass of intermediate composition dominate. Some are crowded porphyries, but most have about 40% phenocrysts. The porphyry resembles the subvolcanic fragments found as lapilli in the Nordenskiold Dacite.

In Conglomerate Formation outcrops near the west shore of Lake Laberge volcanic clasts are commonest. Most clasts are of dark green, chloritized and epidotized greenstone that approaches basaltic andesite. Some retain autoclastic fragmental textures, others have altered augite phenocrysts, but most are aphanitic. This detritus evidently derives from volcanics like the Povoas Formation.

Two types of plutonic clasts occur in the conglomerate. The commonest are massive, unfoliated mesocratic, medium grained, equigranular granodiorite. Euhedral dark hornblende, which makes up 20% or so, is the most prominent mineral, but anhedral plagioclase is most voluminous. Quartz occurs interstitially to about 15% of the volume. Some granodiorite is moderately well foliated and the fabric is a comparatively brittle protoclastic flaser.

Most minerals are fresh, but some hornblende is chloritized. Hornblende from one granodiorite boulder at Conglomerate Mountain gave a K/Ar age of 199 Ma (Tempelman-Kluit and Wanless, 1975).

The second kind of granitic clast in the conglomerate is coarse grained equigranular to porphyritic leucocratic granite with pink feldspar. It is volumetrically less important than the granodiorite. This rock is unfoliated and massive and consists of roughly equal proportions of quartz, K-feldspar and plagioclase with a few percent biotite.

The granodiorite clasts probably derive from intrusions immediately west of Laberge map area or from intrusions like them (Fig. 10). Aishihik Batholith is a granodiorite with radiometric ages of 144, 164, 190 and 268 Ma (Figs. 10, 12, 13) (Tempelman-Kluit and Wanless, 1975; Le Couteur and Tempelman-Kluit, 1976). All but one are younger than the Conglomerate Formation implying that the radiometric ages are not intrusive ages for the batholith (except perhaps the 268 Ma determination). They must represent thermal resetting of the granodiorite after intrusion and after Laberge Group deposition. The single 199 Ma determination on hornblende from granodiorite in a conglomerate clast overlaps with the paleontologic age of the Conglomerate Formation using the Palmer (1983) time scale. It reflects the time of granodiorite unroofing, not its intrusion and provides an independent check on the age of the Formation. The granodiorite is interpreted to have been intruded in the mid Triassic or before (230 Ma+), to have first become unroofed about the Sinemurian (ca 200 Ma), and to have been most recently raised in the Callovian (ca 165 Ma) (Fig. 13). The section headed Nordenskiold Dacite, Depositional Environment contains a discussion of the intrusive and uplift history. If the Aishihik Batholith is displaced from Whitehorse Trough along the Carmacks Fault system, as argued elsewhere, the granodiorite clasts may derive from intrusions lithologically like, and coeval with, Aishihik Batholith, but now northwest of Whitehorse Trough. Granite Batholith or Minto Pluton are possibilities.

The pink feldspar granite clasts in the conglomerate match Carmacks Batholith which is presumed to be their parent. Carmacks Batholith has given radiometric ages in the 160 to 165 Ma range (Callovian), apparently too young to make them a source for Pliensbachian conglomerate. This granite was intruded and unroofed by the Sinemurian and raised tectonically during the Callovian.

Limestone is locally important among the clasts. Even where they make up a tiny fraction of the volume they are prominent. They are volumetrically important near Surprise Mountain and the eastern end of Long Lake, where they comprise about a quarter of the conglomerate by volume. Generally such limestone clasts occur close to outcrops of the Hancock Member and that unit is presumed to be their parent. Some clasts contain corals, sponges or bivalve detritus as seen in the Hancock Member.

7.3.5.4DEPOSITIONAL ENVIRONMENT

Judging by grain size and immaturity the conglomerate was derived from local sources and transported short distances because source rocks for most clast types occur nearby. If the parents for the granitic clasts are identified correctly the source rocks now lie to the west. At farthest the granitic clasts may be transported 50 km, the distance from the west side of Aishihik Batholith to the Conglomerate Formation (Fig. 10). It is argued elsewhere that the Whitehorse Trough is detached and displaced from the granites; if so another pluton like Aishihik Batholith, now displaced should be sought as the source. Because the conglomerate lacks metamorphic clasts from west of Aishihik Batholith the detritus probably comes from the batholith's centre or east side.

Two modes of deposition are hypothesized for the conglomerates-alluvial fans and debris flows. Conglomerate such as that at Five Finger Rapids, that below Eagle's Nest Bluff and that on Mistake Mountain may each be alluvial fans. They have intercalated sandstone, which may be fluviatile and locally coarsen upwards, a characteristic of alluvial fans. By contrast the 1200 m of conglomerate along western Lake Laberge, that east of Coghlan Lake and that on either side of Mandanna Valley probably represent one or more superposed massive debris flows. This conglomerate contains alluvial fan debris, but lacks coarsening upwards sequences. The pebbles and boulders were presumably transported in streams to achieve their rounding, but the ash matrix and local matrix support indicate deposition from mass flows not streams. This conglomerate was evidently laid down as flows of alluvial material mixed with volcanic ash. It may represent one or more slumped alluvial fans. Alternatively it may be alluvial debris mobilized during volcanic ash eruption and incorporated with ash which flowed into the depositional basin. Because of the intercalated strata with marine fossils many conglomerates probably belong in the debris flow category.

Regionally the Conglomerate Formation occupies a broad zone directly east of the Nordenskiold Dacite (Fig. 20). Interfingering and lateral equivalence of the two implies parallel development. The dacite is interpreted as pyroclastic ash flows; the conglomerate as alluvial debris carried at the ash flow front. The coarse conglomerate detritus may have formed in alluvial fans built during volcanic lulls. These fans were removed with each Dacite ash eruption and carried into the basin as an armour of boulders ahead of the pyroclastic flows. They accumulated as thick piles dominated by epiclastic detritus, not by volcanic ejecta related to the Nordenskiold.

The Conglomerate Formation is followed southward beyond Whitehorse. It is traced from Upper Laberge to Robinson through Takhini and Mount Ingram (Wheeler, 1961). The area of preserved thick conglomerate is about 10 km wide and 220 km long. When deposited coarse clastics may have occupied a 30 km wide strip. The Conglomerate Formation perhaps formed as a series of northeast tapering, coalesced and superposed debris flow fronts. Most were probably built across the preserved trend of the Conglomerate Formation and away from the western source indicated by the granitic debris. Presumably the set of flows formed in front (northeast) of a chain of volcanic mountains. These mountains were probably separated from the Whitehorse Trough by a fault active during deposition.

7.3.5.5AGE AND CORRELATION

Few fossils have been recovered from the Conglomerate Formation, but the rocks are Lower Jurassic, mainly Pliensbachian. Localities 76 and 77 (Appendix I and Fig. 18), from upper and lower lenses of the unit east of Mandanna Valley, are Toarcian? and Lower Sinemurian respectively and may represent the maximum range of the unit. Fossils from the Richthofen Formation, below the conglomerate, are Sinemurian and Early Pliensbachian (e.g. collections 3, 7, 8, 60, 61) and those from the Tanglefoot Formation, above, are Toarcian to Bajocian (e.g. collections 1, 2, 4, 9, 62, 55). The Nordenskiold Dacite, which is considered the Conglomerate Formation's western equivalent, is Pliensbachian.

The K/Ar age of 199 Ma from a granodiorite boulder on Conglomerate Mountain (Sinemurian) (Fig. 10, columnn 6 of Fig. 17, Fig. 21) reflects the conglomerate's depositional age (± 10 Ma) and supports the fossils. Presumably the radiometric age is the granodiorite uplift age, not its intrusive age.

Evidence from Whitehorse map area corroborates a Pliensbachian assignment for the Conglomerate Formation. Lower Liassic fossils were found in the thick conglomerate at the base of the Laberge Group at one place and upper Liassic forms at several places immediately above the conglomerate (Wheeler, 1961, p. 51-53). The lower Liassic is roughly equivalent to the Hettangian and Sinemurian, and the upper Liassic represents Pliensbachian and Toarcian time.

The Conglomerate Formation has time equivalents in the Laberge Group of Tulsequah map area. The Inklin Formation there lacks a distinct conglomerate unit (Souther, 1971), but conglomerate is interbedded with the lower shale-siltstone. By contrast the Takwahoni Formation has up to 800 m of conglomerate in the lower part. Best evidence is that this conglomerate is Pliensbachian to Toarcian (Souther, 1971; p. 27-28). This makes the Conglomerate Formation a time and lithologic equivalent of the lower Takwahoni Formation and correlative with the lower Inklin Formation.

In the Hazelton Group of central British Columbia the Nilkitkwa Formation is the Conglomerate Formation's time equivalent, but the Telkwa Formation is lithologically closest. The Nilkitkwa is Pliensbachian, but lacks conglomerate while the Telkwa includes plenty of conglomerate (in the Sikanni clastic-volcanic Facies), but is Sinemurian. If the conglomerate of the Telkwa is the continuation of the Conglomerate Formation the facies is diachronous and youngs northward.

Chert pebble conglomerate in the lower Hazelton Group of central British Columbia (Tipper, 1959, p. 22-24) is roughly, if not precisely, time equivalent to the Conglomerate Formation. No chert detritus is known in the Conglomerate Formation and the origin or source of the two units must differ profoundly.

7.3.6NORDENSKIOLD DACITE

7.3.6.1NAME AND DISTRIBUTION

Cairnes (1910, p. 29) named and described the Nordenskiold Dacite. He recognized its stratigraphic position between the Braeburn Limestone (his name for the Lewes River Group) and the Laberge Group. Lees (1934, p. 18-20) and Bostock and Lees (1938, p. 16) followed this usage and retained the name recognizing "that the Nordenskiold Dacite and the Laberge conglomerate are of the same or nearly the same age." Tempelman-Kluit (1974, p. 50-51) incorrectly equated the Nordenskiold Dacite with volcanic rocks that are apparently younger than the Tantalus Formation and assigned a tentative Tertiary age. The Nordenskiold Dacite is a distinct unit gradational eastward with the Conglomerate Formation and conformably below the Tanglefoot Formation. The name is extended from the original usage and the unit is here given Formation status in the Laberge Group, partly because the rocks are the most voluminous in the Group.

Cairnes (1910) implied that the Nordenskiold Dacite represents volcanic flows, but Lees (1934, p. 18-19) recognized their fragmental nature and thought they might be crystal tuffs; he classified them as dacite breccia. The rocks are herein considered as pyroclastic ash flows extruded from volcanic centres some 40 km west of their depositional sites.

Cairnes' (1910) type area for the Nordenskiold Dacite is in northwest Laberge and adjacent Aishihik Lake map areas. In Laberge map area the unit occurs largely west of Lake Laberge, Coghlan Lake and Chain Lakes. The main outcrops are on both sides of Mandanna Valley, with the largest area between Mandanna and Chain valleys south of the Mandanna Fault (Fig. 6). Cairnes distinguished only one phase of the dacite and included the less obvious relatives in the Laberge Group. When these are included the dacite can be traced throughout western Laberge map area and southward into Whitehorse map area and beyond. The dacite is areally unimportant in southeastern Carmacks map area, but outcrops are seen on the hill north of the mouth of Tatchun Creek.

As used herein Nordenskiold Dacite includes two types separated on the map and considered to be marine and nonmarine lateral equivalents. One, a khaki green, massive, thick bedded "greywacke" is interpreted as marine pyroclastic ash flows; the other is a more colourful, thickbedded bomb and lapilli tuff, interpreted as the subaerial relatives. Nordenskiold Dacite of Cairnes (1910) and Lees (1934) encompasses the second type.

7.3.6.2THICKNESS AND RELATIONS

In its type area on both sides of Mandanna Valley the Nordenskiold Dacite is hundreds of metres thick. It rests on, beneath, and is intertongued with, the Conglomerate Formation. Figure 17 summarizes the local stratigraphic columns and figures 20 and 21 are interpreted syntheses of this data. West of Mandanna Valley the dacite rests above the conglomerate, but a tongue also extends into it. On the flanks of Mandanna Syncline 600 m of section are estimated, mostly above the Conglomerate Formation; the top of the dacite is not seen (columnn 4, Fig. 17). West of the Fairview Fault are about 1300 m of dacite with conglomerate above and in the middle (column 5, Fig. 17). In this fault panel the conglomerates above and below the dacite thin southward, so that on Cone Hill, at the panel's south end, the Nordenskiold Dacite rests directly on reddish volcanics included in the Lewes River Group and below arkose of the Tanglefoot Formation. The laterally gradational relations between the dacite and conglomerate can be seen in outcrops and on the map scale and is well displayed on the northern limb of Mandanna Syncline (e.g. where a sample for K/Ar dating gave the age of 187 Ma). Lees (1934, p. 19) described the lateral and upward gradation between the conglomerate and the dacite in some detail. Bostock and Lees (1938, p. 16) concluded that the "relations apparently indicate that the Nordenskiold Dacite and the Laberge conglomerate are of the same or nearly the same age."

On Conglomerate Mountain the dacite is only 100 m thick and lies above Conglomerate Formation and below Tanglefoot Formation arkose (columnn 6, Fig. 17).

The marine dacite unit occupies a broad area around Fox Lake. It is a thick unit with variable amounts of interbedded epiclastic rocks. The boundary between marine and nonmarine Dacite is near Braeburn. Between Braeburn and Corduroy mountains 1500 m of the marine Nordenskiold Dacite are estimated, but the top and bottom are not seen (columnn 8, Fig. 17).

The Frank Fault marks the boundary between the northwestern terrestrial and the southeastern subaqueous Nordenskiold Dacite. Gradation is lacking and the fault either controlled deposition or telescoped facies later. In northwest Laberge map area the subaerial Dacite may interfinger with the waterlain equivalents, but relations are obscured under younger cover. The Chain Fault, interpreted as a post-Dacite strike-slip, also bounds the colourful dacite. Northeast of the fault, in Carmacks map area, are marine dacite flows; on the opposite side in Laberge map area are its landward equivalents. Broadly the subaerial dacite occurs where the underlying Aksala Formation is also represented by thick terrestrial rocks, the Mandanna Member: the marine facies may coincide with marine parts of the Aksala Formation, the Casca and Hancock members. The subaerial depositional conditions for Nordenskiold Dacite were apparently inherited from the Late Triassic.

7.3.6.3LITHOLOGY

7.3.6.3.1SUBAERIAL DACITE

The colourful Nordenskiold Dacite of northern outcrops, thought to have formed as subaerial pyroclastic flows, is resistant, massive and fairly homogeneous. Although the weathering colour is reddish brown, fresh surfaces range from mauve or lavender to reddish, pink, bottle green and bluish green. This colour variation inhibited correlation from place to place. Bostock and Lees (1938), for example, mapped some of these rocks as Hutshi Group. Mauve dacite is common along Mandanna Creek, bottle green varieties are prominent southwest of Twin Lakes, reddish types are commonest on Conglomerate Mountain.

Although colour varies the texture is uniform; the rocks are breccias and tuffs with lapilli and bombs of feldspar porphyry in a granular matrix of equal parts of coarse to fine ash and prominent, broken feldspar and quartz crystals. The feldspar is mostly fresh, zoned, simply twinned andesine, but composition varies and there may be several populations as noted by Lees (1934, p. 18). Broken sanidine crystals are a minor matrix constituent. Quartz crystals (roughly 20%) are generally equant and broken and their margins are resorbed. Hornblende and less commonly biotite grains make up to 7% of the volume of the matrix. The matrix of the crystals is an extremely fine grained ash of quartzofeldspathic minerals without texture. The coarse ash sized crystals and the minerals of the lapilli and bombs are generally fresh, but the interstitial fine ash is altered and represented by mixed clays and chlorite. Age determinations on detrital hornblende and biotite lack evidence of postdepositional argon loss, a further clue to the rock's freshness.

Bombs and lapilli are generally angular feldspar porphyry clasts. Some are tuff like the matrix, but others are of a subvolcanic phase compositionally like the breccias, but lacking fragmental texture. Porphyry clasts generally resemble the crystal-ash matrix closely so that the fragmental texture is obscure. Where the fragmental texture is obvious, lapilli and bombs make up fully half of the rock's volume. Clasts are invariably matrix supported.

The dacite is massive on the largest scale and depositional units are commonly 50 m thick or more. The direction in which individual units thicken, a possible clue to source, is unknown. Faint layering, defined by variation in lapilli concentrations or by weak gradation in grain size occurs locally and a few units are normally graded. The dacite lacks flattened shards and most other features expected in welded tuffs. Nevertheless they are extremely well indurated, much better than the enclosing sedimentary strata. This may indicate that the material was warm when laid down.

7.3.6.3.2SUBMARINE DACITE

The khaki green dacite of southern outcrops, which is interpreted as the submarine Nordenskiold Dacite, differs from its subaerial equivalent mainly in colour. It weathers dull reddish brown, like the colour of weathered mafic volcanics. The minerals, fabrics, textures and bed thickness are close to those of the colourful dacite. Depositional units or beds as much as 20 m thick are common and some approach 50 m. No bed was traced far enough to determine its thinning direction, but units in western exposures (i.e. near the edge of the Miners Range) are generally thicker than those farther east (i.e. on the northeast side of Fox Lake). Beds generally lack structures. In places lapilli are concentrated in crudely planar layers, presumably bedding, but most clasts are scattered and all are supported by the matrix. Lapilli are locally size graded and the grading is normal (i.e. finer grained upward).

As in the colourful dacite the rocks are homogeneous and the texture fragmental. The dominant grain size is coarse ash (0.3-0.8 mm), but the matrix is of fine ash and lapilli of volcanic rock fragments to several centimetres are scattered throughout. Most fragments are broken crystals, but angular lapilli of fine grained flow or subvolcanic rocks locally constitute 20% of the rock. Andesine, the commonest mineral of the coarse ash, makes up about half the rock's volume. As in the colourful dacite plagioclase differs widely in composition (albite to labradorite). Quartz, the other voluminous mineral in the coarse ash, makes up about a quarter of the volume. Hornblende, the common mafic mineral (about 10%), is generally fresh or marginally chloritized. Potash feldspar is common, but makes up only 10% by volume. Biotite, augite, apatite and opaque minerals are accessories. Altered extremely fine grained quartzofeldspathic material with chlorite constitutes the groundmass. Next to the outcrop relations and distribution the most compelling evidence of a volcanic origin may be the mineralogy and freshness. The mineralogy is that of an andesite, the texture that of tuff and the freshness of the mafics is incompatible with sedimentary deposition.

Whether the subaqueous flows were warm enough to be welded is unknown, but the massive submarine dacite sheets are better indurated than the epiclastic rocks interbedded with them. This suggests that detritus was warm enough to promote lithification and that submarine welding may have occurred locally.

In a canyon three km southeast of Braeburn Mountain shales a few metres thick, are interbedded with 10 m thick massive greywacke-looking volcaniclastics. Five volcaniclastic-shale "cycles" are exposed. Shales are thinly laminated and have common cross lamination and many fine horizontal grazing trails on bed surfaces. They resemble Richthofen Formation shales and have sandstone interbeds a few tens of centimetres thick. The massive volcaniclastics in the shale lack argillaceous partings or interbeds. Ammonite fragments were found in the shale and plant impressions were recovered from the tops of the thick massive volcaniclastics. The volcaniclastics are interpreted as individual Nordenskiold Dacite ash sheets which flowed into a marine basin where shale was being deposited. Plant detritus was carried in with the ash flow.

A peculiar punky and pockmarked, massive volcaniclastic is in interbedded with the massive dacite in many outcrops broadly near Braeburn. Good outcrops are around Bunker Hill and 3 km northeast of Braeburn. It forms the same structureless, thick beds as the drab dacite, but is lighter coloured, less resistant and less indurated. Its mineral constituents are the same as those in the darker massive beds and the distribution of lapilli is similar, but the minerals are more altered and lapilli edges are fuzzy. Lapilli are commonly khaki coloured and darker than the buff coloured matrix. This pockmarked rock is interpreted as a less lithified, hence more diagenetically altered, counterpart of the khaki beds.

Medium to thin bedded, planar bedded greywacke and shale are interbedded with the massive units. Though generally subordinate to the massive beds they make up a quarter of the section locally. In these rocks the concentration of quartz is higher, that of plagioclase lower, and mafic minerals are rare and chloritized. Grain size averages about 0.3 mm. Matrix supported pebbles are absent. This greywacke is the epiclastic cousin of the massive dacite debris flows. The punky, pockmarked units may be transitional between them.

7.3.6.4AGE AND CORRELATION

Fossils were found in shale interbedded with the subaqueous Nordenskiold Dacite and in shale between conglomerate beds above and below the subaerial units. These, the relations with other units and the radiometric age determinations show that the rocks are Pliensbachian and Toarcian. Locally they range downward into the Sinemurian and up into the Aalenian. Fossils from conglomerate below the subaerial dacite include collections 19, and 77 (Appendix I, Fig. 18). Collection 76 is from conglomerate intertongued with terrestrial dacite. They (19, 76, 77) show that the subaerial dacite is Pliensbachian and Toarcian (Figs. 20, 21). Collections 43, 44, 45 and 46 from shales below the marine dacite sheets are Sinemurian; those from a punky greywacke low in the dacite (collection 50) are lower Pliensbachian and ammonites from shale in the top of the marine dacite (collections 47 and 48) are late Pliensbachian or early Toarcian. Collection 50 from well above the dacite sheets is lower Bajocian. Thus the marine and subaerial dacite sheets are Pliensbachian and Toarcian. K/Ar age determinations on hornblende in the dacite from three localities are 187, 200 and 209 Ma (Figs. 10, 17, 20, 21) and overlap within their error limits at about 200 Ma (Sinemurian), about 5 Ma older than expected from the fossil data using Palmer's (1983) time scale (Figs. 17, 20, 21).

The marine Nordenskiold Dacite probably continues in Wheeler's (1962) Western Belt outcrops of Whitehorse map area. Cockfield and Bell (1926, p. 18-19) noted that tuffs are extensive in part of Whitehorse map area. Wheeler (1961, p. 54) gives a section for the area north of Takhini River in which 300-500 m of conglomerate are overlain by more than 1500 m of "massive..... greywacke; possibly crystal tuff." On Mount Landsdowne (p. 58) he gives a section in which 200 m of conglomerate are covered by about 400 m of coarse grit...and gritty quartz bearing greywacke with faint traces of bedding. These last are interpreted as marine Nordenskiold Dacite equivalents. Northeast of Takhini Hotsprings Wheeler (1961, p. 69) noted "thick beds of grit containing angular quartz, euhedral, slightly altered plagioclase, hornblende, and about 40% matrix material. Rock fragments are absent and they may be crystal tuffs." This grit is similarly considered as marine Nordenskiold Dacite.

In summary much of the Laberge Group of western Laberge map area and on trend contains drab coloured massive "greywackes" in thick structureless beds. Their mafic minerals and feldspars are fresh and they lack internal layering, crossbedding, bottom structures and other normal sedimentary features. They are not epiclastic greywackes, but subaqueous pyroclastic flows fed by eruptions of volcanic ash and deposited in the Laberge basin.

The subaerial Nordenskiold Dacite resembles the "Toodoggone Volcanics" of northern British Columbia (Panteleyev, 1983). Specific equivalents are Panteleyev's units 3, 4 and 6. Andesite flows, which occur in the Toodoggone are unknown in the Nordenskiold Dacite. The "Toodoggone Volcanics" are dated isotopically as between 200 and 180 Ma (Gabrielse et al., 1980), the same span seen in the three Nordenskiold ages. The "Toodoggone Volcanics" are a part of the Hazelton Group.

In north-central British Columbia the Nilkitkwa and Telkwa formations are Nordenskiold Dacite time equivalents (Tipper and Richards, 1976). The Telkwa in particular has subaerial volcanics that closely resemble the Nordenskiold Dacite. The Red Tuff at the top of the Nilkitkwa is a Toarcian subareal volcanic unit, possibly a younger, more mafic counterpart of the Nordenskiold Dacite.

Time equivalents of the Nordenskiold Dacite near Tulsequah are the Inklin and Takwahoni formations. The massive, "coarse-grained greywackes, which form thick structureless beds" in the upper Inklin (Souther, 1971, p. 24) may be lithologic equivalents of the marine Nordenskiold Dacite and some of the massive, 10 m thick, unstratified greywackes noted by Souther (p. 26) in the Takwahoni may also be marine Nordenskiold counterparts.

Aishihik Batholith granodiorite resembles that of the Topley intrusions of central British Columbia and has roughly the same radiometric age (Carter, 1982; p. 43). The Topley intrusions are Late Triassic to Early Jurassic (173 to 206 Ma) quartz diorite to quartz monzonite, possibly subvolcanic to the Telkwa volcanics. The Carmacks and Long Lake batholiths are about the same age as some of the Omineca intrusions of central British Columbia (Carter, 1982; p. 44), but differ lithologically. Those are quartz diorite and quartz monzonite, which give ages of 189 to 121 Ma.

7.3.6.5DEPOSITIONAL ENVIRONMENT

Nordenskiold Dacite debris is entirely volcanic and was deposited as subaerial and subaqueous pyroclastic mass flows with little sedimentary reworking. Judging from the thickness of marine dacite (1500 m or less) and from that of individual flows (10-50 m) the entire sequence represents in the order of 30 pyroclastic flows and therefore may have been produced in that number of extrusive pulses. The flows were deposited catastrophically and volcanic debris flooded the environment. Insufficient time passed between events to allow significant reworking. The thick bedded, punky, pockmarked "greywacke", interbedded with the dacite, represents poorly lithified pyroclastic flows. They may have been cooler than the others when laid down.

Centres of Nordenskiold Dacite volcanism presumably lay west of the Nordenskiold Dacite; possible eastern sources such as Tatchun Batholith are far away. The granitic rocks of the

Aishihik, Carmacks and Long Lake batholiths have given ages which overlap broadly with those from Nordenskiold Dacite (Fig. 13). If they are the plutonic root the source lay 40 km to the west (Fig. 10). Elsewhere it is argued that the granitic rocks of Aishihik, Carmacks and Long Lake batholiths are structurally detached from Whitehorse Trough and displaced, perhaps far. If so coeval, similar plutons far to the southeast are suspected as the Nordenskiold's root and local intrusions are not related.

Smith (1979) has related Tertiary volcanic ash flows and plutonism in a synthesis of ash-flow magmatism. His ideas and data relate ash volumes to the size of the parent magma body, to the life and periodicity of the volcanic system and to pluton and ash composition. They permit comparisons of the Nordenskiold Dacite with other ash flow systems.

The subaerial Nordenskiold Dacite covers about 500 km^2; if its average thickness is 1/2 km its volume is 250 cubic km. The submarine Nordenskiold Dacite underlies a 15 km wide, 65 km long strip, roughly 1000 km^2. The average ash flow thickness is between half and one kilometre, so that the volume of subaqueously deposited ash is two to four times that of the terrestrial. Total Pleinsbachian ash in Laberge map area may approach 1000 cubic km. That in Whitehorse and other areas is difficult to gauge, but if the same volume of ash is assumed in two adjacent map areas 3000 cubic km may be present.

The total volume compares with that in the largest eruptive systems known, those of Yellowstone and San Juan mountains eruptions in Colorado, which ejected about 1000 cubic km. If the total ash erupted from the Carmacks Batholith includes the subaerial and submarine ash in Laberge map area it is possible to predict the area of the magma chamber. A pluton about 1000 square km across is predicted; Carmacks Batholith occupies about 1200 square km.

Ash volumes also give clues to the life and periodicity of stratovolcanoes. Smith's (1979, Fig. 12) empirical model predicts one to two million years to generate a 1000 cubic km ash system. For a 3000 cubic km system his model predicts 5 to 10 Ma. Such a system's period would be roughly 100,000 years according to his hypothetical model. Some twenty eruptions (2 Ma divided by 100 Ma) are therefore expected from a system of this size. The predicted life span matches the paleontologic evidence broadly; the entire Nordenskiold episode is apparently restricted to the Pliensbachian. Its duration on the Palmer (1983) time scale is 5 Ma. The periodicity prediction of twenty eruptions compares with the estimate of thirty ash flows based on field data for the marine Nordenskiold.

7.3.7TANGLEFOOT FORMATION

7.3.7.1NAME AND DISTRIBUTION

Distinctive yellowish, orangy and buff weathering, medium bedded arkosic sandstone at the top of the Laberge Group is here called the Tanglefoot Formation after the mountain in northwest Laberge map area. The unit was recognized, but not named in earlier studies. Cairnes (1910, p. 34) described these rocks from east of Nordenskiold Valley as soft, friable, coarse grained and prevailingly white and light yellow with interbedded black shale "which lends the unit a finely striped appearance". Bostock and Lees (1938, p. 13) based their "upper member of sandstone and argillite" on these rocks and noted that yellow grit is the diagnostic rock type. In Whitehorse map area Wheeler (1961, p. 56) described probable equivalents as 300 m of "yellow and brown-weathering quartzose sandstone, quartz-pebble conglomerate, and greywacke" at the top of the Ibex River section and the "quartz-bearing greywacke" at the top of the Mount Landsdowne succession.

Strata assigned to the Tanglefoot Formation occur mainly in northwestern Laberge map area and in southeastern Carmacks map area. They are well developed north of Twin Lakes (their type area), east of Coghlan Lake and on Anticline Mountain. They cover much of the triangle between Miller Lake, Long Lake and Teslin Crossing (Figs. 6, 10).

7.3.7.2THICKNESS AND RELATIONS

West of the Fairview fault, Tanglefoot beds, estimated to be 700 m thick, rest on the Conglomerate Formation (column 5, Fig. 17). They lie directly on subaerial facies of the Nordenskiold Dacite at Cone Hill. Younger beds are not seen. On Conglomerate Mountain 300 m of Tanglefoot beds lie above 100 m of Nordenskiold Dacite and below 200 m of the lower Tantalus Formation (column 6, Fig. 17). Southwest of the Braeburn Fault the Tanglefoot also rests on the Nordenskiold Dacite (column 9, Fig. 17). East of Coghlan Lake (column 7, Fig. 17) 600 m of Tanglefoot strata lie above the thin Conglomerate Formation. On Anticline Mountain (column 8, Fig. 17) only about 200 m of the Tanglefoot are preserved above the marine Nordenskiold.

In Carmacks map area at Raabe's Hills and south of Yukon River the Tanglefoot is well developed and 800 m are estimated above the Conglomerate Formation and above thin marine Nordenskiold Dacite (column 1, Fig. 17). Bostock (1936, p. 24-25) gives good descriptions. Strata above the Five Finger Rapid conglomerate, a total of some 1500 m as estimated in his composite section, are probably Tanglefoot Formation beds. Some of the units Bostock adds in his section are considered to be lateral variants not superposed beds: hence the discrepancy between his thickness estimate and that given here.

The interpreted regional relations of the Tanglefoot Formation are shown diagrammatically in Figs. 17, 20 and 21. At most places the Tanglefoot is interbedded with the underlying rocks so that the contact is gradational. Relations are particularly well displayed on Anticline Mountain where the Nordenskiold and Tanglefoot are interbedded over tens of metres. Around Long Lake Tanglefoot beds similarly grade downward into the Conglomerate Formation. The lower contact of the Tanglefoot Formation is arbitrary and is drawn where light coloured beds predominate in the section. No hiatus or erosional interval preceded Tanglefoot deposition.

Relations at the top of the Tanglefoot Formation are conformable where seen, but because the overlying Tantalus Formation is most likely Upper Jurassic and/or Lower Cretaceous the contact probably represents a depositional hiatus. Conformable relations are seen along the southwest flank of Conglomerate Mountain, and just west of the west central edge of Laberge map area. At the contact an abrupt change in sandstone detritus signals the transition. Beds below are yellowish weathering arkose without chert, those above are slightly lighter coloured quartz and chert bearing gritty sandstone with little feldspar.

Bostock (1936, p. 28) postulated conformable relations in southeastern Carmacks area and Wheeler (1961, p. 74) considered that relations are the same in Whitehorse map area.

7.3.7.3LITHOLOGY

Tanglefoot strata are coarse, gritty, well bedded sandstones, which weather a range of light and buff colours. The weathering colour and bedding character distinguishes the unit from others of the Laberge Group. Brown shale and thin pebble conglomerates are interbedded. Brown shales predominate in the top of the sequence, but sandstone is generally most important. The sandstone approaches arkose and contains feldspar, quartz and rock fragments, in varied proportions. Grains are fresh and generally medium to coarse sand sized (0.3-0.6 mm); scattered granules locally lend the rocks a gritty aspect. The quartz is grey and the feldspar pale pink or white, K-feldspar predominates over plagioclase.

The rocks are poorly indurated by comparison to the lower Laberge Group and they weather more recessively. Thin coal seams occur particularly in the upper part and plant leaf impressions are common. Beds are regular and are half metre to 2 or 3 m thick. Some are cross laminated and have sole markings.

Pebbly beds in the Tanglefoot Formation contain the same type of clasts as are found in lower units: hornblende granodiorite, granite, feldspar porphyries and greenstone. Granitic clasts predominate over volcanic clasts, the opposite of the Conglomerate Formation. Most granitic clasts are hornblende granodiorite. Pebbles are better rounded and smaller (5 cm) than those of the Conglomerate Formation and they are clast supported.

7.3.7.4AGE AND CORRELATION

Tanglefoot strata contain enough fossils to show that the formation ranges through the Toarcian, Aalenian and at least into the middle Bajocian (Figs. 17, 18, 20, 21). Collections 9, 23 and 55 (Appendix I, Fig. 18) contain long ranging Middle Jurassic fossils. Fossil lots with short ranging forms are the Toarcian-Aalenian collection 76, the Aalenian collections 55A and 71 and the lower Bajocian collection 50. The youngest fossil lot with short ranging forms, collection 1, is middle Bajocian. Middle Bajocian fossils were also discovered in Aishihik Lake map area near the top of the Laberge Group in strata correlated with the Tanglefoot. The locality is just west of the west central edge of Laberge map area (Tempelman-Kluit, 1974, p. 96-97). The youngest fossils from the Laberge Group in Whitehorse map area are Late Lower or Early Middle Jurassic (collections 50 and 51 of Wheeler 1961, p. 53).

The oldest fossils from the Tantalus Formation above the Tanglefoot are long ranging forms that do not constrain the age assignment. As some fossils are from high in the Tanglefoot Formation and as there is no lithologic change in the unit above the fossil bearing strata the Tanglefoot Formation probably does not range above the Bajocian. The youngest short ranging fossils from strata certainly below the Tanglefoot Formation are in collections 47 and 48, both late Pliensbachian.

Tanglefoot strata resemble the coeval (Toarcian and Bajocian) Smithers Formation of the Hazelton Group of Tipper and Richards (1976), which also contains feldspathic sandstone. They are also correlatives of, and contain arkose like, the "Middle Jurassic Unit" of Tipper (1959, p. 24-26). Arkose makes up part of the Takwahoni Formation in the Tulsequah area, but its general stratigraphic position in the unit is not specified by Souther (1971, p. 25-27). Like the Tanglefoot, the Takwahoni Formation contains fossils as young as Middle Bajocian, but it is not clear whether these were found in the arkose.

7.3.7.5ORIGIN AND DEPOSITIONAL ENVIRONMENT

Tanglefoot strata accumulated as fluviatile or deltaic beds on a narrow shelf at the east edge of the Lewes River volcanic arc. They reflect a quieter environment than that prevailing while the Nordenskiold Dacite and Conglomerate Formation were laid down. Deposition was under subaerial to shallow marine conditions as indicated by plant debris, coal seams, local anhydrite crystals in the sandstone (Tempelman-Kluit, 1974, p. 35) and massive, thick shelled pelecypods. Although the source for the streams carrying the debris continued to be the western upland the source was evidently lower with respect to Whitehorse Trough than it was early in the Jurassic. Volcanism and the direct contribution of volcanic detritus had ceased. By the beginning of Tanglefoot time (early Toarcian) the volcanics had been largely eroded so that Tanglefoot Formation detritus represents material from the subvolcanic or plutonic root of the arc. Quartz and feldspar may derive from the Carmacks Batholith, a granite that weathers readily to grus only less mature than the arkose. If the Carmacks Batholith is displaced far with respect to Whitehorse Trough, as argued elsewhere, the Tanglefoot arkose may derive from plutons like the Carmacks, which occur in the Intermontane Belt to the south in British Columbia.

The Tanglefoot Formation covers older detritus of the volcanic arc dumped in Whitehorse Trough. It shows that although volcanism had ceased the depositional basin continued to subside relative to the arc. Whitehorse Trough ceased receiving detritus about the middle Bajocian, the end of Tanglefoot time. Presumably differential vertical movement between the trough and the adjacent volcanic arc also ceased at this time and the trough and volcanic arc ceased as entities.

7.3.8TESLIN CROSSING PORPHYRIES

7.3.8.1DISTRIBUTION AND RELATIONS

Feldspar porphyry dykes, sills and plugs invade Laberge Group strata along the northeast side of Whitehorse Trough. They are commonest between Hootalinqua and Teslin Crossing. The largest body, Teslin Crossing Stock, which is named informally here, is 6 km wide and 11 km long (Fig. 10). Many dykes occur north and south of the stock. Lees (1934, p. 30-32) grouped the porphyries in the Klusha Group, a unit named by Cairnes (1910, p. 43-44) in the Nordenskiold District. The Klusha intrusives of Cairnes, in northwestern Laberge and adjacent Aishihik Lake map areas, include two unrelated types: the Middle Jurassic porphyries, and the subvolcanic intrusives related to the Late Cretaceous Carmacks Group. As used here the Teslin Crossing Porphyries are intended to include only the Middle Jurassic porphyries.

Beside the occurrences near Teslin Crossing Middle Jurassic porphyries are found on Fairview, Green, Tanglefoot and, appropriately, Porphyry Mountain in northwest Laberge map area. Bostock and Lees (1938) mapped these as Hutshi Group.

Most porphyry dykes are a few metres across, but some are thicker; those a few kilometres northwest of Mason Landing reach widths near a kilometre. Many dykes are too small to map, and the small bodies generally occur near larger ones. The porphyries intrude Tanglefoot Formation strata exclusively and conform with bedding in the host. Whether they are sills injected during deposition and disturbed with their host is unknown. Teslin

Crossing Stock lacks a recognized metamorphic halo and intrusive relations are not exposed around it, but the outcrop pattern suggests a steep walled pipe or plug.

7.3.8.2LITHOLOGY

The Teslin Crossing porphyries are quartz undersaturated monzonite or syenite. Teslin Crossing Stock is an inhomogeneous syenite to monzonite with a range of porphyries and related fine grained rocks, which may be subvolcanic. Pink, medium to fine grained, equigranular, fresh leucosyenite to monzonite is commonest. The rock is moderately resistant and weathers to undistinctive greyish colours. Anhedral K-feldspar with albite-andesine and minor quartz are the main minerals. Augite and biotite, the common mafics, make up only 5% by volume. Hornblende occurs sparingly. Biotite feldspar porphyry, which occurs as dykes in the syenite, contains 5 mm thick K-feldspar tablets and fresh, anhedral biotite in an aphanitic quartzofeldspathic groundmass. Crowded hornblende porphyry occurs commonly on the stock's south side. It has euhedral andesine, hornblende and biotite phenocrysts several millimetres across in a microgranitic matrix.

Dyke rocks are light grey to light green and range from crowded hypabyssal porphyry to more normal varieties. Hornblende feldspar porphyry and less commonly quartz feldspar porphyry are the main types. The composition is probably andesitic. Euhedral andesine tablets, several millimetres across, make up more than half the volume locally. They are commonly oriented parallel to dyke walls and this gives the rocks a trachytoid texture and slabby habit. Acicular dark green hornblende is prominent, but less important than the feldspar. Quartz occurs as euhedral stubby phenocrysts that make up 10% by volume locally, but many of the rocks lack this mineral.

7.3.8.3AGE AND CORRELATION

Four radiometric age determinations show that the Teslin Crossing porphyries are Middle Jurassic. They are barely younger than their enclosing rocks, and they evidently cooled during, or shortly after deposition of the Tanglefoot Formation. Hornblendes in samples of the three main rock types in the Teslin Crossing Stock gave ages of 173 Ma, 181 Ma and 186 Ma by the K/Ar method (Fig. 10). Within their error limits the dates overlap at 180 Ma (Middle Bajocian), the same as the age of the youngest fossils from the Tanglefoot Formation. The dates reflect the intrusive age of the rocks and show that the stock cooled quickly after intrusion. Whether the stock invaded the Laberge Group during or after deformation is unknown, but considering its probable form as a steep walled plug it was likely intruded after. No geological significance is seen for the range in the three ages.

Feldspar porphyry from the wide dyke 20 km north of the Teslin Crossing Stock gave 164 Ma by the K/Ar method (Fig. 10). The dyke is probably younger than the stock.

The Teslin Crossing porphyries are about the same age as, and may be genetically related to, the volcanic rocks at the base of the Tantalus Formation. Those flows may be Middle Jurassic.

Teslin Crossing Stock overlaps in time with, but is lithologically unlike, the Topley intrusions. "Topley intrusions of Late Triassic to Early Jurassic age (173 to 206 m.y.) are ....a northeast-trending belt of stocks and small batholiths....(of) quartz diorite to quartz monzonite." (Carter, 1982; p. 43). The Teslin Crossing porphyries may lack direct southern equivalents.

8.OVERLAP ASSEMBLAGES

Several rock units occupy two or more of the four main elements into which the project area is divided. They are considered overlap units deposited while, or after, the four elements were juxtaposed. The oldest of these, the Early Cretaceous Tantalus Formation, is thought to have been deposited in local pull-aparts along strike-slips in Whitehorse Trough; in some of these basins it abuts Teslin Suture Zone and Whitehorse Trough. The mid-Cretaceous Mount Nansen Group, the related Casino Granodiorite and the probably coeval Coffee Creek Granite, emplaced across parts of Whitehorse Trough and Yukon Crystalline Terrane, signal that these elements were juxtaposed about 110 Ma ago. The Carmacks Group, deposited across the same two elements about 70 Ma ago confirms this. The Late Cretaceous Open Creek Volcanics rests on Yukon Cataclastic Terrane and Whitehorse Trough showing that they were together by the Late Cretaceous. The two youngest units treated as overlap units, the Pliocene Walsh Creek and the Pleistocene Selkirk Volcanics, only rest on Yukon Crystalline Terrane. They are treated here because they are late in the depositional history of the area.

8.1TANTALUS FORMATION

8.1.1NAME AND DISTRIBUTION

Cairnes (1910, p. 35) named the "Tantalus Conglomerates" and designated Tantalus Butte as their type area. Lees (1934, p. 23) continued this usage, but Bostock (1936, p. 27-28) changed the name to Tantalus Formation and considered it separate from the Laberge Group. This usage is continued.

Unlike the Laberge Group the Tantalus Formation occurs in disconnected small erosional outliers ranged generally along the southwest and northeast sides of Whitehorse Trough (Figs. 10, 22). The largest outlier, near Carmacks, includes the type area. A second occupies Corduroy Mountain at the west central edge of Laberge map area. Two others nearby are just west of Laberge map area. A third outcrop block on Conglomerate Mountain contains only the lower Tantalus Formation. Northeastern outcrops, restricted to the Tatchun Belt, include the northernmost Tantalus Formation 5 km southwest of Minto in central Carmacks map area and four outliers in Laberge map area. One is on Claire Creek, a second along Yukon River, the third just southeast of Hootalinqua and the last near Mason Landing.

8.1.2THICKNESS AND RELATIONS

Where relations are exposed in the southwestern outliers the Tantalus Formation beds are parallel to those of the Tanglefoot Formation. The contact is probably disconformable or paraconformable because Middle and/or Upper Jurassic beds may be absent. On Tantalus Butte are about 300 m of Tantalus beds and the same thickness is estimated south of Carmacks. At Corduroy Mountain is a steeply northeast dipping, fault bounded homocline with 1100 m of Tantalus Formation conglomerate. On Conglomerate Mountain 200 m are estimated conformably above Tanglefoot beds. West of the Braeburn Fault is a similar thickness of these lower Tantalus beds, bounded on both sides by northward trending faults.

At Minto the Tantalus Formation is exposed in a few scattered outcrops whose relations are unknown. Probably the unit lies between faults within the Tatchun belt like the Claire Creek occurrence where about 200 m stand upright in a fault slice. Near Cassiar Bar on Yukon River the Tantalus presumably lies unconformably on dark green volcanic and volcaniclastic rocks correlated with the Povoas Formation. The contact is not exposed, but the beds form a moderately northeast dipping homocline, about 150 m thick and the volcanics occur underneath. Southeast of Hootalinqua the Tantalus rests on the same volcanic rocks, presumably also unconformably. About 150 m are preserved. Opposite Mason Landing the Tantalus underlies two adjacent blocks probably separated by a fault. In the northeastern block it stands as a near vertical homocline estimated as 600 m thick faulted against Povoas Formation correlatives on the northeast. The southwestern slice dips gently northeast and the Tantalus Formation is at least 100 m thick. The slice is faulted against the Laberge Group across the Teslin Fault.

8.1.3LITHOLOGY

The Tantalus Formation weathers light orange. Its lower part is recessive, the upper resistant by comparison. The rocks weather as massive to extremely thick bedded sheets with bedding commonly 5 m thick. Sandstone beds commonly cut lower units and sand filled channels are well developed. In southwestern exposures the Tantalus Formation locally has two members, a lower coarse sandstone and an upper pebble conglomerate. Chert pebble conglomerate is the diagnostic and dominant type. Clasts are of black, greenish grey, light green and white chert, and white or grey quartz. In some places felsic volcanics greenstone and limestone occur as clasts, but their proportion is small. Pebbles are poorly to moderately well rounded, of low sphericity and generally 2 to 5 cm across. Grain size, rounding and sphericity range widely. Pebbles are invariably close packed and commonly imbricated. The cement is siliceous and though the rocks are well indurated pebbles break out readily. The rocks are generally porous. Grain size is bimodal with pebbles of 2 or 3 cm and coarse sand.

The lower Tantalus is dominantly sandstone and shale, the latter with abundant detrital muscovite. Sandstone is whitish, immature and poorly bedded; its constituents are the same as those of the conglomerate matrix namely quartz and chert with minor feldspar. Black chert and white quartz lend these rocks a salt and pepper look. Unlike Tanglefoot sandstones the Tantalus lacks K-feldspar and volcanic grains. Sandstone is more poorly indurated than the conglomerate.

Shale in the lower Tantalus is brown with numerous plant and leaf impressions on bedding surfaces. It is thinbedded, and interlaminated and cross laminated with siltstone. Coal occurs as discontinuous beds several metres thick, in shale, at several localities, notably Tantalus Butte and Tantalus. Cairnes (1910, p. 48-54) and Bostock (1936, p. 58-63) described the coal and the workings near Carmacks.

East of Hootalinqua Tantalus conglomerate rests conformably? on about 100 m of massive, red weathering, volcanic breccia, interpreted as a subaerial flow. About 20 m of the same volcanic rocks lie conformably under the Tantalus west of Mason Landing and on Mount Cooper in Aishihik Lake map area. They may be local flows at the base of the Tantalus.

The Tantalus of northeastern exposures is generally less regularly bedded, has less interbedded sandstone, and its clasts are less rounded and less spherical, than the southwestern Tantalus. Nevertheless clast types are generally the same and dominated by chert and quartz, with less quartzite and cherty tuff or slate. Judging from the interlayered coal the northeastern Tantalus is subaerial like its southwestern counterpart.

8.1.4DEPOSITIONAL ENVIRONMENT

The Tantalus Formation is interpreted as the product of downcutting rivers that drained across the uplifted and eroded Whitehorse Trough and which accumulated in structurally created basins. Northeastern Tantalus outcrops generally lie along the Teslin Fault system, which is interpreted as a dextral strike slip coeval with the Tantalus. Because of this spatial relationship the Tantalus is thought to occupy fault bounded pull-aparts formed by strike-slip on the Teslin Fault. Tantalus debris was perhaps laid down as alluvial fans which built into the structural basins.

Southwestern Tantalus deposits roughly follow the Carmacks Fault (Fig. 22) and were laid in similar extension basins generally along the faulted southwest margin of Whitehorse Trough. They cover a broad zone and their fault control is partly obscured by their Carmacks Group cover.

The Tantalus Formation is dominated by chert and quartz clasts. But no source for the chert is seen north, west, southwest and northeast of Whitehorse Trough; volcanic granitic and metamorphic rocks occur to the west and metamorphic, granitic and sedimentary strata on the northeast. The only nearby chert bearing succession is the Cache Creek Group southeast of Whitehorse Trough. The Kedahda Formation is dominantly chert and occupies about 13,000 square km (Monger, 1975). The resistant Tantalus clasts and the unit's maturity means that chert and quartz need to be present, but need not dominate the source; sedimentary "refining" has removed the less resistant detritus.

A second possibility is that the chert derives from a source, now remote, northeast of the Teslin Fault. Possibly the basins are disconnected from their source by Teslin Fault strike-slip. If so a stranded source should be sought to the southeast across the Teslin Fault. The Slide Mountain and Sylvester terranes, both with substantial, not dominant chert, and many hundreds of kilometres to the southeast are candidates. Only a few clasts of intensely sheared rocks, perhaps from Teslin Suture Zone, were seen in the Tantalus (near Mason Landing). Muscovite on bedding surfaces of Tantalus shales may come from schist in Teslin Suture Zone or the Big Salmon Complex.

The general drainage direction of Tantalus rivers is unknown. Its clasts likely derive from the top of the detachment zone's Cache Creek and Atlin Terrane and as such the unit only signals that the detachment was being eroded by Tantalus time and had therefore reached the surface. Because few or no lower detachment zone clasts occur in the Tantalus it may be safe to conclude that Tantalus basins were filled when these rocks reached surface. Individual Tantalus basins probably filled as quickly as the basins opened, perhaps in a span of one or two Ma.

The Tantalus Formation is not a molasse deposited quickly and in volume from a tectonically active mountain belt, like the coeval Kootenay and Blairmore formations of the Rocky Mountains and Alberta plains. It represents a comparatively small volume of material accumulated in local, fault controlled basins, whose material was supplied by local river systems. The volume of preserved Tantalus can be calculated as the product of the basin area and known thickness. This gives the following volumes in cubic kilometres are preserved: Claire Creek-1, Cassiar Bar-7.2, Hootalinqua I-1.8, Hootalinqua II-1.5, Mason I-10.8, Mason II-20.4, Minto-6, Carmacks-24, Nordenskiold-20, Conglomerate-6, Vowel-65, Cooper-120, Corduroy-15.4. The total, 298.1 cubic km, is heavily weighted by the Cooper and Vowel Mountain outliers. In Whitehorse map area are another 64 cubic km near Fish Lake. If the basins are deeper than the observed stratigraphic thickness volumes are proportionally larger. If the entire 362 cubic km is derived from the Kedahda Formation's 13,000 square km outcrop area an average of 27 m were eroded from the unit.

8.1.5AGE AND CORRELATION

Precise equivalence between the Tantalus of different outliers can not be proven and different blocks may include rocks of different ages. Correlation between Tantalus exposures on the northeast and southwest sides of Whitehorse Trough is particularly tenuous. Nevertheless all Tantalus outcrops probably fall broadly in the Late Jurassic-Early Cretaceous range, a span of some 60 Ma.

Some western outliers, but no northeastern exposures, have yielded fossils. One collection (33, Appendix I, Fig. 16), was made during the present work from the lower sandy part of the unit at Conglomerate Mountain; it contains Lower Cretaceous palynomorphs. Lowey (1984, p. 54-57) recovered a well preserved microfloral assemblage from drill core of the Tantalus Formation at Tantalus Bute. He considers that they are Middle to Late Albian. Earlier evidence suggested that the Tantalus is older. Wheeler (1961, p. 74) assigned the Tantalus Formation of Whitehorse map area to the Late Jurassic and/or Early Cretaceous on fossil evidence. Macrofossils from Tantalus beds in Aishihik Lake map area, examined and reported by G. Rouse (Tempelman-Kluit; 1974, p. 95), also show that the unit is Late Jurassic or Early Cretaceous. Because collection 33 is from low in the formation evidence for a Jurassic age for the Tantalus needs to be reassessed.

The maximum age of the southwestern Tantalus is limited by the underlying Bajocian Tanglefoot Formation and by the 160 Ma uplift age on the Long Lake Batholith, which lies unconformably under the Tantalus. The Upper Cretaceous Carmacks Group unconformably above the Tantalus is a younger limit. This makes the Tantalus post Oxfordian and pre-Late Cretaceous.

Tantalus exposures in the Tatchun Belt may also fall in the Upper Jurassic-Lower Cretaceous, but critical stratigraphic limits are lacking. The rocks rest above the Semenof Formation (Pennsylvanian) and Triassic (or Lower Jurassic?) volcanics correlated with the Povoas Formation. They are cut by faults that probably predate the Late Cretaceous. If they accumulated in strike-slip pull-aparts as speculated, their age is critical to understanding the movement history of the Teslin Fault system.

The Tantalus of the pull-aparts may be dated by determining the radiometric age of the volcanic rocks that occur as flows at one or two places low in the unit (e.g. at Hootalinqua). These rocks are not fresh, but they are the best available.

Tantalus strata resemble the Bowser Lake Group of central British Columbia, but according to Tipper and Richards (1976, p. 31-36) that unit is generally older than the Tantalus, namely Bajocian to Kimmeridgian (Middle to Late Jurassic).

8.2MOUNT NANSEN GROUP

8.2.1NAME AND DISTRIBUTION

Bostock (1936, p. 29-33) named and described the Mount Nansen Group in Carmacks map area. He included a variety of rocks which are omitted because they are older or younger than the Group as used here. The group's extent is severely reduced by comparison to Bostock's usage. The group includes late Early Cretaceous andesitic feldspar porphyry along the Dawson Range's backbone which have given late Early Cretaceous radiometric ages (Figs. 10, 23). Klaza Mountain, Tritop Peak, Victoria Mountain and Mount Nansen (Fig. 6) are type localities. The strip of massive green (Triassic?) volcanics astride the Yukon River, which Bostock included in the Group and which is here called the Tatchun Belt, is now correlated with the Povoas Formation. Also excluded are the small patches on Prosector Mountain, now known to be younger than the Mount Nansen and probably Carmacks Group.

Strata correlated with the Mount Nansen Group occupy two areas in Laberge map area. The largest is on Packers Mountain; the second in south central Laberge map area is on Teslin Mountain (Fig. 23). These volcanics were mapped as Hutshi Group by Bostock and Lees (1938). Earlier Tempelman-Kluit (1978, 1978a) incorrectly grouped the Miners Range volcanics, now known to be late Cretaceous, in the Mount Nansen Group.

8.2.2LITHOLOGY AND RELATIONS

In its type area the Mount Nansen Group is interpreted as the remnant base of a largely eroded volcanic complex dominated by massive, dark grey volcanic breccia, tuff and porphyry of intermediate composition. The breccias are cut by dykes and plugs of nonporphyritic andesite and porphyry, crowded porphyry and syenite or granite. The breccias and porphyries can be separated, but they are undifferentiated on the map.

The Mount Nansen volcanics and Casino Granodiorite probably accompanied slip on the Big Creek Fault, interpreted as extensional. Apparently the large block of Big Creek Syenite foundered and dropped while Casino Granodiorite was intruded on its southwest side and while subvolcanic dykes and plugs of Mount Nansen Group invaded the syenite.

8.2.2.1FRAGMENTAL ROCKS

The commonest rocks weather dark and blocky and are massive, resistant volcanics without texture or fabric. They are hard, almost flinty and dark greenish grey on fresh surfaces. Ghostly outlines of lapilli in a fragmental matrix are seen on some weathered surfaces, but generally fragments and matrix are so similar and the rocks are so densely welded that the fragments and matrix are obscure and the rocks look massive. Nevertheless the majority of the rocks are considered to be breccias. Clast proportions and sizes vary so that the rocks display an endless textural range. Fragments are angular and unrounded and range from bombs 10 cm across, to lapilli and ash. Most clasts are aphanitic, but feldspar porphyries are also common; some clasts are granodiorite like that under the volcanics, and interpreted as a subvolcanic phase, a few are gneiss like the surrounding basement. Some tuff is faintly layered, and layering dips steeply. Most rocks, including those without obvious fragments, are tuff and breccia. Thin sections show that the rocks are a fine grained mixture of chlorite, sericite and quartz, with oligoclase phenocrysts about a millimetre long and fewer hornblende euhedra. Phenocrysts constitute up to a quarter of the rock; feldspars are generally weakly sericitized and hornblende is chloritized. The breccia and tuff are probably largely andesite to dacite; some may approach rhyolite. Sawyer and Dickinson (1976) described the geology, alteration and mineralization around a late breccia pipe near Mount Nansen. They considered that it formed by explosive ejection of material from a vent by boiling the fluid phase and they explain the mineralization and alteration in this context.

Because of their restricted lateral extent and the lack of volcanic stratigraphy the fragmental rocks are interpreted as intrusive or tuff pipe breccias and the porphyries as subvolcanic feeders related to them. No flow breccia or volcanic flow rocks were identified. The steeply dipping layering is interpreted as flow banding formed during explosive discharge of the volcanic debris in the vent(s). Some porphyry grades texturally to the biotite hornblende granodiorite under the Dawson Range's southern flank. The Casino Granodiorite is considered the main plutonic equivalent of the porphyries and breccia because its age is the same.

8.2.2.2DYKE ROCKS

Johnston (1937, p. 7-9) subdivided the dykes north of Seymour Creek into two broad types, a generally dark greenish andesite and more colourful, paler porphyries. He recognized that they are one suite, possibly near surface phases of the plutonic rocks and considered the darker dykes generally older than the light porphyries. Johnston's two groups occur throughout the Dawson Range and his descriptions apply beyond the restricted area he mapped. The dark and light coloured dykes are coeval and neither predates the other consistently; in some places one cuts the other and elsewhere the reverse relations are seen. Five kilometres west of the divide between Lonely Creek and Klaza River is a several hundred metres thick dacite to rhyolite sill injected along the foliation of the schist and gneiss. It is correlated with the Mount Nansen Group. The prominent north trending swarm of white weathering felsite and dacite dykes across Maloney Creek in southwesternmost Carmacks map area is similarly correlated with the Mount Nansen Group. It is the same as dyke swarms in adjacent Snag map area (Tfp of Tempelman-Kluit, 1974, p. 41-42) which are overlain by the upper Carmacks Group.

The dark green dykes have an aphanitic to fine crystalline feldspar, quartz, hornblende and biotite groundmass with a few small white andesine and K-feldspar phenocrysts. These dark dykes are difficult to distinguish from the massive appearing breccias.

Porphyries are generally lighter coloured than the breccias and vary from hornblende feldspar quartz porphyry to quartz feldspar porphyry. The main variation is in the proportion of phenocrysts, which ranges from a few percent to near half the rock's volume. The matrix is an aphanitic or microcrystalline mixture of quartzofeldspathic constituents and the feldspar phenocrysts are generally subhedral, white andesine tablets about 2 mm across. Most quartz forms subhedral, partly resorbed crystals, slightly smaller than feldspar. Hornblendes are fresh stubby dark green crystals, generally subordinate to quartz and feldspar. Rock colour is generally light pastel to lavender and many porphyries weather to rusty colours because they contain disseminated fine grained pyrite.

Prominent orange weathering, salmon pink felsite dykes cut the Dawson Range basement. These fine grained aplites are the porphyry's granitic relatives.

The porphyries form steep dipping dykes to 10 m across and irregular shaped plugs hundreds of metres in diameter. Many dykes on Mount Nansen cut the breccias, but on the Dawson Range's north flank they intrude gneisses and the Big Creek Syenite that make up the basement and still others invade the Casino Granodiorite, their plutonic relative. Johnston (1937) mapped the intrusions north of Seymour Creek in detail and documented their range in shape and orientation. Where he worked the dykes trend generally northwest and dip steeply; on and near Mount Nansen northeast trends prevail.

8.2.3AGE AND CORRELATION

Because the breccias and porphyries occur together and because they grade from one type to the next all are assumed to be broadly coeval. A single whole rock K/Ar determination of 109 Ma on a light coloured felsic dyke rock from Klaza Mountain (Fig. 23) shows that Dawson Range dykes and porphyries are late Early Cretaceous. Other relevant radiometric dates are those of about 100 Ma determined on the Casino Granodiorite, interpreted as the plutonic companion (110, 91.0, 98.4 Ma; Fig. 12). Stratigraphic data do not limit the felsites closely, but agree with the radiometric evidence. Bracketing units are the Early Jurassic Big Creek Syenite and the Latest Cretaceous Carmacks Group.

Correlation of Packers Mountain and Mount Nansen strata is based on the generally similar rocks and relations and on one K/Ar age determination of 116 Ma (Fig. 23), which shows that the rocks are roughly coeval. Teslin Mountain rocks are included in the Group on the same basis. Their age is indicated by that of the granodiorite (118 Ma), assumed to be coeval.

Bostock and Lees (1938, p. 20) grouped the Packers Mountain felsites with the middle Jurassic porphyries of Teslin Crossing, because they resemble each other. They considered them all to be Tertiary. They included the Teslin Mountain volcanics in the Hutshi Group along with various other volcanics. Wheeler's (1961) Hutshi Group on peak 5840 and Mount Byng in northern Whitehorse map area are surely the same as those of Teslin Mountain and are therefore Mount Nansen equivalents, but Wheeler's Hutshi Group of Flat Mountain in the southern Miners Range belong in the Carmacks Group.

Mount Nansen Group volcanics are interpreted to represent the roots of mid-Cretaceous continental volcanoes built on Whitehorse Trough and its southwest margin. That the Mount Nansen Group is eroded to about the same level in Whitehorse Trough and outside implies there has been no vertical differential movement between Trough and margin since the mid-Cretaceous. The absence of Mount Nansen strata northeast of the Teslin Fault suggests that this break may have slipped since Mount Nansen time. Isotopic evidence for the Tatchun and Granite batholiths suggests Early Cretaceous strike-slip on the Teslin Fault.

8.2.4INTRUSIVE ROCKS

Unfoliated hornblende biotite granodiorite, included in the Casino Granodiorite (Tempelman-Kluit, 1974) and interpreted as the plutonic root of the Mount Nansen Group, occupies much of the Dawson Range, particularly the south flank (Figs. 10, 12). It is described here because of its presumed relationship to the Mount Nansen Group. Granodiorite on Teslin Mountain is considered equivalent to it. A second granitic unit, the Coffee Creek Granite (Tempelman-Kluit, 1974) is described here because it is seen as a Mount Nansen Group time equivalent.

8.2.4.1CASINO GRANODIORITE

The southern Dawson Range is underlain by coarse to medium grained, equigranular, hornblende biotite granodiorite, which forms large castellated outcrops on ridge tops (Figs. 10, 12). It is included with the Casino Granodiorite and correlated with the Nisling Range Granodiorite (Tempelman-Kluit and Wanless, 1975, 1980). Though homogeneous the rocks range to quartz diorite and granite. The rocks are mesocratic, lack fabric, and are distinctly post tectonic. The granitic texture is formed by about 40% oligoclase-andesine, 25% quartz and about 10% K-feldspar. Hornblende and biotite clots of dark green, subhedral grains constitute about 20%. In places the biotite forms euhedral books a few millimetres across and appears as a late deuteric mineral. Here the rock resembles the Nisling Range Granodiorite. Sphene is the most prominent accessory, but apatite and magnetite are also present. The rocks are weakly saussuritized, hornblende and biotite are partly chloritized and feldspars are sericitized. The lack of fabric and post tectonic nature distinguish the Casino Granodiorite from the older Klotassin granodiorite.

On the south flank of Teslin Mountain a granodiorite has the same relations to Mount Nansen subvolcanics and age as the Casino granodiorite (Fig. 23). The rocks are fresh, grey, massive, unfoliated, medium grained, equigranular biotite hornblende granodiorite. Locally they have the texture of a crowded porphyry, but are generally granitic. Morrison et al. (1979) showed that these rocks are part of a heterogeneous suite which includes small syenite, diorite, monzonite and quartz diorite plugs besides the more voluminous granodiorite in the Whitehorse map area.

Although intrusive contacts were not seen the Casino Granodiorite presumably cuts the Big Creek Syenite and Pelly Gneiss. The boundary between the syenite and granodiorite along the Dawson Range ridge is invaded by Mount Nansen Group breccias and dykes, but is presumed to be faulted from its straight trace. Mount Nansen strata cut, lie above, and grade to, the granite. The relations appear as a subvolcanic to plutonic downward gradation, not a depositional contact. Comagmatic relations are supported by the similar mid-Cretaceous radiometric age determinations on the rocks. The southern contact was not seen, but it too is presumed to be intrusive.

8.2.4.1.1AGE AND CORRELATION

K/Ar age determinations of 98.4 and 91.0 on biotite and hornblende respectively on one sample at the west edge of Carmacks map area and one determination of 110 Ma on hornblende from a second sample northwest of Victoria Mountain show that the rocks are mid-Cretaceous (Figs. 12, 23). Similar ages were determined on the Casino Granodiorite and the Nisling Range Granodiorite in adjacent Snag map area (Tempelman-Kluit and Wanless, 1975; Godwin, 1975; Le Couteur and Tempelman-Kluit, 1976). Though lithologically distinctive the Casino and Nisling Range granodiorites and the Coffee Creek Granite have all given mid-Cretaceous K/Ar ages and have the same relations to older rocks. They are considered to be plutonic sources for Mount Nansen Group volcanics, which have given similar ages. Morrison et al. (1979) demonstrated that a wide range of mid-Cretaceous intrusives including syenite, hornblende diorite, quartz monzonite and granodiorite occur extensively in Whitehorse map area. They may be southern equivalents of the Casino, Nisling and Coffee Creek intrusives.

8.2.4.2COFFEE CREEK GRANITE

Along the northern side of upper Big Creek and on both sides of upper Hayes Creek is poorly exposed, strongly altered granite (Fig. 12) that is considered equivalent to the Coffee Creek Granite of Snag map area (Tempelman-Kluit, 1974). The rocks are treated as an "overlap" unit because they are thought to be the same age as the Mount Nansen volcanics, also overlaps. No genetic relationship to Mount Nansen Group rocks is implied.

The granite is made up of equal parts cloudy or milky white quartz and buff feldspar, which is replaced by clays and sericite. A little biotite occurs locally, but the rock generally contains only a few percent chlorite. Pyrite is a common disseminated constituent. The rock is light coloured and weathers recessively to light buff or rusty colours. The grains are poorly held and the rock breaks down readily to a coarse gruss. It lacks fabric, but is strongly shattered and irregularly broken so that pieces larger than a few centimetres across are uncommon. The original rock was coarse grained leucogranite with anhedral, equant grains.

Intrusive relations are unknown. The granite is interpreted to be faulted against the Big Creek Syenite across the Big Creek Fault. It may also be faulted against the Pelly Gneiss and is overlain unconformably by the Carmacks Group. Probably this is the Coffee Creek Granite of adjacent Snag map area, which is mid-Cretaceous (Tempelman-Kluit and Wanless, 1975). The alteration is a pervasive, high level hydrothermal effect, unrelated to the original igneous processes and perhaps connected with groundwater channelled along the Big Creek Fault or with Carmacks Group volcanism.

8.2.5PACKERS MOUNTAIN

At Packers Mountain in northern Laberge map area (Figs. 6, 23) are poorly exposed, rusty weathering felsic aphanitic rocks dominated by light coloured dacite to rhyolite, which grade to porphyritic varieties. Lees (1934, p. 31) and Bostock and Lees (1938, p. 20) described them and thought that the rocks are an intrusive complex citing textural gradation from crystalline to aphanitic types as evidence. Packers Mountain felsites may be a subvolcanic complex of dacite domes, dykes and plugs with their plutonic equivalents. No clearly extrusive rocks were noted. The dark, resistant breccias seen on Mount Nansen are absent on Packers Mountain.

Relations are not exposed, but the Packers Mountain felsites are apparently truncated by the Claire Fault on the northeast and they intrude or overlie Laberge Group beds on the south.

8.2.6TESLIN MOUNTAIN

Teslin Mountain in southern Laberge map area (Figs. 6, 23) is underlain by a third set of volcanic rocks correlated with the Mount Nansen Group. On the top and south side are massive, dark green, resistant, intermediate, volcanics, altered to chlorite-epidote mixtures. Although most appear massive and aphanitic some show fragmental textures. As at Mount Nansen the massive varieties are assumed to be cryptofragmental subvolcanic breccias. On Teslin Mountain's north side, near the contact with the Lewes River Group, are more fragmental volcanics, but some amygdaloidal green andesite flows were also noted. The flows and breccias are not distinguished on the map.

On the mountain's east flank is a crowded porphyry plug. It is a massive, clean looking rock dominated by andesine, K-feldspar, quartz and hornblende crystals, a couple of millimetres across. Hornblendes are marginally chloritized, but otherwise the rocks are fresh.

Mount Nansen strata on Teslin Mountain differ in their relations to basement. Though poorly exposed the northern contact with Lewes River Group strata is subhorizontal judging from its map pattern. Here the volcanics are considered to be flows and flow breccias laid unconformably across the older rocks. The southern contact with granodiorite is faulted as is the eastern boundary with Laberge Group beds. On air photos the massive rocks on, and near, the peak show prominent north trending, closely spaced fractures; they may alternatively be a dyke swarm. The crowded porphyry is finer grained, but otherwise so similar to the granodiorite on the mountain's south side that the two are assumed to be gradational phases. The porphyry and massive cryptobreccias also appear gradational.

8.3CARMACKS GROUP

8.3.1NAME AND DISTRIBUTION

Cairnes (1910, p. 44) named the volcanic rocks that lie unconformably across older strata near Carmacks the Carmacks basalts. Bostock (1936, p. 40-43) changed this to Carmacks Volcanics to reflect the range in composition of these rocks. This is formalized here to Carmacks Group. Cairnes thought that the rocks are Tertiary on the basis of their similarity to the Miles Canyon Basalt and Bostock argued that they are Miocene or older. In the Dawson Range the Carmacks Group can be separated into a lower andesite and an upper basalt. In Snag map area, just west of Carmacks map area, Tempelman-Kluit (1974, p. 42-54) correlated the lower andesites with the Mount Nansen Group and the upper with the Carmacks, thinking that the two are separated by an erosional interval.

Present work shows that the Carmacks Group is more extensive than originally thought and that it differs from place to place. In its type area it has two distinctive, conformable formations, a lower of epiclastic andesite breccia with some lava flows and an upper of tholeiitic basalt. Porphyritic andesite flows with breccias at the base, found in the Miners Range are now known to be coeval with the Carmacks. In addition green tuffaceous sandstone, tuff and andesitic basalt of Prospector Mountain are here correlated with the lower epiclastic unit of the Group. Both were formerly correlated with the Mount Nansen Group. The formations are distinguished on the maps, but not named. The

Carmacks Group also includes granite-syenite and gabbro to diorite, which occur as plugs interpreted as feeders and subvolcanic relatives.

As used here the Carmacks Group includes (1) all the strata formerly mapped as Carmacks Group by Bostock (1936) and by Tempelman-Kluit (1974); (2) some, but not all the, rocks formerly included in the Mount Nansen Group by Bostock (1936) and Tempelman-Kluit (1974); (3) the rocks formerly mapped as Hutshi Group by Bostock and Lees (1938) in the Miners Range; (4) the Little Ridge Volcanics of Bostock and Lees (1938, p. 20); and (5) some syenite in the Dawson Range as mapped by Bostock (1936).

Strata assigned to the Carmacks Group occupy three large areas, one in southwest Laberge and adjoining Aishihik Lake map area, a second just west of Carmacks and a third in west central Carmacks map area astride Big Creek (Figs. 10, 24). Other outcrops are in northeast and northwest Carmacks map area.

8.3.2THICKNESS AND RELATIONS

The main Carmacks Group outcrop areas define three large homoclines tilted gently northwest and dropped on the north by normal faults. The Miners Range exposes one of them (Figs. 24, 25). On the Range's southwest side the rocks are subhorizontal and rest unconformably on Aishihik Batholith granodiorite, but on the northeast they dip moderately southwest and are faulted against the Laberge Group on an inferred break called the Miners Fault. Near Corduroy and Ottawa mountains the block southwest of the fault fell at least several hundred metres relative to the northeast side during or after the Latest Cretaceous. Throw on the fault decreases from northwest to southeast. Near Corduroy and Ottawa mountains displacement may be several hundred metres and the Tantalus may also be displaced. Opposite the outlet of Fox Lake, subvolcanic Carmacks dykes follow the contact and obscure its relations. Still farther southeast at the southern edge of Laberge map area and on the south slope of Flat Mountain relations may be unconformable. About 1100 m of strata are preserved in the northeast Miners Range, elsewhere there is less. The Miners Range Carmacks Group has lower greenish hornblende feldspar porphyry flows and upper purplish brown amygdaloidal hornblende augite porphyry flows.

The Miller's Ridge block, west of Carmacks, is the second north tilted fault block (Figs. 24, 25). The lower and upper Carmacks Group are subhorizontal over a broad area and are probably faulted against the Granite Mountain Batholith on the north (the inferred Miller Fault). Across the fault the south side fell relative to the north. On the east this block may overlie, or be faulted against, Tantalus Formation and Laberge Group beds. On the west and south the volcanic rocks rest unconformably on a granite and metamorphic basement. In the Miller Ridge block the lower Formation thins northward; near the block's north edge only the upper unit is distinguished. The lower Carmacks Group includes about 300 m of epiclastic breccia, tuff and flows: the upper Formation is some 500 m of basalt flows. South of Carmacks, just in Aishihik Lake map area at least 250 m of the lower Carmacks are preserved, and on the east edge of Carmacks map area, just north of Yukon River, about 200 m of the lower Carmacks Group lie unconformably on the Laberge Group. The upper Formation is absent.

On and near Prospector Mountain the lower Carmacks Group includes about 300 m of waterlain tuffs, which rest unconformably on older granitic and metamorphic rocks (Figs. 24, 25). Relations are exposed on the south flank of Prospector Mountain 5 km south of the peak. The tuffs are overlain by up to 500 m of basalt. The transition from tuff to basalt is gradational and the two rock types are interbedded over several tens of metres in the same general area. North of Big Creek the transition is more abrupt. Fifteen kilometres west of Klaza Mountain the lower Formation is missing and the upper lies directly on basement. Although the relations at the base are unconformable most exposed contacts are faults. For instance the Carmacks is dropped on a generally north trending fault about 10 km west of Klaza Mountain. Similarly the lower Carmacks abuts the Big Creek Syenite across a northeast trending fault along upper Big Creek.

The granite-syenite, interpreted as a subvolcanic Carmacks Group relative, is restricted to Prospector Mountain and Mount Pitts. At the first place it may be a laccolith with a gently domed, lens shaped top and flat base, injected between the Carmacks Group and its basement. If so the lens is 1 km at its thickest.

Carmacks Group strata north of Big Creek define the third large northeast tilted block (Figs. 24, 25). The lower and upper Carmacks Formations are essentially horizontal over a large area along the southern side of this block. They lie unconformably above metamorphic and plutonic rocks and attain maximum thicknesses of 100 and 150 m respectively. On the northeast the Carmacks Group is juxtaposed against the Minto Pluton on a southeast trending break. The fault must have dropped the southern side 100 or 200 m. Upper Carmacks Group outliers north of Granite Mountain are subhorizontal and less than 150 m thick.

The isolated outcrops in northern Carmacks map area are interpreted as outliers of upper Carmacks Group. Relations are not exposed, but the outcrop pattern suggests unconformity at the base. No more than 600 m are estimated northeast of Diamain Lake and perhaps half that near Grand Valley Creek.

8.3.3LOWER FORMATION

The Carmacks Group's lower Formation differs from place to place and the various types are interpreted as roughly coeval equivalents (Fig. 25). In the Miners Range andesitic hornblende feldspar porphyry flows dominate. Near Carmacks coarse, immature volcanic breccias are common and on upper Big Creek relatively clean waterlain tuffs with intercalated flows are the norm. North of Big Creek the lower Carmacks includes andesite flows with minor epiclastic rocks.

Near Carmacks the lower Formation contains coarse volcanic breccia with angular basalt-andesite bombs to a half metre across in a sand sized matrix of the same material. The matrix to clast ratio is 3:2. The rocks form massive sheets, about 5 m thick, but locally 20 or 30 m. They weather resistantly as cliffs and make spectacular exposures. The bombs weather maroon, and are purplish, greenish and blue grey, locally vesicular, lavas. They hold augite and less commonly olivine in a felted ground of fine andesine laths. The tuffs have these minerals in devitrified glass. A few flows and sintered tuffs are intercalated with the breccia. The proportion of flows to breccia varies. Bostock (1936) correlated the lower Carmacks Group's coarse conglomerate or agglomerate, southeast and northeast of Mount Miller, with Lewes River and Laberge Group strata.

On the west slope of Five Finger Mountain near Carmacks and on the opposite side of Yukon River are volcanic and feldspathic sandstone and shale with intercalated felsic tuff and minor coal, which Bostock (1936) included in the Laberge Group. The sandstone is medium to thick bedded, light grey to white and coarse grained with plenty of volcanic lapilli and bombs. It grades to bomb and lapilli tuff by increase in the volcanic component. Many bombs are silicified felsic volcanic rocks. White tuff with pumice, lapilli and quartz crystals is intercalated with the volcanic sandstone. Grey argillite with common plant impressions, thin lignite or coaly seams and some amber is interbedded with the volcanic sandstone. Beds are planar, but large scale channelling is seen. The rocks are correlated with the lower Carmacks Group, although they appear fresher and are more felsic than most of it. They also resemble the immature clastic rocks of Walsh Creek, which lack coeval volcanic tuff. No palynomorphs were recovered from these rocks although carbonized fragments are common. The age is unknown and the relations are not exposed. On the northeast the rocks are probably faulted against the Laberge Group across the Hoochekoo Fault and on the southwest they lie on Carmacks Group strata (conformably?). The rocks are distinguished as a problem unit on the map.

Bostock (1936) mapped conglomerate, tuff, tuffaceous sandstone and shale south of the divide between Crossing and Seymour creeks and at two other localities northeast of Mount Pitts. They represent the lower Carmacks Group's epiclastic unit and are included with it. On the north edge of the Mount Pitts block are outcrops of granodiorite boulder conglomerate up to 50 m thick, which represent the Group's base. The boulders were deposited subaerially judging from their hematite coatings and derive from the underlying Minto Pluton.

Churchill (1980) and Grond et al. (1984) described the rocks and gave analyses and data on K/Ar age determinations. They showed that the lower Carmacks Group near Carmacks ranges from calc-alkaline andesite to alkali basalt.

On and near Prospector Mountain the lower Carmacks Group is green, well bedded waterlain tuff. As near Carmacks the detritus is exclusively volcanic, but it is more felsic and much better sorted than near Carmacks (Fig. 25). Grain size is generally below 3 cm and the rocks are epiclastic tuffs, in planar and crossbedded sheets one to 10 m thick. Clasts are angular to subrounded and of green to red altered andesite. Toward the top the tuffs have intercalated, brown weathering flows, several metres thick, of andesitic basalt.

Five kilometres north of Victoria Mountain, between plutonic basement and upper Carmacks Group basalt are about 30 m of pink, welded tuff, a distinct lower unit of the Carmacks Group (Fig. 24). It probably represents a single subaerial, welded ash flow; the lower half is partly devitrified glass. Similar felsic tuff occupies an isolated spot about the west central edge of Laberge map area, where the 64.0 Ma whole rock K/Ar age was determined. The tuffs are correlated with the Varicoloured Acid Tuff of Aishihik Lake map area (Tempelman-Kluit, 1974, p. 50) on lithology and age.

8.3.4UPPER FORMATION

The Carmacks Group's upper Formation in Carmacks map area is a uniform succession of lavas without epiclastic rocks; it is the classic Carmacks Group. Good exposures are on Miller Ridge, in the Dawson Range and on the ridge north of Big Creek. The unit is dominated by rich brown weathering, resistant, fresh andesitic basalt. Flows are several metres thick and form resistant benches on hillsides visible from afar. Jointing is perpendicular to the flows, but is not columnar. On fresh surfaces the rocks are dark brown to black or greenish. Augite and less commonly olivine or andesine phenocrysts, less than a millimetre across, are scattered through a microcrystalline andesine-labradorite groundmass. Flow tops are commonly vesicular. Small agates occur commonly as vesicle fillings.

8.3.5MINERS RANGE

The Miners Range Carmacks Group has a lower hornblende feldspar porphyry and an upper hornblende augite porphyry, which together are considered the equivalents of the lower Formation near Carmacks. The succession is locally capped by trachytoid basalt correlated with the Carmacks Group's upper Formation.

The lower unit has about 500 m of resistant, reddish weathering, medium green, hornblende feldspar porphyry with a few interbedded thin rhyolite flows and one or two volcanic breccias. The porphyry has 20% euhedral andesine phenocrysts and 10% hornblende crystals, both 2 or 3 cm long, with minor augite in an aphanitic saussuritized groundmass. Breccias are massive aphanitic, green, saussuritized, splotchy andesite. Splotches may represent poorly defined, partly assimilated breccia fragments. Fragment size ranges from coarse ash through lapilli. Rhyolite forms a few prominent light grey, aphanitic, rusty weathering flows or dykes, generally less than 15 m thick, in the top. It is pyritic with tiny quartz and feldspar phenocrysts. Locally, as on the knoll 6 km north of the south edge of Laberge map area and 9 km west of Jackfish Bay, the lower unit is represented by immature, volcanic boulder conglomerate or breccia. It is interpreted as alluvial detritus transported as a lahar and derived from the Carmacks Group and older rocks.

The upper unit, about 400 m thick, weathers purplish brown and is resistant. It is dominated by amygdaloidal and massive hornblende augite andesite with minor interlayered breccia and tuff. The rock contains roughly equal proportions of hornblende and augite (5% each) and about 15% andesine, all as phenocrysts a millimetre or two across, in an altered aphanitic groundmass. Chalcedony and/or calcite filled amygdules are common.

At upper unit's top are distinctive, pretty looking, brownish weathering, 20 m thick flows of vesicular to amygdaloidal basalt with spectacularly developed trachytoid texture. Feldspar laths to a centimetre across are oriented generally parallel to flow boundaries. These are the Little Ridge Volcanics of southwestern Laberge map area and adjacent Aishihik Lake map area (Bostock and Lees, 1938, p. 20; Tempelman-Kluit, 1974, p. 53-54). They are correlated with the upper basalt of the Carmacks Group of Miller Ridge. Minor flow? breccias in this basalt weather the same dark colour as the flows and contain its fragments.

Pilot Mountain and peaks 6324 and 6295 high in the Miners Range are capped by black weathering andesite flows. Though they weather distinctively they are feldspar porphyries and augite hornblende porphyries like those lower down.

Grond (1980) and Grond et al. (1984) contain comprehensive descriptions, with analyses and geochronologic data for a section through the two Miners Range units. Analyses show that the hornblende feldspar porphyry and augite hornblende porphyry are calc-alkaline andesite.

8.3.6INTRUSIVE ROCKS

Porphyries, interpreted as intrusive or subvolcanic Carmacks Group relatives from their spatial association, occur at several places around the Miners Range and on Prospector Mountain and

Mount Pitts (Fig. 24). They range from light coloured syenite to dark gabbro and most are fine grained, with porphyritic to granitic texture. Dykes and small plugs are the norm, but those on Prospector Mountain are probably laccoliths.

Bunker Hill, the three knolls 10 km west of Jackfish Bay, and the top of Peak 6324 are localities with such rocks in the Miners Range. Bunker Hill is an 800 m diameter pipe in Laberge Group strata, of light grey, aphanitic felsite with white albite tablets and stubby dark green hornblendes and biotite flakes. The three knolls near Jackfish Bay expose feldspar porphyries, fresh, fine grained, equigranular, mesocratic hornblende biotite granodiorite to quartz diorite and narrow, pink rhyolite dykes. They invade and locally bake Laberge Group strata and form long, steep dipping, dyke like bodies, many too small to map. The feldspar porphyries are saussuritized and resemble the lower flows of the Carmacks Group in the Miners Range. On Peak 6324 is a small porphyritic syenite plug, about 700 m across intruded in the andesite porphyries. Tabular, subhedral, white, fresh K-feldspar phenocrysts to 1 cm across lie in a very fine grained, mesocratic ground of feldspar and hornblende. The dykes 6 km southwest of Fox Lake's outlet are a swarm of feldspar porphyries similar to the lower Miner Range flows along the faulted(?) contact between Laberge and Carmacks Group strata.

The core of Prospector Mountain and the north side of Mount Pitts are fresh, resistant, pale mauve coloured, equigranular granite and crowded porphyry. Small intercrystalline open spaces grade locally to miarolitic texture. About 40% of the rock is oligoclase-andesine, which occurs as mauve, euhedral, thick tablets to 5 mm across. Hornblende (20%) is as stubby, subhedral green prisms a few millimetres long with small biotite inclusions. Anhedral K-feldspar and grey quartz, about 15% each, lie between plagioclase and hornblende crystals. Mineral proportions and grain size vary so that the rocks grade to hornblende feldspar porphyry like that in extrusives related to the Carmacks Group. Locally biotite is the dominant mafic mineral. In places quartz falls below 10% so that the rocks are hornblende syenite. Most minerals are fresh, but hornblendes are commonly chloritized. Bostock (1936, p. 35) included the rocks with the Big Creek Syenite on the basis of its composition, but the texture, fabric, alteration and grain size differ drastically.

At its margins on Prospector Mountain the granite dips gently under lower Carmacks Group strata conforming with bedding in the tuff. It has baked and locally metasomatised the overlying tuff. Contacts dip gently away from the mountain. Apophyses of granite in the overlying Carmacks Group are rare. The granite on Mount Pitts also dips under the Carmacks Group on the southern side, but is faulted on the northeast. The rock's mineralogy and texture and the intrusion's shape at the top suggests it may be a laccolith injected between the Carmacks Group and basement. The Pattison Pluton, an Eocene alaskite in Snag map area, may be a younger phase of the granites on Prospector Mountain (Lynch and Pride, 1983, p. 38-49).

About 4 km north of Mount McDade is a subcircular plug of beautiful, dark, coarse grained gabbro or pyroxenite. It has euhedral, fresh, black augites to 5 mm across and somewhat smaller greenish olivines surrounded by interstitial calcic plagioclase. Bostock (1936, p. 34) thought this rock is overlain unconformably by the Carmacks Group, but the gabbro is here interpreted to intrude the Carmacks lavas and it is probably a feeder to the upper Carmacks Group. Relatives of this gabbro, mostly unmapped, are found as small plugs through the Upper Carmacks Group. Several biotite hornblende andesite volcanic necks, one dated by K/Ar, were noted on the south flank of Mount Pitts. About 11 km west-northwest of Klaza Mountain on the Dawson Range ridge is another such plug surrounded by upper Carmacks Group flows.

8.3.7DEPOSITIONAL ENVIRONMENT

The Carmacks Group is dominated by plateau lavas, but it includes andesite flows, acid welded tuff, epiclastic breccia and waterlain tuff. Volcanic centres are marked by subvolcanic plugs, dykes and laccoliths which invade basement and the Carmacks Group. They are concentrated between Mount Pitts, Klaza Mountain, Prospector Mountain and Victoria Mountain. The lower Carmacks Group breccias are interpreted as lahars or sheet washes off volcanic edifices. Most were deposited on land, but some were laid in lakes. They presumably formed ahead of, and down hill from, coeval lava flows. Volcanism high in the Dawson Range produced lavas which flowed southeastward. Debris sheets were washed down toward Carmacks ahead of the flows. Afterward lava overflowed the debris eroded from earlier flows. This suggests that the surface under the Carmacks sloped southeastward. Lower Carmacks Group breccias in the southeast may therefore be coeval with Upper Carmacks basalt flows in the Dawson Range.

While basalt was extruded in the Dawson Range the Miners Range saw andesite extrusion over a vast area. The extrusive centre may be generally under the Miners Range's high point. The syenite on Peak 6324 may represent a late plug dome in the succession. No general flow direction is recognized; perhaps the region lacked a general slope.

The thin tuff wedge just north of Victoria Mountain is welded, subaerial, felsic ash laid down early in Carmacks time. The thickest accumulations are in central Aishihik Lake map area and the extrusive centre lay near Aishihik Lake. The explosive event that produced it coincided roughly with basalt extrusion near Carmacks and with andesite flows to the east in the Miners Range.

Broadly the Carmacks Group outliers follow the western margin of Whitehorse Trough. The Carmacks and Miners Range occurrences cover long stretches of the contact though the Mount Pitts and Prospector Mountain outcrops are some distance away. Extension that that permitted Carmacks Group extrusion was perhaps localized along Whitehorse Trough's western margin where Tantalus basins had been created earlier.

Lava composition in the Carmacks Group varies with stratigraphic position and location (Fig. 25). Lower flows are calc-alkaline andesite, higher up are alkali basalts. Southern flows (those in the Miners Range) are andesite, to the northwest (near Carmacks and in the Dawson Range) are basalts. Felsic welded ash flows were extruded from southwestern centres. The Carmacks Group lacks systematic geographic variation and it shows no general chemical trend with time.

8.3.8AGE AND CORRELATION

The Carmacks Group is Late Cretaceous as indicated by a dozen K/Ar age determinations from widespread samples (Figs. 24, 25). The oldest date is 78.4, the youngest 63.5 and the mode is about 70 Ma (Maastrichtian). A hornblende biotite andesite plug that cuts the Carmacks Group north of Big Creek, about 12 km south of Mount Pitts gave 78.4 (hornblende) and 65.8 Ma (biotite). Hornblende in an andesite porphyry from the Carmacks Group northeast of Diamain Lake gave 74.4 Ma and a biotite sample from a basalt dyke at Granite Canyon nearby gave 63.5 Ma. Biotite in subvolcanic granite related to the Carmacks Group, from Mount Pitts and Prospector Mountain gave 71.7 and 68.2 Ma. A sample of reddish weathering aphanitic andesite from an isolated outcrop a few kilometres southwest of Twin Lakes gave a whole rock age of 64.0 Ma.

Near Carmacks Churchill (1980) dated two whole rocks and a biotite separate. Alkali basalt from low in the lower Carmacks Group at the east end of Miller Ridge returned 73.1 Ma, andesite from about the same stratigraphic position just south of Carmacks gave 67.9 Ma and biotite from a trachybasalt also in the lower Carmacks a few kilometres east of the Carmacks map area boundary, gave 68.0 Ma. Determinations of a plagioclase separate and a whole rock on samples from midway in the Miners Range succession returned 69.1 and 72.4 Ma (Grond, 1980). A felsite sample from Bunker Hill, supposed to be a Carmacks Group subvolcanic relative, gave a K/Ar age of 56.5 Ma. Although most determinations are on lower Carmacks Group samples, the ages of the two Formations are indistinguishable and both Upper Cretaceous.

The volcanic sandstones in the lower Carmacks Group near Carmacks were sampled for palynomorphs, but no identifiable pollen was recovered and the radiometric age can not be corroborated by fossils. The next older unit in the Dawson Range is the late Early Cretaceous Mount Nansen Group and the next youngest are Quaternary Selkirk Volcanics.

If real the range in Carmacks Group ages suggests that the unit is the culmination of a protracted extrusive event that began with Open Creek volcanism, at about 80 Ma, which climaxed with Carmacks Group extrusion between 73 and 67 Ma, and which closed with minor volcanism and intrusion of subvolcanic plugs about 55 Ma. This suggests that the Nisling Range Alaskite (Tempelman-Kluit and Wanless, 1975) and related rocks may be a closing phase of Carmacks volcanism, not a separate event. This would make the Carmacks a 25 Ma long event.

The Carmacks Group is coeval with the Casino Volcanics (Tempelman-Kluit, 1974, p. 45) (69.5 and 71.2 Ma) and with certain biotite quartz monzonites in Whitehorse map area which gave dates of 64.3 and 75.3 Ma at two localities (Morrison et al., 1979). The plutonic rocks may be subvolcanic and related to Carmacks extrusion.

8.4OPEN CREEK VOLCANICS

8.4.1NAME AND DISTRIBUTION

Colourful volcanics around Open Creek and on Solitary Mountain in southeastern and northeastern Laberge map area are here called the Open Creek Volcanics. The largest area and reference locality for the unit is northeast of Baker Lake on both sides of Boswell River, and a second area is a few kilometres north of Teslin Mountain west of Open Creek (Figs. 10, 24). Relations were not seen, but the volcanics probably overlie the local rocks unconformably at both places. Other exposures are just north of Hootalinqua, where the rocks rest unconformably? on massive Povoas Formation greenstone.

Bostock and Lees (1938, p. 21) described the rocks briefly and considered them Tertiary correlating them with the Carmacks volcanics. Wheeler (1961) correlated these rocks with the Eocene Skukum Group. Bedding dips gently and the rocks are not much disturbed. Age determinations show that the volcanics are Late Cretaceous (Campanian), about 10 Ma older than the Carmacks Group.

8.4.2LITHOLOGY

West of Open Creek are about 100 m of massive ash flows and breccias. They are fresh dacite to rhyolite porphyry, with clear subhedral quartz crystals and small andesines in an aphanitic ground. They generally lack mafic phenocrysts, but biotite locally makes up 2 or 3%. The rocks weather red, brownish and white and are recessive; they form a large landslide scar northeast of Teslin Mountain.

At the mouth of Boswell River are at least 300 m of reddish, flow banded, dacitic, welded ash flows with up to a quarter of the volume of feldspar and another ten percent lithic fragments. Dark brown weathering amygdaloidal basalt is intercalated and makes up a small proportion of the section. The base of the volcanics is not preserved so that the relations to older rocks are unknown - the rocks may occupy a downfaulted block. Flows generally dip northwest at the north of this outlier and northeast and east on the south end.

The outcrops just north of Hootalinqua are subhorizontal, red weathering breccia of hornblende feldspar porphyry bombs and lapilli in an ash matrix of the same intermediate composition. About a hundred metres of the breccias are preserved.

The rocks are interpreted as dacite-rhyolite ash flows with associated domes and debris flows. They probably represent an early stage of Carmacks Group volcanism, but they are distinguished because they occur separately, are distinctly older and generally more felsic. It is unknown if the Open Creek volcanics are cut by Teslin Fault.

At Solitary Mountain resistant, brown weathering, columnar jointed, fresh, vesicular, andesitic basalt, locally with olivine, rests directly on metamorphic rocks. The flows are nearly horizontal and about 400 m are preserved. The rocks are included with the Open Creek suite for lack of data, but they may be younger. They resemble the Neogene Plateau Basalt of central British Columbia.

8.4.3AGE

Two age determinations on the Open Creek volcanics show that the rocks are Late Cretaceous. A biotite dacite welded ash at Boswell River, dated by whole rock K/Ar, gave 80.0 Ma and a sample from Hootalinqua gave 83.4 by the same method (Fig. 24). The occurrence west of Open Creek is correlated with confidence because the rocks are the same, but the Solitary Mountain outlier is less certainly a part of this suite; as stated it may be Neogene. Detritus of the Solitary Mountain lavas is common in the Pliocene conglomerate on and near Walsh Creek and this indicates that the volcanics at Solitary Mountain are Pliocene or older.

8.5WALSH CREEK FORMATION

8.5.1NAME AND DISTRIBUTION

In north-central Laberge map area, along Walsh Creek and its tributaries are nearly flat lying beds of moderately indurated conglomerate with locally derived clasts and immature sandstone and claystone (Figs. 10, 26). These rocks, here referred to as the Walsh Creek Formation, were correlated with the Tantalus

Formation by Bostock and Lees (1938, p. 16), but they are now known to be Pliocene, much younger than the Tantalus. A large conglomerate outcrop forms a cliff on the north side of an abandoned outwash channel 2 km west of the mouth of Lokken Creek on the south side of Walsh Creek (fossil locality 29). Other good exposures are on the southwest side of the hill between lower Illusion and Walsh creeks. Slumped claystone and interbedded mudstone and lignite are exposed on the low banks of the small tributary that enters Walsh Creek from the north side about 10 km above its mouth.

On both banks of the Yukon River on the northwest side of Five Finger Mountain, near Carmacks, are similar poorly indurated rocks provisionally included with the Carmacks Group, which may be Walsh Creek bed equivalents. Bostock (1936) included them in the Laberge Group.

8.5.2THICKNESS AND RELATIONS

The thickness of conglomerate on the hill between Walsh and Illusion creeks is difficult to gauge. The hill may be mantled or underlain from bottom to top by the coarse clastics. In the second instance at least 500 m, the hill's height, are present although at most 30 m are seen in the largest single outcrop. If the hill is underlain by conglomerate from bottom to top the deposit is a southwestward tapered wedge. The mudstone and claystone are probably thinner than the conglomerate; 5 m are exposed in single stream cut banks and there is no reason to think the unit is more than a blanket. Nevertheless the mudstone and claystone may blanket the triangular area between Walsh and Illusion creeks and Big Salmon River west of the Big Salmon Fault. These rocks conceivably overlie older Tertiary strata, but such older rocks can only be discovered through drilling.

At the base the conglomerate is assumed to rest unconformably on older strata. In southwestern outcrops conglomerate overlies Boswell Formation limestone directly. The limestone surface is irregular with several metres of relief and the conglomerate appears as the fill of a cavity, possibly a karst cave. Relations between the conglomerate and claystone are not exposed, but the two are assumed to interfinger or overlap. On the northeast the conglomerate is faulted against Boswell Formation limestone on the Illusion Fault. Southeast side down dipslip at least equivalent to the conglomerate thickness is the minimum movement.

8.5.3LITHOLOGY AND ORIGIN

At Walsh Creek the conglomerate is thick bedded to massive; lenses of sandy conglomerate mark bedding. Beds are massive and planar, but large scale crossbeds and channels are seen in large outcrops. Most detritus is pebble to cobble sized, and the matrix is coarse to fine sand. Rounding is poor and clast sphericity low and the sand matrix contains mostly angular K-feldspar and quartz. The rocks are moderately indurated and clasts break out readily. Pebbles include graphitic quartzite derived from the Nasina Formation, quartzite like that of the Hogg Formation, red volcanic clasts of basaltic composition, which resemble the rocks of Solitary Mountain, siliceous mylonite clasts derived from the Nisutlin Assemblage and granite which evidently comes from the Cretaceous Quiet Lake intrusions. Proportions of clast types differ from place to place, but a possible source for each type is seen in the drainage basin of Lokken Creek and the rock looks like the lithified equivalent of Lokken Creek or Big Salmon River gravel. None needs to be derived from farther than 30 km away.

On the hill just north of Illusion Creek are white weathering, white, fresh, aphanitic rhyolite and quartz feldspar rhyolite, which intrude or are faulted against the Boswell Formation. Nothing is known of their age, but because they occur near the Walsh Creek Formation they may be coeval.

The conglomerate is stream transported debris deposited on an alluvial fan, which was about 20 km long, and which lay along the ancestral Big Salmon valley edge. Streams feeding the fan were precursors to Lokken and Illusion creeks which drained to the west from the Big Salmon Range in the late Tertiary. The claystone, mudstone and lignite represent lake beds and swamp deposits laid in the centre of the same intermontane valley. The fan evidently encroached on the lake at some stage. Collection (at locality 29) from shale interbedded with the conglomerate is suggested to be Tertiary (S. Hopkins), which indicates that the rocks cannot be Tantalus Formation time equivalents. Hopkins reexamined the locality and collected more material, but found no diagnostic palynomorphs (collection 29). Hopkins' several samples of claystone, made at the same time, (collection 28) were more successful. Concerning their pollen flora he wrote "Although

I would be hard pressed to prove it, I would suggest a ?Miocene or Pliocene age for this assemblage." The fossil evidence agrees with the broad limit imposed by clast age. Solitary Mountain volcanic clasts are considered Late Cretaceous and those of granite are mid-Cretaceous. The Walsh Creek Formation is therefore Late Cretaceous or younger; in any instance younger than the Tantalus Formation.

No Late Tertiary beds are known near the two fossiliferous outcrop areas. The rocks probably formed as isolated deposits and more of these rocks may be found. The Tummel Basin in Glenlyon map area may be particularly fruitful although natural outcrop is scarce and drilling or judicious stripping would be needed. During the present work equivalent strata were noted in a road cut on the north side of the Campbell Highway about km 539.5 (Fig. 26). They may have been physically connected with those of Walsh Creek.

8.6SELKIRK VOLCANICS

The Selkirk Volcanics of northern Carmacks map area were named and described by Bostock (1936, p. 45-47). They are spectacular, fresh, columnar jointed, flat lying, plateau basalt that mantles the low country around the Pelly and Yukon rivers confluence (Fig. 26). They make some fine scenery along what would otherwise be a dull stretch of the Yukon River upstream and downstream from Fort Selkirk.

The lavas flowed in shallow valleys from four or more extrusive centres (Fig. 26). In places the lava filled the ancestral Yukon River channel, blocking it and causing rerouting. Thus at the time of extrusion Yukon River probably flowed northeast of the volcanic centre opposite the mouth of Wolverine Creek and made a broad sweep around Victoria Rock. Damming by lava changed the river's course and sliced the Wolverine cone and truncated Victoria Rock's northern spur (Bostock, 1936, p. 47).

Bostock's descriptions of the rocks and relations are comprehensive and readily accessible so no new description is given here. Bostock also summarized the evidence for the age concluding that extrusion "commenced in preglacial time, very late Tertiary, or in Pleistocene time, and did not cease until perhaps only a few thousand years ago."

The Selkirk Volcanics are equivalents of the Miles Canyon Basalt (Wheeler, 1961, p. 85-86), and of the Plateau Lavas in central British Columbia. Similar basalt along the Tintina Fault in Finlayson Lake map area that was considered of the same age (Tempelman-Kluit, in press) has recently been shown to be Eocene by Jackson (198-). Lherzolite nodules from Wolverine Volcano, one of the extrusive centres, were described by Sinclair et al. (1978).

9.STRUCTURAL GEOLOGY

The project area has three structurally superposed elements. From the base they are an autochthon, a ductilely deformed complex and a sheet deformed by brittle faults (Fig. 27). The autochthon includes late Proterozoic and Paleozoic ancestral North American rocks, which were metamorphosed and deformed in the Jura-Cretaceous. The ductilely deformed complex, several kilometres thick, comprises Paleozoic(?) sedimentary, volcanic and granitic rocks deformed and metamorphosed in the Jurassic. And the brittle deformed sheet, also several kilometres thick, is of Mesozoic volcanic and sedimentary rocks folded and faulted in the Jura-Cretaceous.

The upper and lower elements, the brittle deformed sheet and the autochthon, are broken by spaced faults and folded. Between faults these elements retain sensible stratigraphy. By contrast much of the middle element is penetratively deformed and particularly in the lower half its stratigraphy is mostly obliterated. The upper several kilometres of this zone is weakly strained and retains stratigraphic integrity.

Boundaries between elements are faults; those between the ductilely deformed and autochthonous parts are ductile faults parallel to the moderately dipping foliation. Those with the brittle deformed sheet are steep-dipping strike-slips, which merge with the ductile foliation.

In plan (Fig. 9) the autochthon is represented by Cassiar Platform on the northeast of the project area and by Yukon Crystalline Terrane on the southwest. The upper, brittle deformed sheet, Whitehorse Trough, occupies a large northwest trending zone that crosses the project area diagonally. And the middle slice, collectively called Yukon Cataclastic Terrane, occupies a discontinuous zone around Whitehorse Trough.

The style of deformation differs dramatically between the three elements and characterizes them as distinctly as their stratigraphy. The autochthon is a thrust belt, the ductile slab a mylonite zone and the brittle deformed slab a zone of transpressional strike-slip. Structures in Cassiar Platform are thrusts spaced at 1 or 2 km; between thrusts are large folds. By contrast the structure of Yukon Crystalline Terrane is dominated by minor folds which deform a metamorphic fabric coincident with compositional layering. This is deformation characteristic of the interior of mountain belts. Whitehorse Trough rocks are broken by steep dipping, northwest trending, strike-slips between which the strata are folded into large upright folds. The style is dextral transpressional. The ductilely deformed rocks are a complex of large sheets, each hundreds or thousands of metres thick, separated by ductile faults parallel to the pervasive flaser fabric in this element.

Deformation in the three elements, excepting the Yukon Crystalline Terrane, may be coeval; the deformation spans for each overlap in the Late Jurassic. Thrusting and folding in Cassiar Platform is post-Triassic and pre-mid-Cretaceous. Penetrative strain in the ductilely deformed zone is probably Jurassic. And strike-slip in Whitehorse Trough occurred between the Middle Jurassic and mid-Cretaceous. Yukon Crystalline Terrane deformation falls outside the Jurassic interval - it may be Paleozoic.

Fabric in the ductilely deformed rocks dips under Whitehorse Trough from the northeast and southwest and is projected underneath. The ductilely deformed rocks are interpreted as the zone along which Whitehorse Trough is detached from the autochthon.

Whitehorse Trough is apparently a slab separated structurally from the autochthon by Yukon Cataclastic Terrane. The latter absorbed the shear strain due to movement between the two. The upper and lower plates each slipped with respect to the ductilely deformed rocks. Relative slip probably varies from place to place as fault blocks in the upper and lower plates moved independently.

Whitehorse Trough is interpreted as the remnant of a fore-arc basin detached structurally from its oceanic basement and plutonic roots. Basement is represented by Atlin Terrane and the Semenof Block, the roots by granodiorite batholiths such as the Tatchun, Granite and Carmacks.

Yukon Cataclastic Terrane may represent the subduction complex of the Lewes River Arc and offscraped sediments (Nisutlin Assemblage), slices of oceanic crust (Anvil Assemblage), the deformed plutons of an oceanic crustal fragment (Simpson Assemblage), slices of the autochthon (Nasina Formation), and the tectonized base of the Lewes River Arc (Atlin Terrane, Tatchun Batholith et al).

Several faults southwest of Whitehorse Trough in Carmacks map area displace the "overlap" assemblages and are later than the others. They are related to the volcanic rocks which they cut. The Big Creek Fault, one of them, may have dropped the Big Creek Syenite several kilometres from the top of the detachment zone into the autochthon.

Structures are described element by element from the base up (Figs. 10, 28). Those of the autochthon, Cassiar Platform and Yukon Crystalline Terrane are described first. Yukon Cataclastic Terrane's minor structures and faults are considered next followed by Whitehorse Trough's bounding faults and internal folds and faults. The "overlap" faults that postdate juxtaposition of the elements are treated separately.

9.1CASSIAR PLATFORM STRUCTURE

Cassiar Platform structure is dominated by eastward directed thrust faults, spaced at 1 or 2 km intervals, and with overlaps of several kilometres each. Strata between the thrusts are folded into open folds with amplitudes of many kilometres (Tempelman-Kluit, in press). The thrusts and folds lie east of the the project area; in eastern Laberge map area Cassiar Plaform rocks form a large west dipping homocline. It is the top of the highest of four large thrust sheets, called the McConnell sheet, and the thrust at its base is exposed outside the project area.

The west edge of the Cassiar Platform is the D'Abbadie Fault, a thrust which separates it from Yukon Cataclastic Terrane.

9.1.1D'ABBADIE FAULT

Near Laberge map area's east edge is a well defined break, that separates metamorphosed ancient North American strata and ductilely deformed rocks of Teslin Suture Zone (Figs. 9, 10, 28). It is called the D'Abbadie Fault for the stream of that name, where outcrop is good. On the east are metamorphosed and deformed strata, which are traced directly into those of the ancient North American Paleozoic miogeocline. On the west are ductilely deformed suspect rocks, which are dismembered stratigraphically and which lack obvious stratigraphic ties to the miogeocline or to Whitehorse Trough. Stratigraphic discontinuity is more obvious in the rocks west of the fault than in those on the east, but those on the east are also penetratively deformed.

The contact is a sharp, innocuous break across a few metres that dips steeply to moderately westward with the foliation of the enclosing rocks. A fault is inferred from the profound stratigraphic discontinuity. In the footwall is graphitic, fine grained quartzite and light grey marble, the metamorphosed dark grey siltstone of the Nasina Formation with limestone lenses. The hanging wall generally has amphibolite included in the Anvil Assemblage, but peridotite, muscovite schist and granodiorite gneiss occur at other places.

The fault is followed northward into Glenlyon map area, where Campbell (1967) mapped it at the east end of Little Salmon Lake and along Drury Lake. At the northwest it must terminate on, or in, the Tintina Fault. It probably dips steeply west here. Campbell recognized that the fault is likely a strike-slip or northeast directed thrust. Southeastward the break is traced into Quiet Lake map area and from there it trends toward Teslin map area. In Quiet Lake map area the fault is folded into a tight syncline which returns the fault to Laberge map area (Tempelman-Kluit, in press). The break is folded over two tight anticlines and an intervening syncline or is repeated by unrecognized fault imbricates and thence trends southeast to the Quiet Lake Batholith. It reappears southeast of the granite about the valley of Sidney Creek in Teslin map area and must continue farther southeast through Teslin map area. Mulligan (1963) mapped strata that belong on opposite sides of the fault in his unit 1.

The klippen of serpentinized peridotite on Dunite Mountain and its companion peak (Fig. 10, 28) were mapped in detail by Erdmer (1982). They are gently west dipping sheets of alpine ultramafics that probably root in Teslin Suture Zone. The fault under them is interpreted as part of D'Abbadie Fault, as is the surface under other klippen farther east outside the project area.

Probably the D'Abbadie Fault slipped about the Jurassic or Early Cretaceous, but critical data are lacking and the timing is based on comparisons with nearby areas with similar relations. The ductilely deformed rocks in the hanging wall are intruded by the Quiet Lake Batholith, which has given K/Ar ages as old as 83 Ma. Micas in the metamorphosed hanging wall rocks of the McNeill Klippen gave K/Ar ages of 226 and 230 Ma - Early Triassic. Slip occurred between then and the mid-Cretaceous.

Displacement on D'Abbadie Fault is unknown. No strata are matched across it locally or on the grander scale. The fault brings penetratively and ductilely deformed, metamorphosed, suspect rocks above less metamorphosed North American strata. Klippen of the suspect rocks are locally preserved as much as 130 km northeast of the Suture Zone in adjacent Quiet Lake map area.

9.2STRUCTURES OF YUKON CRYSTALLINE TERRANE

Yukon Crystalline Terrane's metamorphic rocks in southwestern Carmacks map area have a well developed schistosity that is folded on the outcrop and map scale (Fig. 11). Small scale and large structures are described separately.

9.2.1MINOR STRUCTURES

The metamorphic rocks of Yukon Crystalline Terrane southwest of Whitehorse Trough have a well developed, regularly oriented foliation parallel to compositional layering. The foliation is a coarse schistosity, not a ductile strain fabric like that of the Yukon Cataclastic Terrane. It may be a strongly recrystallized ductile strain fabric, but it is more continuous and lithologic members are followed more readily than in the cataclastic rocks. Foliation trends northeast at right angles to Whitehorse Trough and Yukon Cataclastic Terrane trends. Southward outside the project area the schistosity changes to northwesterly strike (Tempelman-Kluit, 1974). Mineral lineations and wrinkles in the coarse grained schists trend northeast and plunge gently also across Whitehorse Trough trends (Fig. 11).

If the deformation and metamorphism are coeval the mid-Permian U/Pb discord age of zircon (ca 250 Ma) is a clue to the time of folding. It and the structural discordance between Yukon Crystalline and Yukon Cataclastic terranes suggest that the two were deformed independently, the schists and gneisses before the mylonites and before Whitehorse Trough was thrust over them both. The schist's structure and metamorphism are unaffected by those younger events. If the zircon age determination is interpreted correctly their metamorphic and structural history also differs from that of ancient North American Paleozoic strata northeast of Whitehorse Trough, their speculated counterparts.

9.2.2LARGE STRUCTURES

The fabric and compositional layering in Yukon Crystalline Terrane are folded by open, symmetrical, northeast trending folds. Two structures, the Maloney Syncline and an unnamed anticline 15 km to the southeast are recognized and mapped (Fig. 11). Limbs dip moderately, about 20 or 30° southeast or northwest. On outcrop scale foliation is also folded into subisoclinal recumbent folds with undetermined vergence. Between Sekulmun and Aishihik lakes in Aishihik Lake map area such folds trend northwest and verge southwest.

9.2.2.1FOLDS

The folds may be second phase structures superposed on a large isoclinal nappe, which is hypothesized on the basis of inverted metamorphic grade. The most strongly granitized rocks in the sequence are expected near the base, but occur at the top. If this inversion is structural a thrust or large nappe are responsible. If a nappe explains it the granitized rocks in the core of Maloney Syncline must outline its axis. If a thrust is the answer the fault lies between the dominantly schistose and the dominantly gneissic parts. If a nappe exists it likely closes on the southeast; gneiss in the nappe's core is absent southeast of the Maloney folds, but amphibolite, which may mark the fold closure, is abundant there. The gently plunging lineation argues against large early folds, but can be accommodated by early thrusts.

Ultramafic rocks and amphibolite interfoliated, with the schist and gneiss may be thrust over the metasedimentary rocks. If so the thrust stack was metamorphosed and folded after thrusting; the zircon age says before the latest Permian. These are different relations and emplacement times than for similar rocks of the Anvil Assemblage. Perhaps they are not Anvil Assemblage slices and signal a separate collision or the age determination is interpreted wrongly.

9.3STRUCTURE OF THE DETACHMENT ZONE

The detachment zone between Whitehorse Trough and the autochthon has a base and a top which are separated by ductile faults or foliation parallel contacts. The base has the ductilely deformed rocks of Yukon Cataclastic Terrane. It is bounded by moderately dipping ductile faults and includes the Nisutlin, Anvil and Simpson Allochthonous assemblages. Measured across the fabric it is about 10 km thick in Teslin Suture Zone, thinner elsewhere. The top is a weakly sheared zone of granites and oceanic rocks bounded by steep faults. It includes the Semenof Block and Atlin Terrane and the Tatchun, Granite and Aishihik batholiths. It too is several kilometres thick. The detachment zone's top of weakly sheared rocks is locally absent, as northwest of Tatchun Batholith, and the ductilely deformed rocks abut directly against those of Whitehorse Trough. Elsewhere the detachment's sheared base is missing. The southeast side of Aishihik Baholith is an example.

The Big Salmon Fault represents the boundary between the top and base of the detachment. It is the only large fault within the detachment. The equivalent boundary on the southwest side is that between Selwyn Gneiss and the Granite Batholith north of Big Creek and north of Selkirk Creek. Those contacts may be faulted, but are interpreted as interfoliated.

9.3.1BIG SALMON FAULT

Big Salmon valley presumably marks an important fault (Figs. 10, 11, 28); ductilely deformed Teslin Suture Zone rocks are juxtaposed next to much less strained Pennsylvanian strata of the Semenof Block. It may follow a strike-slip with large offset or a dip-slip fault. Little outcrop occurs near the valley, but at its southeast end, in Fish Creek, northeast of Boswell Mountain, the fault is close to outcrop on both sides. Here the metamorphic change across the fault is small; the sheared metamorphic rocks on the east abut phyllites interpreted as Boswell Formation strata.

No stratigraphic ties can be made across the Big Salmon Fault, but the ductilely deformed rocks may be sheared equivalents of strata in the Semenof Block. Thus the Semenof Formation's basalt may be the precursor for Anvil Assemblage amphibolite and the clastic and carbonate rocks of the Boswell Formation may be represented by sheared sedimentary rocks and marble in the Nisutlin Assemblage. In Laberge map area no ultramafic rocks are known in the Semenof Formation to match those in the Anvil Assemblage, but such rocks do occur in the Semenof Block along Little Salmon River in Glenlyon map area. Some distinctive units of the Boswell Formation, the red and green greywacke for example, are not recognized in the Nisutlin Assemblage.

Big Salmon Fault continues northward into Glenlyon map area and may join the break between ductilely deformed rocks in the Big Salmon Range and Tummel Basin mapped by Campbell (1967) (Fig. 28). Alternatively the fault may continue roughly along the northern edge of the Tatchun Batholith toward Tatlmain Lake or it may split into two branches. No fault is mapped here, but because the fault is in structurally the same position as the southwest contact of the Granite Batholith, that with the Selwyn Gneiss, a ductile fault is likely. Although outcrop is poor the relations mapped by Campbell (1967) permit this interpretation. If there is a fault along the northeast side of Tatchun Batholith it presumably dips southwest and swings and joins the Semenof Fault beyond Towhata Lake.

Southwest of Little Salmon Lake the relations are the same as in Laberge map area-Semenof Block against Teslin Suture Zone. The Semenof Block ends on the northwest about the valley of Little Salmon River. The valley may mark an east trending, unrecognized fault or an intrusive contact with Tatchun Batholith. The Big Salmon and Teslin faults converge southeastward and may join near Rosy and Swift lakes in Teslin map area (Mulligan, 1963).

The Big Salmon Fault probably dips southwest with the foliation of Teslin Suture Zone strata and because it brings weakly metamorphosed rocks above higher grade strata omitting intermediate grade rocks. Amphibolite grade metamorphic rocks are structurally overlain by unsheared, greenschist facies strata so the fault straddles the brittle-ductile transition. It may be a normal fault with unknown dip-slip. Alternatively it may be a strike-slip, but no offset strata can be matched across it. If it is a strike-slip the displacement could be large.

Lokken Batholith in northern Laberge map area encompasses the youngest dated rocks truncated by the Big Salmon Fault. Its granodiorite has given a K/Ar model age of 185 Ma and if this is the intrusive age, the fault is Middle Jurassic or younger. If the age represents the time of the batholith's uplift the fault is late Lower Jurassic or younger. If the fault continues along northeastern Tatchun Batholith the radiometric ages (162, 160, 144 Ma) of that intrusion date the displacement more closely. At the southwest corner of Laberge map area the fault is apparently overlain by ash flows of the Open Creek volcanics indicating that movement was complete by the Late Cretaceous. Most likely the fault slipped during the Jura-Cretaceous; the time of dextral slip on the Teslin system.

The Big Creek Fault was apparently reactivated about the Pliocene, when the Walsh Creek beds were deposited along a scarp localized near it. West side down dip-slip is indicated in this event. The Walsh Fault (Fig. 28) is a dextral tear (with 3 km slip) or northwest side down normal fault across the Big Salmon Fault. It moved during or after deposition of the Pliocene Walsh Creek beds.

9.3.2MINOR STRUCTURES IN THE DUCTILELY DEFORMED ROCKS

The ductilely deformed rocks exposed on opposite sides of Whitehorse Trough fall in the same three broad lithologic groupings. The Nisutlin Assemblage matches nicely across the Trough and amphibolite and serpentinite in south central Carmacks map area southwest of the Trough may be Anvil Assemblage equivalents. The Selwyn Gneiss is similarly considered to be the Simpson Assemblage's equivalent. The rocks occur in the roughly same structural sequence on opposite sides of the Trough: Nisutlin Assemblage is lowest and Anvil and Simpson assemblages lie above. Detailed lithologic correlation is no more possible across the Trough than on one side. Lithologic members are laterally discontinuous; they are sheared out.

Contacts between the assemblages are also the same on opposite sides of Whitehorse Trough; they are ductile faults developed under penetrative shear conditions. Thus contacts between the Nisutlin and Anvil Assemblage rocks are sharp, fabric parallel breaks without lithologic gradation. Locally the rocks are interfoliated across the contact. The contact between Nisutlin and Simpson Assemblage rocks southwest of the Trough, at Selkirk Creek for example, is the same - a sharp break oriented in the foliation. The Selwyn Gneiss-Granite Batholith contact, just north of Big Creek for example, is interfoliated. Granodiorite, which is foliated weakly to moderately near the contact, contains schlieren or folia of gneiss. The contact is parallel to foliation in the gneiss and dips moderately northeast. The granodiorite was evidently intruded during the strain. It was foliated with the gneiss as it cooled before 142 Ma, the K/Ar cooling age. The same relations are seen at the contact between Selwyn Gneiss and the granodiorite southwest of Fort Selkirk and the relations for the northeast contact of Tatchun Batholith are postulated to be the same.

Fabrics in the ductilely deformed rocks are also similar on opposite sides of Whitehorse Trough. They are dominated by penetrative flaser fabrics which dip under the Trough from the northeast and southwest. Bedding and other depositional features are masked or destroyed by the fabric. Other minor structures include colour and compositional lamination, lineation and small scale folds transposed on a crenulation cleavage. Fabrics are generally better developed in Nisutlin Assemblage and Nasina Formation slices than in Anvil Assemblage amphibolites.

Foliation ranges from a fine flaser to a coarse schistosity or gneissosity. In mylonite and protomylonite it is extremely closely spaced and results from parallel layers of crushed and recrystallized minerals bent around few large grains. By contrast blastomylonite schist has a schistosity that reflects its form-oriented, recrystallized micas and quartz. In mylonite, grains commonly 0.005 mm across, are strung out into a very fine and intense fabric. In blastomylonite micas are commonly 0.05 mm thick and two to five times as large in the plane of the fabric. The mylonite schist has still coarser grains and its fabric is rougher. In amphibolite the foliation is given by strongly oriented actinolite needles about 0.01 mm thick. The same range in grain size and consequent variation in coarseness of fabric is seen as in more siliceous rocks, and the rocks range to amphibole gneiss.

Colour lamination or streaking is compositional and reflects variation in the proportion of micas and quartz-feldspar matrix between laminae. Quartzofeldspathic laminae are generally thicker than micaceous layers. In mylonite the laminae are thinner than a millimetre; in the mylonite schist they may be 2 or 3 mm thick. Laminae are parallel, but laterally discontinuous in detail. They coalesce and split in anastomosing patterns along their length. Colour lamination is common in the coarser grained amphibolites; it results from segregation of feldspar and amphibole in separate laminae 1 or 2 mm thick.

Form oriented, elongate quartz grains in the blastomylonite and mylonite schist also give the rocks a spectacular and common rodding lineation. Quartz grains are ovoids with axial ratios about 1:2:4. The lineation is strong in quartz rich layers; micaceous laminae have an accompanying crinkle lineation. Lineation by preferred orientation of acicular actinolite is present locally in amphibolite.

On both sides of Whitehorse Trough the planar fabrics are commonly folded over small-scale folds, but folds are commonest in northeastern Carmacks map area. They range from open and upright, to isoclinal and recumbent, flexures. The two fold types are gradational; they are considered the arrested stages of a deformation continuum carried to various stages of completion in different places. Open folds have limb angles near 90°, sharp hinges, amplitudes of several centimetres and steeply dipping axial planes along which recrystallization is rare. Tighter folds are progressively more recumbent, with rounder axes and amplitudes of many centimetres or tens of centimetres. The folds are generally transposed on a newer crenulation foliation which cuts the limbs and which localized recrystallization. In places the folds are isoclinal and the new foliation is sub- parallel with the older. The small scale folds seem to be haphazardly distributed; few are seen in large areas, but else- where they are common. The open folds are locally superposed on the subisoclinal types, but generally one style is seen at one place. Folds are more common in the mylonite schist and blastomylonite than in mylonite or protomylonite. Open folds are commonest in micaceous blastomylonite; quartz-rich varieties have tighter folds. Folds are rare in the amphibolite.

Fabrics, minor structures and textures in the strained rocks reflect arrested development during concurrent, repeated strain and metamorphism. Mineral textures reflect the relative timing and dominance of grain growth by metamorphic regrowth, versus grain destruction by high strain rates. The rocks are made up of metamorphic minerals without detrital grains or volcanic or plutonic crystals. Yet the minerals are bent, crushed and strained in most rocks, showing that some strain postdates metamorphic mineral growth. In the same rocks the crushed and strained groundmass is recrystallized and healed and in other places metamorphic minerals are grown across the flaser. Regrowth and strain therefore accompanied each other.

Foliation in Teslin Suture Zone dips 40° or more: uniformly to the west-southwest. Lineation, also consistent in Teslin Suture Zone, plunges northwest at moderate to steep angles. In Carmacks map area, northeast of Whitehorse Trough, foliation trends northwest consistently, but the dip varies from moderately northeast to southwest. Presumably the foliation is broadly folded. Lineation also trends northwest plunging gently. Nisutlin and Simpson Assemblage strata southwest of Whitehorse Trough dip consistently northeast at moderate angles. Lineation plunges eastward locally; too few observations were made to know its general trend.

Metamorphism and deformation occurred during the Late Triassic and/or Jurassic and most likely the Early to Middle Jurassic. No radiometric age determinations were made on the rocks in the project area, but micas from equivalent rocks nearby are dated by the K/Ar method. Micas from Simpson Assemblage near Finlayson Lake gave 183 and 201 Ma and those from Nisutlin Assemblage around McNeil Lake gave 226 and 230 Ma. Equivalent rocks from near Dawson gave 160, 161, 168, 175, 178, 181, 182, 187, and 202 Ma. The range may reflect cooling during a protracted interval or incomplete argon loss about 160 Ma ago - the youngest determined age.

Intrusions into?, on? the ductilely deformed rocks point to the Jurassic as the time of strain. The Granite, Tatchun, Carmacks and Aishihik batholiths and Minto Pluton intruded the ductilely deformed rocks during strain; they are interfoliated at the margins. Intrusion of Minto Pluton, one of the bodies, is Early Jurassic as dated by the concordant 192 Ma U/Pb date of its zircon. Last argon loss was during the Late Jurassic as shown by the 160 Ma ages.

9.4STRUCTURES AROUND WHITEHORSE TROUGH

Whitehorse Trough is bounded by faults (Figs. 9, 28); on the northeast is the Teslin, Mason, Boswell, Hootalinqua, Semenof set and on the southwest are the Carmacks, Hoochekoo, Ingersoll and Selkirk faults. Faults northeast of the Trough are interpreted as right slips and all part of one system, those on the southwest are also considered to be right slips. Internally the Trough is also cut by many interconnected faults which are interpreted as part of the Teslin Fault system, a strike-slip with large dextral offset. The faults distribute the dextral strike-slip over a system of faults instead of single breaks. Parallel faults are connected through restraining and releasing double bends and folds are part of the strike-slip story.

The faults trend northwest and dip steeply. In cross-section they presumably end downward in, or on, the detachment zone because they can not be followed into that zone. They may merge with, or be cut by, the detachment or both. In any case the strike-slips are interpreted as confined to the detached slab and shallowly rooted.

In Laberge map area the Teslin Fault's displacement is largely transferred away from the Teslin Fault into two main branches, a northeastern one marked by extension basins and a southwestern one with compressional structures. The northeast branch is called the Semenof system, the southwestern is the Chain system. The northeast branch incorporates the Mason, Boswell and Hootalinqua faults, which define two releasing double bends in the trace of the Teslin Fault system. Extension basins are localized where strain is transferred between the two _en echelon_ breaks. The Teslin system's southwestern branch follows the Chain, Braeburn and Big Creek faults. Their displacement is transferred through connectors, the Open and Fairview faults, which are interpreted as restraining bends in the strike-slip system.

While the main and early slip on Whitehorse Trough's bounding faults is transcurrent late extensional displacement of a few kilometres is possible. Breaks such as the Semenof and Carmacks faults bring the Trough's essentially unmetamorphosed strata next to weakly metamorphosed beds. K/Ar age determinations on granodiorites around Whitehorse Trough suggest that some, such as the Tatchun and Granite batholiths, last rose through the argon retention isotherm about 140 Ma ago. This can be interpreted to mean that the granites rose relative to Whitehorse Trough about the earliest Cretaceous. If so the faults dip steeply inward to the Trough and slip could be 1 or 2 km. The Big Salmon Fault which also brings low grade rocks directly above high grade may also have dip-slip. The Big Salmon, Teslin, Semenof, Carmacks, Hoochekoo and Selkirk faults may all have suffered late dip-slip.

Other structures in Whitehorse Trough, mainly tight synclines, tighter anticlines and faults that displace them are part of the general dextral slip pattern. They relate to the northwestward slip of Whitehorse Trough along Chain and Teslin faults and above the detachment zone.

9.4.1STRUCTURES ON WHITEHORSE TROUGH'S NORTHEAST MARGIN

Whitehorse Trough's northeast margin is faulted on dextral breaks collectively called the Semenof Fault system. It includes the Teslin, Boswell and Semenof faults and their extensional connecting faults (connectors), the Mason and Hootalinqua faults. They are strike-slips whose dextral sense is defined by the geometry of extension basins along the connectors. Their displacement is interpreted to be large because the rocks juxtaposed are unrelated; Whitehorse Trough's nearest possible match northeast of the Teslin Fault system is 1000 km away. The time of slip is Late Jurassic; it is defined by several rocks including dated feldspar porphyry dykes intruded along the faults.

9.4.1.1SEMENOF FAULT AND FAULT SYSTEM

The Semenof Fault is inferred on the northeast edge of Whitehorse Trough where the Semenof Formation abuts volcanic and volcaniclastic rocks of the Lewes River Group. Both units are greenstones and difficult to distinguish, so that the fault locus is poorly constrained where these rocks abut. In Carmacks map area the fault brings the Lewes River Group next to Tatchun Batholith - no intrusive relations are seen. The fault is not exposed and no minor strain features related to it were noted in the walls. The Semenof Fault is inferred to be part of a system whose juxtaposition relations are similar.

The Semenof Fault system is an interconnected set of dextral strike-slips along the northeastern margin of Whitehorse Trough (Fig. 28). Master faults trend N35^{o}W; connectors strike nearly north. The fault system separates the Lewes River Group from the Semenof Formation; units that are not seen in stratigraphic context anywhere. The system's main breaks are the Semenof and Teslin faults and their subsidiaries are the Hootalinqua, Boswell and Mason faults.

Displacement is transferred from the Teslin to the Semenof Fault through connectors. Where the master fault loses displacement, indicated by abrupt decrease in stratigraphic omission, its slip is transferred. Thus the Semenof Fault's offset decreases suddenly where it is intersected by the Hootalinqua Fault. Southeast of this fork the Semenof Fault juxtaposes two panels of the Semenof Formation with opposing dips; small displacement. But northeast of the junction the Semenof Fault separates Lewes River Group greenstone from Semenof Formation basalt. Teslin Fault shows similar evidence of profound slip loss northwest of Mason Fault. It brings Lewes River and Laberge Group beds next to each other northwest of its transfer-minor slip compared to that required southeast of Mason Fault where the Semenof Block's Boswell Formation and Whitehorse Trough beds are side by side.

Small basins filled with Tantalus Formation are evidence of the dextral displacement sense. The basins lie along the connectors between the Teslin and Semenof faults in the displacement transfer zone. Given the plan geometry they can only have formed with dextral slip on the Semenof Fault system (Fig. 29).

The small Tantalus basins in the displacement transfer zone presumably formed and filled during strike-slip. The Tantalus Formation in the extension basins is not dated. The Tantalus on Whitehorse Trough's southwest margin may be as young as Albian or as old as Late Jurassic and it may not be coeval with that in the northeastern basins. The best guess for the age of the basin fill is Late Jurassic through Early Cretaceous.

Evidence for the time of slip on the Semenof Fault may be the K/Ar ages determined for the granodiorite of Tatchun Batholith. Three samples gave ages of 162, 160 and 144 Ma which probably reflect the time of uplift, not the intrusive age of the granite. Late Jurassic displacement is indicated if the uplift accompanied strike slip.

Hootalinqua Fault is inferred because it places Semenof Formation next to the Lewes River Group - the same relations as the two master faults. It also brings together the Semenof and Tantalus formations. Relations are not conclusive, but the fault is apparently overlapped by the Open Creek volcanics just south of Klondike Bend. If so the model K/Ar age of 83.4 Ma on those rocks near Hootalinqua shows that displacement had ceased by the Late Cretaceous. Hootalinqua Fault strikes N10°W.

Boswell Fault is a break inferred between, and parallel to, the Teslin and Semenof master faults. It is required because along the short stretch between the Hootalinqua and Mason faults the Semenof Formation is beside the Tantalus. This is interpreted as the fault's large offset stretch. Northwest of the Hootalinqua Fault the inferred fault doubles the Lewes River Group and southeast of the Mason Fault it puts the Boswell and Semenof formations against each other - both minor offsets compared with that in the short central stretch.

Mason Fault is required by the map geometry because a moderately northeast dipping panel of the Boswell Formation trends directly into vertical Tantalus beds across Teslin River. A connector is therefore inferred between the Boswell and Teslin faults. The break itself is not exposed and the trend is constrained between N8°W and N20°E. In other Tantalus basins along connector faults the beds dip moderately. The steep dips here require substantial slip on the faults slipped following some or all Tantalus deposition and this supports the idea that the faults and basins evolved simultaneously.

9.4.1.2TESLIN FAULT

The Teslin Fault (Fig. 28) is required by juxtaposed unrelated strata - the Boswell and Lewes River Group. Its trace is not tightly constrained by outcrop and the fault is not exposed. It slices diagonally northwest across Laberge and into Carmacks map area and is named for the Teslin River, which it follows for part of its length.

Southeast of its junction with the Mason and Open faults it juxtaposes Boswell Formation and Lewes River Group beds; northwest of there it is placed where the Tatchun Belt Lewes River Group abuts the Laberge Group. The displacement northwest of the Mason Fault is probably small compared with that southeast of there.

The fault is the northern extension of a system that has been traced southward at least to central British Columbia (Fig. 30). South of Teslin Lake in northern B.C. the break is called the Kutcho Fault and still farther south it is offset by the Finlay Fault from near Fort St. James, where it is the Pinchi Fault. For much of its length, in and outside the project area, the fault juxtaposes unrelated strata of different age.

Offset on the Teslin Fault system is gauged by matching displaced strata. Whitehorse Trough is truncated on the northeast by the fault. Its nearest correlative northeast of the fault system is in northern B.C. near Tuya Lake, about 350 km southeast of the project area, but the best match on the opposite side of the Teslin-Kutcho-Finlay-Pinchi faults is with beds mapped as Takla Group east of Fort St. James - fully 1000 km southeast of Laberge map area (Fig. 30). The Takla Group in this area contains Lower Jurassic strata which have not been differentiated (Tipper, pers. comm., 1985).

9.4.1.3TATCHUN FAULT

The Tatchun Fault in eastern Carmacks and adjacent Glenlyon map areas (Fig. 28) is not exposed, but is inferred because Lewes River Group strata lie next to those of the Laberge Group along the northern side of Tatchun Lake-Yukon River Valley. These are the same relations as seen across the Teslin Fault in northern Laberge map area. The Tatchun and Teslin faults define a wedge. Perhaps Tatchun Fault broke from the Teslin to isolate the wedge when dextral slip was transferred from the Teslin Fault to Semenof and Chain faults. Early in the Teslin's history it was dextral, but when dextral slip was transferred Tatchun Fault formed to accommodate the sinistral slip. Thus the relative slip in the faults bounding the wedge may be opposite - dextral on the Teslin, sinistral on the Tatchun. Tatchun Fault has the more profound juxtaposition of the two. Campbell (1967) did not map the fault in Glenlyon map area, but relations northeast of Frenchman Lake are the same as in Carmacks map area - permissive.

9.4.2WHITEHORSE TROUGH'S SOUTHWESTERN BOUNDING FAULTS

Like its northeast boundary Whitehorse Trough's southwestern edge is also faulted (Fig. 28). Displacement is inferred to be dextral, extension basins at double bends define the sense, and broadly the same age as on the northeast. Three faults, likely parts of one break, are distinguished. The Carmacks, Hoochekoo and Selkirk faults juxtapose Lewes River Group against Late Jurassic granitic rocks across steep dipping contacts. Rocks on either side are commonly sheared and foliated unlike those at other faults where wall rocks lack penetrative strain.

Time of slip is Latest Jurassic or Early Cretaceous as indicated by K/Ar model ages. Granites, which give ages between 180 Ma and 142 Ma, are faulted against Trough strata; they were presumably raised through the argon retention isotherm during strike-slip. Assuming incomplete argon loss during uplift means that the ages only limit the oldest time of slip and implies that the youngest ages probably approximate the time of slip. Slip is most likely Earliest Cretaceous. The data resembles that for the Semenof Fault in Carmacks map area. Tatchun Batholith, which is cut by the Semenof Fault, has given K/Ar ages in the same range as those on the southwestern intrusions (162, 160 and 144 Ma) placing the same time constraints on the Semenof and Carmacks Fault systems.

The largest patches of the Carmacks Group, those around Mount Pitts and Prospector Mountain, that west of Carmacks, that around Satasha Lake in Aishihik Lake map area and that in the Miners

Range, lie near, or on, the southwestern boundary faults and are not displaced. The Carmacks volcanics evidently flowed over the faulted contact during the Late Cretaceous.

9.4.2.1CARMACKS FAULT

The contact between Whitehorse Trough beds and the Carmacks, Aishihik and Long Lake batholiths in Aishihik Lake map area is called the Carmacks Fault; in central Carmacks map area it is the Hoochekoo Fault (Fig. 28). Faults are inferred because instead of intrusive relations the rocks are sheared and metamorphosed to greenschist facies. In northeastern Aishihik Lake map area Tempelman-Kluit (1974) mapped Lewes River Group volcanics against Carmacks batholith along a broadly curved, steep dipping contact. Though not mapped as such, a fault that swings through an a 40° arc from N20°E at the south to N20°W at the northern end is inferred. The volcanics are sheared over a several hundred metres wide zone and the shear zone parallels foliation in the granodiorite and follows the contact. Northward and southward the contact runs under Carmacks Group strata, which it does not offset on map scale.

Granodiorite of Carmacks and Aishihik batholiths has given several K/Ar model ages which cluster near 160 Ma (Fig. 10). As argued elsewhwere the ages probably reflect a structural event, not the time of intrusion. About 160 Ma, the early Late Jurassic, the granites rose tectonically through the argon retention isotherm and this dates Carmacks Fault slip.

The Carmacks Fault runs northward into Carmacks map area and disappears there under a cover of the Carmacks Group. The fault presumably joins the Hoochekoo Fault along a north trending connector which is now covered. The Hoochekoo and Carmacks faults have the same juxtaposition relations and fabrics. Occurrences of the thickest known Tantalus Formation generally along the trend of this hypothesized connector dextral slip on the Carmacks and Hoochekoo faults. If the Tantalus extension basin was created by extension across the connector dextral slip is required on the main faults.

9.4.2.2HOOCHEKOO FAULT

Hoochekoo Fault, the N55^{o}W trending break postulated northwest of Five Finger Rapid has relations like those of the Carmacks Fault for part of its length (Fig. 28). The Granite Batholith is faulted directly against the Lewes River Group across a steep dipping contact without intrusive relations. Rocks on either side are sheared and metamorphosed to greenschist facies implying displacement at substantial depth. The fault is not exposed, but follows a topographic break.

Northwest of Ingersoll Fault the Hoochekoo Fault juxtaposes Carmacks Group strata. This is a reactivated the older structure. Last movement on Hoochekoo Fault postdates the Carmacks Group; the fault's northeastern extension along Dark Creek cuts those strata, but they are unsheared. Two slip stages, early wrenching coeval with last cooling of the Granite Batholith and later (post Carmacks) north side down dip-slip, are deduced from this. The early stage is dated the same way as for the Carmacks Fault, by the K/Ar model age of 142 Ma on Granite Batholith. It shows that the intrusion rose, tectonically?, in the earliest Cretaceous. Hoochekoo Fault is traced southeastward to the Chain Fault and may be joined near Carmacks by the Braeburn Fault.

The Hoochekoo Fault is presumed to be a dextral strike-slip because of its hypothesized connection to the Carmacks Fault.

9.4.2.3INGERSOLL FAULT

Ingersoll Fault at the northwest end of Whitehorse Trough is inferred because it juxtaposes Carmacks and Lewes River Group strata (Fig. 28). It trends N25°W and is interpreted to merge with the Hoochekoo Fault at the southeast. At the northwest it ends inconspicuously in a covered area in Yukon River Valley. Displacement is Tertiary and presumably related to the second stage of Hoochekoo Fault offset. It is likely a normal break that dips southwest and on which the southwest side fell relative to the northeast side. Hoochekoo Fault probably follows the older boundary between Minto Pluton and Lewes River Group strata.

Ingersoll Fault presumably joins the Selkirk and Hoochekoo faults. It defines a bend in the southwestern fault system which should localize an extension basin if the displacement is dextral. The small Tantalus basin just east of, and parallel to, the fault is it.

9.4.2.4SELKIRK FAULT

The contact between Povoas Formation and foliated hornblende granodiorite is exposed in northeastern Carmacks map area on both sides of Yukon River (Fig. 28). Both units are foliated and a 50 m thick granodiorite lens occurs in the volcanics near the contact. Foliation dips steeply northeast and the contact is interpreted to dip steeply in the same direction. Relations are the same as those at the Carmacks and Hoochekoo faults; this too is assumed to be faulted and the slip is considered coeval with the uplift of the granitic rocks. Samples of Minto Pluton have given three Middle Jurassic K/Ar ages of 174, 177 and 180 Ma (Fig. 10) although the rock was intruded at 192 Ma, the U/Pb age of its zircon. Incomplete argon loss during uplift may explain the difference between Minto Pluton and Granite Batholith ages and the 142 Ma age on the latter is considered closest to the displacement event.

The sense of displacement on the Selkirk Fault is not independently defined. However the break trends east for 10 or 15 km south of Victoria Rock. If Selkirk Fault is sinistral extension is expected along this stretch; the absence of a Tantalus basin here suggests dextral slip, the same as the Carmacks and Hoochekoo faults. The east trending stretch of the fault should have reverse movement or thrust relations. Unfortunately the outcrop is too poor to see any evidence.

9.4.3FAULTS UNDER WHITEHORSE TROUGH

The Laberge Faults in Whitehorse map area (Fig. 28) are the contact between Whitehorse Trough and the underlying Atlin Terrane. They are a pair of steep dipping breaks on opposite sides of a northwestward narrowing, 50 km long, finger of Permo-Triassic strata faulted against Whitehorse Trough strata. They occupy the same structural position as the faults on the northeast and southwest sides of Whitehorse Trough, but the fault separation is greater. Laberge Group beds are juxtaposed next Cache Creek Group equivalents.

9.4.3.1LABERGE FAULTS AND RELATED FOLDS

Four kilometres west of Lake Laberge at the northern edge of Whitehorse map area Wheeler (1961) mapped a 2 km long, northwest trending lens of ultramafic rocks between Laberge Group strata (Fig. 31). Relations between the ultramafics and the Laberge Group beds are not exposed. On trend with the ultramafics to the southeast, across the covered Yukon River Valley, are probable Permo-Triassic volcanic rocks (Wheeler's units A and Aa, perhaps Atlin Terrane eqivalents, possibly also equivalents of the Semenof Formation of this report) with a few other lenses of ultramafics.

Contacts dip steeply judging from the map trace and because rocks and structures are truncated (Permo-Triassic rocks are juxtaposed directly against the Laberge Group without intervening Lewes River Group beds) the contacts are interpreted as faults -

here called the Laberge Faults. Wheeler (1961) did not map faults, but Morrison (1981) showed faults in his reinterpretation of Whitehorse map area.

Whitehorse Trough strata are considered an upper plate; those of the Permo-Triassic units are thought of as the lower. The faults may be the bowed up detachment under Whitehorse Trough or detachment that was mechanically injected into its structural cover on new faults.

Upper plate folds end against the lower plate faulted horst and do not match it in amplitude or wave length (Fig. 31). The lower plate horst is a northwestward narrowing wedge faulted into the upper. In a 20 km stretch from near Whitehorse where it is 3 km wide it narrows to zero. The upper plate folds are bundles of tightly appressed, upright structures, which angle toward the lower plate arch on both sides southwest of Jackfish Bay. Individual folds are traced for 10 or 15 km. Their wave length is a couple of kilometres and their amplitude is a half to one kilometre. The southwestern folds are truncated obliquely by the faulted lower plate arch, those on the opposite margin apparently not. Northwestward the ultramafic rocks end and disappear innocuously with the faults under, or in, the fold bundle, and still further northwest the number of folds decreases. Aeromagnetic data indicate that the ultramafic rocks continue about 10 km under the Laberge Group. The folds only involve Laberge Group strata, neither the Lewes River Group from above the detachment, nor the Permo-Triassic rocks from below it, are folded. The folds occupy substantial zones, 8 km wide southwest and 6 km northeast of the basement arch. Because some folds terminate against the Permo-Triassic horst and bear no direct relationship to the arch the folds probably predate the faults.

Like many folds in Whitehorse Trough those southwest of Jackfish Bay are not simple flexures, but faults that juxtapose homoclines, commonly with opposing dips. The structures are tight, have planar limbs and lack hinges because the apices are faulted. In many folds the northeast limbs dip less steeply than the opposite limbs. The southwest limbs are locally overturned. Northeast limbs dip 50° or more, southwest limbs at 60° or more; the apical angle is commonly about 30°. The axial faults follow one limb or the other, commonly the steeper. Southwest of Jackfish Bay the orientation hints at southwestward directed asymmetry, but this is by no means general. Opposite fold limbs juxtapose generally equivalent strata and because of this the axial faults are probably not normal or reverse, but strike-slip. The sense and amount of slip is not independently determined.

Their proximity to the dextral slips of Whitehorse Trough might suggest that the Laberge Faults are dextral strike-slips related to the Teslin system. But unlike Whitehorse Trough's dextral slips they are, or displace, the upper-lower plate contact, but are not upper plate faults. The Laberge Faults are either dip-slips that cut and reactivated the contact between Whitehorse Trough and its basement or they are that contact bowed up. They need not be dextral or even strike-slip.

The Laberge Faults may be the extension of the Big Creek Fault, which is thought to be strictly a lower plate plate break. They are on trend and only upper plate strata and their Carmacks Group cover separates them. The Big Creek Fault is argued to be younger than the Laberge Faults.

At the southeast the Laberge Faults enter the Atlin Terrane northeast of Little Atlin Lake (as mapped by Morrison, 1979). They probably merge with the main strand of the Teslin Fault near the south end of Teslin Lake south of the B.C.-Yukon border.

Independent evidence for the time of slip on the Laberge Faults is lacking. Displacement is assumed to be coeval with that on the Teslin and Carmacks faults - Late Jurassic and/or Early Cretaceous.

9.5STRUCTURES IN WHITEHORSE TROUGH

9.5.1CHAIN FAULT SYSTEM

The Chain Fault system is the Teslin Fault's second, main dextral strike-slip branch (Fig. 28). In contrast to the Semenof transfer array, which is extensional, the Chain system is considered a compressional transfer. The Chain system's master breaks are the Chain, Braeburn and Big Creek faults; the Open and Fairview faults are connectors. Mandanna and Twin Lakes faults and folds and the folds and faults in the wedge between Open and Teslin faults are parts of the compressional slip transfer.

9.5.1.1Chain Fault

Chain Fault is inferred from the map pattern because different parts of the Lewes River and Laberge groups abut each other with inconsistent structural relations. The fault itself was not seen and mostly follows low ground. Near Teslin Crossing on the northeast side of the postulated fault are strata stratigraphically much lower than those on the other side. Elsewhere the stratigraphic separation is minor with stratigraphically lower beds on one side at some places and on the other side elsewhere. Units on the Chain Fault's southwest side trend into, and are truncated obliquely by, the break, those on the northeast strike in the same direction as the fault.

Chain Fault extends from its junction with the Open Fault in southeastern Laberge map area the the Hoochekoo Fault near Five Finger Rapids in Carmacks map area. Between the Fairview and Hoochekoo faults the Chain Fault is defined by the truncated segments of Carmacks Group strata, but in the rest of this section the fault juxtaposes Tanglefoot strata next to each other. At the forks with the Open Fault displacement is transferred from the Chain Fault to the Teslin system and at its junction with the Fairview Fault part of its displacement is transferred onto the Braeburn Fault.

Displacement on Chain Fault is difficult may be gauged by the two truncated segments of Carmacks Group on opposite sides of the fault. If these were once connected, about 20 km of Late Cretaceous or younger dextral offset is indicated. The fault is assumed to also have Jura-Cretaceous displacement because it is part of the Teslin system. The amount of Jura-Cretaceous dextral slip may be measured by the length of the two compressional transfers, the Open and Fairview faults, they are 35 and 50 km long. Chain Fault offset is interpreted to equal their total.

Chain Fault need not have any Jura-Cretaceous strike-slip northwest of its junction with the Fairview Fault if all its strike-slip is transferred to the Fairview Fault. The possible 20 km post-Carmacks time offset on the Chain Fault in Carmacks map area may therefore be the total displacement on that strand of the Chain Fault. In effect the Chain Fault of Carmacks map area could be a Tertiary break that connects two older, previously unconnected faults.

9.5.1.2Braeburn Fault

Like other faults in the project area the Braeburn Fault, on the southwest side of Whitehorse Trough (Fig. 28), is not exposed but inferred from its effects on the geology. The fault follows Nordenskiold valley and its locus closely limited; strata and structures on opposite sides are truncated obliquely. A few kilometres west of Carmacks the fault is apparently overlapped by the Carmacks Group. It trends N20^{o}W, which is 15 degrees more northerly than other large dextral faults in the region. Its separation is not profound nor consistently of one sense; one side has the stratigraphically higher beds at one place, the other has them some distance away. Stratigraphically equivalent beds are seen on both sides.

At its northern end the Braeburn Fault presumably joins the Big Creek Fault or the Chain-Hoochekoo Fault and on the southeast it apparently dies in the broken folds on St. Hilary Mountain, just west of Little Fox Lake. Beyond there it cannot be recognized. The fold on St. Hilary Mountain is a paired asymmetrical syncline and anticline that verges east.

Tempelman-Kluit (1974) did not map the Braeburn Fault in Aishihik Lake map area, but Lewes River and Laberge Group strata abut each other across Nordenskiold valley and a fault is possible here.

The total strike-slip on the Braeburn Fault is unknown, but the sense and a minimum displacement are defined by offset Tantalus Formation and Nordenskiold Dacite. At its southern end the fault separates two bands of Tantalus Formation, that may have been one to begin; 8 km of right hand offset is required. This is the same amount by which parallel strips of Nordenskiold Dacite are offset on the same fault. The Braeburn Fault is assumed to be coeval with, complementary to, and synthetic of, the Teslin Fault. If so most of the slip should have occurred during Tantalus deposition so that the 8 km of post Tantalus slip is a minimum.

The Carmacks volcanics on both sides of the Braeburn Fault near Carmacks can not be traced across the inferred fault trace, but come close enough that they need not be offset. Braeburn Fault slip was apparently completed during or before the Late Cretaceous. But the Tantalus is truncated and at least some movement postdates its deposition, which is possibly Albian (Lowey, 1984).

Two faults are inferred in the acute triangular wedge between the Braeburn and Fairview faults near Twin Lakes (Fig. 32). At the southeast they merge with the Fairview Fault or continue to the Frank Fault and at the northwest these two presumably end against the Braeburn Fault. They are postulated because strata in the wedge are truncated at acute angles. The northern fault truncates the Tanglefoot Syncline; the southern one cuts off the Conglomerate Mountain homocline. These two breaks presumably allowed the wedge between the Chain and Fairview faults to tighten while it was squeezed between them as it moved southeast. The Twin Lakes faults have roughly the same arrangement with respect to their two masters as the Mandanna Fault pair to its controlling breaks (Fig. 32).

9.5.1.3Fairview Fault

The Fairview Fault in northwestern Laberge map area (Figs. 27, 32) is the steep dipping, north trending (N05^{o}W) break connecting the Chain and Braeburn faults. It is not exposed, but is postulated from truncated strata and structures; its locus is closely defined because outcrop is good. It cuts Lewes River and Laberge Group strata and generally puts the Casca Formation on the east side against Nordenskiold Dacite. The Fairview Fault truncates strata obliquely - on the east side for a stretch and on the west side in the next segment.

Stratigraphy on either side is roughly the same; extreme displacement can be ruled out. The amount and sense of slip are not gauged from the map as no unique match is seen across it. Nor is there evidence that closely defines the time of slip; Laberge group beds are the youngest that are cut.

From its geometry the Fairview Fault is assumed to be the transpressional connector between the Braeburn and Chain master faults. As such it should be antithetic to the dextral slips, that is its movement is expected to be left handed, as it transfers right slip be between the two synthetic masters. Presumably it originated as an antithetic Riedel shear between the dextral structures. The implications are explored elsewhere.

9.5.1.4Mandanna Fault and related structures

Two faults are postulated on the basis of truncated stratigraphy and structure in the acute-angled wedge between the Fairview and Chain faults in northwestern Laberge map area (Fig. 32). Outcrop here is good and the control on the locus of structures excellent. The straight traces imply steep dips for the faults.

Mandanna Fault trends westnorthwest (N75°W). Generally the southern side dropped relative to the northern, but the main movement may be strike-slip. If the large northeast dipping homoclines of Lewes River Group strata on opposite sides were one before faulting, about 9 km of dextral slip is indicated by matching the top of the Lewes River Group. Mandanna Syncline, which has no match across the fault, shows that the fault is not a simple strike-slip, but a tear with different structures on opposite sides.

A second fault, unnamed on the map, but north of the Mandanna Fault, angles northwest from the junction of the Mandanna and Chain faults. Like the Mandanna Fault it connects the Chain and Fairview faults. Near its southern union it truncates two tight folds that trend into it from the northern side and brings them directly against a northeast dipping panel of Nordenskiold Dacite. By contrast strata on the northwest end of the fault, near its Fairview Fault junction, nearly match across it. This implies that the northeastern side of this tear fault is unevenly tightened; more at the east than at the west. The paired folds on the northern side have tightened that side with respect to the southern side. As with Mandanna syncline the folds are considered a consequence of, and contemporaneous with, the faulting.

Mandanna Syncline is a northwest trending (N40°W) fold south of the Mandanna Fault (Fig. 32); it parallels the dextral faults. Near its termination against Mandanna Fault it is broken by a fault along its axis, but southeastward it is an open fold with moderately dipping limbs. It is considered an example of how some Whitehorse Trough faults may have evolved from folds. Initial tightening created the fold; further displacement broke the hinge. Continued displacement might displace the limbs so that all signs of their former connection are lost.

Structures are more tightly appressed against the Chain Fault than against the Fairview. This may mean that the Chain Fault had more displacement than the Fairview Fault.

The compressional wedges between the Chain and Fairview faults and between the Braeburn and Fairview faults have symmetrical fold-fault geometries (Fig. 32). The Twin Lakes faults and their masters, the Fairview and Braeburn faults are mirrors of the Mandanna faults between the Fairview and Chain faults. Mandanna Syncline and Tanglefoot Syncline are analoguous as are the northern Twin Lake and southern Mandanna faults and so on. The panel between the two connector faults strikes generally parallel to the connectors in both examples while strata in the blocks north and south of the connectors trend roughly with the master faults in both instances.

From their spatial relationship the Chain, Fairview, Braeburn, Twin Lakes and Mandanna faults and the Mandanna and Tanglefoot synclines are considered complementary parts of one dextral slip system. The wedge between the Chain and Fairview faults moved northwest relative to strata west of the Fairview Fault. Similarly the wedge between the Braeburn and Fairview faults slipped southwest. The structures in the apices presumably accommodated constriction during slip.

9.5.1.5Open Fault

Open Fault (N20^{o}W), in southern Laberge map area (Fig. 28), is inferred to explain the truncated beds and structures that trend into Open Creek Valley from the southeast. The fault locus is poorly constrained by outcrop and the fault itself is not exposed. At the southern edge of Laberge map area the fault juxtaposes probable Lewes River Group against Mount Nansen correlatives. Farther north Lewes River Group of the Tatchun Belt and Whitehorse Trough occur on opposite sides.

Like the Fairview Fault the Open Fault is interpreted as antithetic to the dextral fault system. It is a left-slip break joining the Teslin and Chain faults just as the Fairview connects the Chain and Braeburn faults left handedly. Both breaks transfer displacement away from the Teslin Fault to an en echelon synthetic partner decreasing offset on the Teslin Fault. Although their effect is the same as that on the extensional or synthetic transfer Hootalinqua-Boswell-Mason faults the offset sense is opposite.

In the triangle between Open and Teslin Fault are several west-northwest trending faults and folds, assumed to be compressional structures in the wedge between the faults. They may be analogues of the Mandanna Fault and folds or of the faults and folds between the Fairview and Braeburn faults east of Twin Lakes.

At the southern boundary of Laberge map area the Open Fault cuts volcanics correlated with the Mount Nansen Group. The age of the volcanics is considered to be Early Cretaceous on the basis of a 118 Ma age determined on presumed granite relatives. If correct last displacement on Open Fault may be Late Cretaceous or younger. The Open Creek Volcanics do not demonstrably cut or overlie the Open Fault although they approach it closely.

Open Fault trends toward Whitehorse map area, but Wheeler (1961) did not map its extension in Whitehorse map area. The fault may end close to the mutual map area boundary.

9.5.2EARLY STRUCTURES SOUTHWEST OF CHAIN FAULT

Povoas Anticline and its bounding breaks, the Goddard, Ogilvie, Miller and Thomas faults are the largest structures southwest of the Chain Fault (Fig. 28). Innumerable smaller, secondary structures are seen southwest and northeast of Povoas Anticline. The anticline forms a large, rigid, tectonically high element between two lower blocks which expose stratigraphically higher units and which are folded and broken by faults. Most structures southwest of the Chain Fault trend between north and northwest. They are thought to have formed during a short interval coincident with slip on the Chain Fault system.

9.5.2.1Povoas Anticline

Povoas Anticline in central Laberge map area is defined by opposed dips of Lewes River Group strata. Much of the anticline is underlain by the Povoas Formation, but the structure is outlined by the flanking beds of the Aksala Formation. The fold is unique within Whitehorse Trough because it is a long, unbroken fold (100 km long including 30 km in Whitehorse map area, 8 km wide). It is a gently arched, north-northwest trending horst of Lewes River Group strata flanked by blocks of generally younger strata from which it is separated by the Goddard-Ogilvie and Miller-Thomas faults. The lower blocks on either side are broken by faults and intricately folded on map scale, but the arch is intact. At the north the arch is truncated obliquely by the Chain Fault; at the south it apparently ends against the Laberge

Fault in Whitehorse map area. Fold limbs dip about 20°; the east limb locally dips more steeply than the west giving a hint of easterly vergence. The amplitude is about a kilometre.

Povoas Anticline with its bounding faults is considered as the rigid member in the block southwest of the Chain Fault that moved northwest. It is thought of as an 8 km wide horse between the Goddard-Ogilvie and Miller-Thomas faults that slid northwest and rotated anticlockwise as it moved. Its western bounding faults should be compressional left slip breaks - its eastern faults compressional and right handed.

Povoas Anticline may represent a buckle presumably formed in response to the general dextral disruption in Whitehorse Trough during slip on the Chain Fault. Chain Fault is a transverse tear across the fold.

9.5.2.2Goddard, Ogilvie, Miller and Thomas Faults

The Goddard and Ogilvie faults (Fig. 28), companions with similar relations on the west side of Povoas Anticline, generally cut Lewes River Group strata. For much of their length they are closely defined by stratigraphic cutoffs and truncated structures. Thus the Goddard Fault is hypothesized from the southern boundary of Laberge map area generally along the eastern shore of Lake Laberge and thence to Frank Lake and the Ogilvie Fault from northwestern Lake Laberge to near Frank Lake. The fault east of Ptarmigan Syncline is interpreted as the continuation of Ogilvie Fault; it ends against a cross fault just northwest of Richthofen Island. Between the Casca and Aksala faults the Goddard and

Ogilvie are hypothetical. Both faults trend N15°W for most of their length except between the Casca and Aksala faults where they presumably strike more easterly with Povoas Anticline. The Goddard Fault juxtaposes Lewes River Group next to itself and the Ogilvie places Lewes River Group next to Laberge strata. The faults themselves were not seen. Though younger than many folds and faults, both are cut by the Aksala and Casca faults. No evidence for the sense or amount of slip is seen in the field data, but their west side fell relative to the east because stratigraphically lower rocks occur on their east sides. Time of slip is not constrained closely as the faults cut a range of strata are presumably they have a common origin.

The faults strike parallel to compressional transfers, such as the Fairview Fault, but do not connect the Chain Fault to an analogue of the Braeburn Fault. The structures expected in the acute angled wedge of such connectors are also missing.

The faults separate a rigid block, Povoas Anticline east of them, from a thoroughly disrupted block on the west. They permitted slip between the unfaulted Povoas Anticline and the two western adjacent broken blocks which are strained differently. Thus the Goddard and Ogilvie faults allowed more compression on the west than on the east. They separate three panels, the eastern is the least disrupted by faults and the western the most, the central panel has intermediate strain. The Hancock Hills on Lake Laberge's east shore display the complexity of this internal deformation nicely (see map).

If the Povoas block is rotated anticlockwise as predicted from simple shear orientations and if its relative slip was northwest along Chain Fault, the Goddard and Ogilvie faults are sinistral. Both are also compressional. They dip steeply if the straight trace is the criterion - possibly to the east. The amount of slip (possibly many kilometres) may equal that on all the folds and faults west of them.

Miller and Thomas faults east of Povoas Anticline are also postulated on the basis of truncated strata and structures (Fig. 28). No field evidence defines their amount or sense of slip. As with other faults the stratigraphic separation across them is inconsistent and changes rapidly along the fault trace - a sure sign of transcurrent slip. The time of slip is not closely limited.

Miller Fault is traced from near Miller Lake, the source of its name, to Laberge map area's southern boundary. The fault forks several times along its course, but the name applies to the central strand, that bounding Povoas Anticline. At Teslin Mountain it is presumably cut by Early Cretaceous granite because the fault cannot be traced through. South of the intrusion in Whitehorse map area the fault reappears on the west side of Joe Mountain according to Wheeler (1961); it probably joins the Laberge Fault zone about McClintock Bay on Marsh Lake. In Whitehorse map area Permo-Triassic rocks are exposed east of Miller Fault's extension. The fault evidently has more profound juxtaposition there than in Laberge map area. Northward the

Miller Fault apparently dies by losing omission near its fork with several faults from the southeast. The southeastern faults apparently reduce strike-slip on the Miller Fault.

Thomas Fault, a smaller break than the Miller Fault, is postulated to extend from its fork with the Miller Fault southward to the Laberge map area boundary and slices into the Povoas Anticline. Wheeler (1961) did not map a fault at the boundary, but a candidate for the extension is the fault south of Joe Creek east of peak 5840 mapped by him.

Thomas and Miller faults (Fig. 28) do not transfer strain from the Chain Fault to another through-going break as might be expected from their N15°W trend. They presumably complement faults on the opposite side of Povoas Anticline. Like the Goddard and Ogilvie faults they separate the rigid Povoas Anticline from thoroughly disrupted younger strata. If the Povoas Block, the controlling element, slid northwest and rotated anticlockwise as part of Chain Fault's displacement, faults on its east side must have dextral, compressional slip. As such they may dip steeply west.

Laurier Fault (Fig. 28), in south central Laberge map area, follows Thomas Lake and links the Thomas and Miller faults. Its southern side fell relative to the northern, but displacement need not be entirely dip-slip. The fault is inferred from the profoundly different facies across it; on the north the Lewes River carbonate is thick and well developed, it is thin on the other side. Perhaps the fault follows an old syndepositional break that controlled facies. Laurier Fault allowed differential movement in the wedge between the Miller and Thomas faults.

Faults bounding Povoas Anticline cut Lewes River and Laberge Group strata exclusively. Most slip must postdate deposition of the youngest Laberge beds i.e. the Bajocian Tanglefoot Formation. Lower Cretaceous (118 Ma) granodiorite on Teslin Mountain, which apparently truncates the Miller Fault, may provide a younger limit to the time of movement. As with the other faults slip is limited broadly to the Late Jurassic and Early Cretaceous.

9.5.2.3Structures between Fox Lake and Lake Laberge

Laberge Group beds between Lake Laberge and Fox Lake are folded into tight anticlines and synclines and broken by steep dipping faults (Fig. 33). Northwest trending folds are generally obliquely truncated by faults at both ends. Folds and faults trend northwest between ten and seventy degrees west of north. No consistent angular relationship is seen between the folds and faults. The structures are interrpreted as part of the general dextral slip.

Some folds can be matched across faults showing that they predate the faults; other folds can not be followed so that some faults and folds are evidently coeval.

9.5.2.4Surprise and Edith Folds and Faults

This set of N40^{o}W trending structures includes two parallel faults, which separate two open synclines of Conglomerate Formation, the Surprise and Edith synclines (Fig. 33). The folds are roughly 3 km across; their amplitude is a third that or less. Edith Fault, between the two synclines, may be only a broken fold; dips away from it are generally steep. Surprise Fault is also a broken anticline, but with moderately dipping limbs. Strike-slip can not be ruled out on either fault. In its core the Surprise Fault exposes upper beds of the Lewes River Group, lower strata than in its companion fault. Surprise Syncline and the Surprise and Edith faults may end against the Ogilvie Fault on the southwest or may continue across Lake Laberge to merge with structures in the Hancock Hills. On the map Edith Fault is hypothesized to cross the lake, but Surprise Fault and Syncline are shown as truncated. Edith Syncline diverges from its companion structures and ends against the same fault as Ptarmigan Syncline. At the northwest the structures apparently end against Casca Fault as they cannot be traced farther.

On Mistake Mountain just west of Lower Laberge a thick, steep dipping panel of the Conglomerate Formation is juxtaposed against gently dipping Lewes River Group beds. A fault, which trends N15°W, is therefore postulated between the Casca and Surprise faults (Fig. 33). Near its southern termination the panel of Conglomerate Formation dips steeply northeast, farther north it is vertical or dips steeply southwest. It may represent the continuation of the southwest dipping panel of the same rocks west of Coghlan Lake and/or the Conglomerate Formation in Surprise Syncline. The tectonic gymnastics that produced the three panel configuration of Conglomerate Formation, west of Coghlan Lake, on Mistake Mountain and in Surprise Syncline are not understood.

9.5.2.5Ptarmigan Syncline

Ptarmigan syncline is the north trending fold along Lake Laberge's west shore (Fig. 33). It is a 3 km wide, tight fold, which widens slightly southward. Limbs, outlined by thick beds of the Conglomerate Formation, dip steeply. At the north the fold is truncated obliquely by the Edith Fault and at the south it is offset 2 km left handedly on a the same small northwest trending fault that truncates Edith Syncline. Ptarmigan Syncline's west and east sides are interpreted as faults. The west boundary is marked by opposed dips in different strata; this is not just a broken anticline it must have dip-slip or strike-slip. The eastern fault separates the Richthofen and Conglomerate formations. Both units dip steeply west and if the fault also dips that way this is a reverse fault or strike-slip.

It is tempting to consider Ptarmigan and Surprise synclines as one across the Edith Fault; they contain the same tightly folded conglomerate and their ends are close together. Possibly the Surprise and Edith synclines and the intervening Edith Fault formed as parallel structures. Ptarmigan and Surprise synclines were one and the Edith Fault was one with the fault west of the Ptarmigan Syncline. With dextral slip on the Ogilvie Fault the structures were rotated anticlockwise and bent as they became confined between Ogilvie and Fairview faults. The Edith Fault then cut into this bend isolating the northwestern and southeastern segments. Surprise Syncline, now separate from Ptarmigan Syncline continued to rotate while Ptarmigan Syncline was aligned along Ogilvie Fault. This hypothetical evolution implies dextral slip on the Edith Fault in the late stages and that Surprise and Ptarmigan synclines and Edith Fault are larger, more evolved, analogues of the faulted syncline at Anticline Mountain. It also implies that the faults bounding Ptarmigan Syncline are the abandoned Surprise (on the east) and Edith (on the west) faults.

Two small wedges of Conglomerate Formation south of Ptarmigan Syncline are separated from the fold by faults. The northern wedge is presumably the syncline's west limb isolated by a sinistral break; the second wedge may be its east limb isolated by the Ogilvie Fault. The second wedge is rotated about 30° anticlockwise, or its converse in the opposite direction, with respect to the rest of the fold and displaced dextrally on Ogilvie Fault.

9.5.2.6Richthofen Fault

This fault, named after the island in Lake Laberge, strikes northwest from near the island along the northeast side of Fox Lake (Fig. 33). Its locus is not as tightly constrained as that of many other faults, but is required by the juxtaposition of different Laberge Group Formations near Little Fox Lake and is indicated by truncated bedding trends southeastward near Richthofen Island. Anticline Syncline and two other folds are truncated in the intervening section. The amount and sense of slip is unknown; its trend (N40°W) parallel to the other dextral faults suggests the same sense of slip.

Two northwest trending faults are inferred on either side of Richthofen Fault because strata and structures are truncated. The amount of displacement is unknown, but the trend suggests dextral slip.

9.5.2.7Anticline Syncline

On Anticline Mountain is a broken and displaced syncline (Fig. 33). The fold, nicely outlined by the Nordenskiold Dacite and Tanglefoot Formation, is fairly open with limb dips of 30 or 40° at the west and trends N55°W. It is cut obliquely and displaced about 3 km to the right across a steep dipping fault that trends N70°W. Cairnes (1910) recognized the fold, and thinking it an anticline, perhaps because of the opposed dips across the fault, named the mountain.

The faulted fold is a neat model for the larger structures because it demonstrates the fold-fault interrelation. Evidently the syncline formed with the fault on its southwest side and as both rotated, through the general dextral slip, the fault cut and displaced its companion fold. The same history is postulated for Surprise and Ptarmigan synclines. And similar relations may hold for the folds truncated against the Richthofen Fault's southern partner.

The north trending, unnamed fault north of Little Fox Lake is inferred because the Anticline Syncline cannot be followed westward and because strata cannot be matched on Braeburn Mountain. Its displacement is not understood.

9.5.2.8Coghlan Faults

Structures east and west of Coghlan Lake (Fig. 33) are the least studied and understood in the project area. West of Coghlan Lake is a rib of the Conglomerate Formation juxtaposed next to the Lewes River Group on the eastern side and against the Tanglefoot Formation on the west. Faults are postulated on both sides to explain the truncated structures and strata and the dip reversals. The eastern break strikes N25°W and dips steeply, the western, also steep, curves and trends more northerly. The breaks terminate against the Frank Fault on the north and on the southeast against the Casca or Aksala faults - structures do not match across those faults.

East of Coghlan Lake two north-northwest trending anticlines separated by a curved steep dipping fault outlined in the Conglomerate and Tanglefoot formations are postulated. Ground control on these folds is poor.

Broadly the faults probably formed with the folds, but the mechanism and the ties to other structures and to possible matching panels of Conglomerate Formation in the Surprise Syncline and on Mistake Mountain are questionmarks. A possible scheme is that the folds began developing, bounding faults formed and later cut by the folds which continued to tighten as they were rotated.

9.5.2.9Structures between Povoas Anticline and Chain Fault

The panel of Laberge Group beds between Povoas Anticline and the Chain Fault is a 15 km wide, 30 km long, open basin with little structural relief (Fig. 28). Beds are subhorizontal or dip gently over large areas, an anomaly in Whitehorse Trough. At the south the basin is truncated by branches of the Miller Fault, which trend N60^{o}W, but at the north the basin is connected to Povoas Anticline.

The faults at the basin's south are well defined breaks recognized by truncated units and structures, and by juxtaposed strata with opposed dips. The breaks join, and end on, the Miller Fault just south of Miller Lake. Southeastward, they die out. They trend toward, but don't join the Chain-Open faults fork. Generally they place the Conglomerate Formation next to the Tanglefoot so that younger strata occur on the north sides. North side down dip-slip may explain the relations, but because of the rapid and irregular stratigraphic omission across some faults strike-slip is likely.

The faults are interpreted as complements of the Miller Fault. With it they isolate a wedge between Povoas Anticline and the basin. If the wedge moved independently it should have pulled away from the basin and Povoas Anticline to account for the lack of deformation north of its apex - in other words it moved southeast relative to the basin and anticline. On this basis the Miller Fault's displacement should be dextral; that on the branches sinistral. The amount of slip was small, perhaps a few kilometres. Large displacement should have opened a basin along the west-northwest trending faults.

The basin may represent an extended zone southwest of Chain Fault. If Teslin Crossing Stock, in the centre, is localized by this extension its age, 173 to 186 Ma, dates the.

9.5.3LATE STRUCTURES SOUTHWEST OF CHAIN FAULT

Three faults truncate folds and faults indiscriminately on the southwest side of the Chain Fault and trend at large angles to the other structures. They are the northeast striking Frank Fault and the east and southeast striking Casca and Aksala faults, Whitehorse Trough's newest breaks. Their distinctive trends reflect stress conditions or a history different from those of the other structures.

9.5.3.1Casca and Aksala Faults

The Casca and Aksala faults (Figs. 28, 33) are prominent and easily recognized, because they cut all other structures, commonly at large angles. Casca Fault is traced from near Miller Lake west-northwestward to near Braeburn. It is well defined along Casca Creek where the Aksala Formation is placed abruptly against Povoas Formation. At the northwest the fault explains the abrupt end of the panel of Conglomerate Formation west of Coghlan Lake. Aksala Fault is defined by the abrupt southward termination of the Goddard Fault and by the displacement of Povoas Anticline. Its westward extension from Mount Lewes to the Casca Fault is hypothetical. Both faults postdate other folds and faults and their last movement is younger than displacement on the Goddard and Ogilvie faults and Povoas Anticline because they displace and rotate those structures. They likely formed late in the strike-slip history of Whitehorse Trough when other structures were no longer favourably oriented in the stress field.

Povoas Anticline is displaced to the left across the Aksala and Casca faults, but the Goddard Fault may be displaced to the right. The Goddard Fault displacement across the Casca and Aksala faults is poorly constrained. The amount of slip as measured by the offset of Povoas Anticline is small for the Aksala and 6 km for the Casca Fault.

Between the Casca and Aksala faults the Povoas Anticline is rotated 45^{o} clockwise with respect to the segments north and south. This is opposite to the sense of rotation of the fold and other structures southwest of Chain Fault. Their sense of rotation opposite that of the other structures implies that they formed when the Chain Fault and the associated counterclockwise pivoting had ceased. The faults and their opposite rotation may be related to slip on the Carmacks, Hoochekoo and Selkirk faults, which are considered to have slipped opposite to the dextral faults and which could have opposite rotation associated.

9.5.3.2Frank Fault

Frank Fault, the northeast trending break that links the Braeburn and Chain faults (Figs. 28, 33), differs from other faults in its strike and in its juxtaposition of contrasting facies. It is a clearly defined break that separates profoundly different strata and generally juxtaposes the Laberge and Lewes River groups. The subaerial facies of the Nordenskiold Dacite, in its best development north of the fault, is hardly present to the south; the equivalent unit on the fault's south side is the Conglomerate Formation.

Frank Fault truncates Mandanna Syncline and a second asymmetrical syncline outlined by Lewes River Group strata near Braeburn. Both folds trend directly into it from the northwest. It also cuts structures that strike into it from the southeast. Structures are as difficult to match across the fault as the strata. The fault dips steeply and is probably transpressional. Its slip sense is unknown from field relations, but its trend is antithetic to the dextral faults; left slip is likely.

Frank Fault may be a reactivated syndepositional fault because of the facies jump across it, but it must also have late displacement to account for the relations on opposite sides. During Lewes River time it had no effect so presumably had not yet formed. By Nordenskiold Dacite time the block to the north was raised so that subaerial dacite was deposited while the Conglomerate Formation accumulated on the southern block. It was revived late in Whitehorse Trough dextral slip as a convenient strain path.

9.5.4HYPOTHETICAL EXTENSION FAULTS IN WHITEHORSE TROUGH

Small occurrences of the Tantalus Formation at widely separated localities are difficult to explain without postulating extension faults to create the depressions in which to accumulate the unit. Along Claire Creek in northernmost Laberge map area is one such occurrence (Fig. 22). A 5 km long, northwest trending sliver of Tantalus beds is enclosed by volcanics correlated with the Povoas Formation. Beds are nearly vertical. The sliver is probably faulted on the northeast and southwest; the faults can not be traced far because there is no contrast in lithology. Likely the faults are part of the Semenof to Teslin strain transfer and these beds may have been deposited in an extensional basin like those associated with the Mason and Hootalinqua faults. Because beds are vertical and the sliver trends northwest the basin must be compressed more than those depressions and rotated. This implies substantial movement after basin filling.

Along the southwestern margin of Whitehorse Trough are other Tantalus Formation occurrences which seem to require extension for the depressions. But they are more difficult to relate to large strike-slips than the northeastern Tantalus basins because if they abut faults these contacts are covered by the Carmacks Group. In central Carmacks map area a few kilometres south of Minto is one northwest trending sliver of Tantalus strata about 7 km long and 1 km wide (Fig. 22). Outcrop is poor and the bedding orientation is unknown; like the Claire Creek sliver it may stand on end. The same sort of relations are postulated as on the Claire Creek sliver and the fault traces joining the Hoochekoo and Teslin faults are hypothetical. The Tantalus at this locality may mark a small basin formed by extension related to dextral slip on the Ingersoll-Hoochekoo faults.

The Tantalus Formation at Carmacks (Fig. 22) is also not as easily related to extension in strike-slip as the basins along Teslin Fault. Northeastern contacts of the Tantalus Formation in this basin are depositional and conformable on the Tanglefoot Formation and the fault at the southeast postdates the folding of the basin fill. The main extensional fault for this basin is predicted to be a north trending fault under the Carmacks Group west of Carmacks (shown dashed on Fig. 28). It presumably marks a releasing double bend between the Carmacks or Braeburn faults and the Hoochekoo Fault. With such a connector only dextral slip on the main faults can explain the geometry.

Tantalus outcrops just southeast of Conglomerate Mountain are stratigraphically tied to the Tanglefoot Formation on the northwest, but faulted against the Fairview Fault at the east (Fig. 22). The outcrop just west of Conglomerate Mountain is fault bounded on three sides. It may fill a small extension basin at the releasing end of the Braeburn Fault, just where strain is transferred to the Fairview.

Corduroy Mountain outcrops of the Tantalus Formation (Fig. 22) are difficult to relate to extension basins connected with strike-slips bounding Whitehorse Trough. The Carmacks Group covers critical boundaries and many contacts on the basin's west are stratigraphic. In Aishihik Lake map area for example, the Tantalus rests disconformably on Tanglefoot Formation and unconformably on Pink Quartz Monzonite. At the northeast contact of Corduroy Mountain the Tantalus is faulted, against Nordenskiold Dacite, but this is not interpreted as a big strike-slip. Nevertheless the 1 km or more of Tantalus Formation is difficult to explain without a structural raison d' etre. Because it marks a place where the Whitehorse Trough widens to the southeast dextral slip on bounding faults and extensional connectors, now covered by the Carmacks Group can explain the geometry. Sinistral slip along the bounding faults would produce compressional relations. An extensional connector from the southern end of the Carmacks Fault under the Carmacks Group and between the two Tantalus outliers on Vowel Mountain and Mount Cooper (Aishihik Lake map area) is therefore hypothesized (Fig. 28).

9.6AGE OF WHITEHORSE TROUGH STRUCTURES

The steep dipping faults in Whitehorse Trough formed broadly during the Jura-Cretaceous. The age of the youngest displaced rocks, the oldest "overlaps", and the age of extension basin beds along the strike-slips constrain timing (Fig. 35). The Tanglefoot Formation (Bajocian) is the youngest involved unit. Teslin Crossing Stock, well dated as late Lower to early Middle Jurassic, provides the same upper limit to the time of slip. Most, or all, strike-slip postdates the early Middle Jurassic.

The age of the Tantalus Formation, the unit deposited in the extension basins, is poorly known. Some could be as young as Albian (ca. 100 Ma) and as old as Late Jurassic. But another, better dated unit, porphyry dykes injected along Teslin Fault between Hootalinqua and Mason Landing, gives a clearer clue (Fig. 10). A 1 km dyke has given a model K/Ar age of 164 Ma - late Middle Jurassic. Displacement was presumably underway and openings created by that time. Radiometric ages on granitic rocks faulted against Whitehorse Trough also date displacement directly. The granites give ages between 180 and 142 Ma (Fig.

12) and assuming that this range reflects incomplete argon loss during the tectonic unroofing by strike-slip the youngest ages, earliest Cretaceous, should most closely approximate the time of slip.

Finally the oldest strata extruded or intruded across the faults are the volcanics on Teslin Mountain - the Mount Nansen Group - and related intrusive rocks, which are dated radiometrically as late Early Cretaceous (118 Ma on Teslin Mountain). Together the data mean that the strike-slip occupied some or all of the 50 Ma interval between about 170 and 120 Ma. The preferred interval for the main displacement is 165 to 140 Ma.

The postulated displacement on the Teslin Fault system, about 1000 km, suggests that all or much of the available 50 Ma span may have been occupied by the strike-slip. Averaged over the available time the displacement occurred at 2 cm annually. Averaged over the shorter, preferred span the rate is 4 cm per year.

Strike-slips and folds in Whitehorse Trough presumably formed during one interval. Folds formed early, the faults later though overlapping in time; many folds are truncated by faults. Of the strike-slips the Casca, Aksala and Frank faults are evidently the youngest; they cut other structures. Whether Whitehorse Trough strike-slips developed systematically and in sequence is not shown by the data. If the dyke age of 164 Ma generally dates slip on the northeastern faults and if the Albian age of the Tantalus at Carmacks does the same for the southwestern faults northeastern faults developed before their southwestern counterparts.

Several faults at the Trough's southwest side, the Hoochekoo, Ingersoll and perhaps the northern end of the Carmacks Fault, were apparently revived to accommodate normal slip following or during Carmacks Group extrusion. This is considered a separate slip episode.

9.7LATE STRUCTURES

Several faults in Yukon Crystalline Terrane evidently postdate the Whitehorse Trough strike-slips; they displace the Carmacks or the Mount Nansen groups. These faults are unrelated to detachment of Whitehorse Trough from the autochthon. They are "overlaps" just as the late stratigraphic units are. Two sets of breaks are distinguished, those related to Mount Nansen Group emplacement and those which offset the Carmacks Group. The first includes the Big Creek and Dawson Range faults and some breaks on Victoria Mountain and Mount Nansen. The second is made up of the Miller Fault, the small unnamed break that crosses the Dawson Range 10 km west of Klaza Mountain, the faults along Dark Creek, and the break northwest of Mount Pitts are probably younger - Latest Cretaceous or Tertiary. The following section describes them.

9.7.1LATE CRETACEOUS FAULTS

9.7.1.1BIG CREEK FAULT

Big Creek Fault, the main break in Yukon Crystalline Terrane strata, is in western Carmacks map area (Fig. 28). It differs from the other large northwest trending faults as it is confined to the autochthon southwest of Whitehorse Trough and displaces younger strata. It cuts detachment zone gneiss and syenite and "overlap" granites and volcanics along Big Creek. It is probably late Cretaceous, younger than the Whitehorse Trough strike-slips. The Big Creek Fault is interpreted as one of a set that bound the Big Creek Syenite. Others of this set are the Dawson Range Fault and the break southeast of Prospector Mountain.

The fault is postulated because several intrusive bodies are truncated across Big Creek. Outcrop is fair and the fault locus is well constrained. The Big Creek Fault is not mapped northwest-ward from Carmacks map area in Snag map area (Tempelman-Kluit, 1974). If it continues there it follows the contact between Klotassin Batholith and the Schist-Gneiss unit.

Big Creek Fault generally juxtaposes Early Jurassic syenite and Cretaceous granite, but it also brings gneiss on the northern side against late Cretaceous granite at Seymour Creek. Near the west margin of Carmacks map area it truncates the Carmacks Group, but the offset may be small. On the southeast the fault apparently disappears under Carmacks Group lavas without disrupting them. The fault strikes N50°W, close to that of the Teslin Fault system.

The amount of Carmacks Group displacement is small compared to that of the older units suggesting substantial or dominant slip before Carmacks time. The old movement may be Late Cretaceous - the granite on the fault's north side is likely mid-Cretaceous. If the Cretaceous granite on the northeast is offset from Coffee Creek granite in Snag map area, 50 to 75 km of

Late Cretaceous dextral slip are required. The syenite on the southwest side is distinctive, but no match is known northeast of the fault; large offset is possible. A problem with postulating tens of kilometres strike-slip is the short trace. The Tertiary movement was probably normal, southwest side down, and because offset is larger near Prospector Mountain than near Carmacks, the slip evidently decreased from northwest to southeast.

The possible large offset in the older rocks where the Big Creek Fault disappears at the southeast suggests that the fault may continue under the Carmacks Group. If related to the Teslin's dextral strike-slips it may join the Braeburn Fault, perhaps near where Rowlinson Creek flows into Nordenskiold River. Alternatively it may connect with the Carmacks Fault which separates Carmacks Batholith and the Lewes River Group in Aishihik Lake map area. In each instance it must be extended into the autochthon unlike other Whitehorse Trough faults.

The possibility that best fits the data is that the Big Creek Fault is a late normal break through Yukon Crystalline Terrane and the detachment. Its apparent large lateral offset results from dropping the Big Creek Syenite from the detachment zone's upper part into the Yukon Crystalline Terrane. The fault presumably dips southwest. If the detachment zone dips northeast at 10° on average as estimated from general cross-sections the dip-slip could be 2 km. Its spatial relationship to the Mount Nansen Group and Casino Granodiorite implies a genetic connection. Perhaps the Big Creek Syenite is the foundered roof of a Mount Nansen Group magma chamber. If so the fault marks the edge on which that roof collapsed. Perhaps the Casino Granodiorite extruded southwestward from under the Big Creek Syenite and causing the roof to fall.

9.7.1.2DAWSON RANGE FAULT

The contact that juxtaposes Jurassic syenite and mid-Cretaceous granodiorite along the Dawson Range is assumed to be faulted because it is abrupt, although no evidence for a fault was seen in outcrops (Fig. 28). Beside the two units mentioned the contact truncates Mount Nansen Group dykes and breccias. The time of slip is post mid-Cretaceous and pre-Late Cretaceous-Casino Granodiorite is cut, Carmacks Group lavas are not.

Perhaps the Dawson Range Fault is best thought of a member of the set which bounds the Big Creek Syenite (with the Big Creek Fault and the southeastern Prospector Mountain fault). They either dropped or raised that block. A clue that they dropped it in relation to its surroundings is that its K/Ar age determinations (142, 152, 184 Ma) are not thermally reset to Late Cretaceous values. If the block had been substantially raised between Coffee Creek Granite and Carmacks Group time, when the faults presumably slipped, the ages should be reset to between 100 and 70 Ma. This idea implies that the syenite could be a block from the top of the detachment zone that has fallen several kilometres. If so the Big Creek Fault's main movement is southwest side down, that on the Dawson Range Fault northeast side down. Similarly the southeastern Prospector Mountain fault dropped the southeast side.

9.7.2TERIARY FAULTS

The younger "overlap" faults include some that reactivated older structures such as the Hoochekoo and Ingersoll faults and others which follow new breaks such as the Miller and Miners faults. Their general northwest strike is presumably inherited from preexisting structures. The southern side on each dropped in relation to the opposite.

9.7.2.1HOOCHEKOO AND INGERSOLL FAULTS

The Hoochekoo and Ingersoll faults are old (Jura-Cretaceous) faults related to Whitehorse Trough strike-slip that were evidently reactivated in the Tertiary because their extensions displace Carmacks Group strata. Tertiary slip on the Hoochekoo Fault and on the unnamed fault along the south side of Minto Pluton dropped a Carmacks Group graben. Each fault could have several hundred metres of Tertiary displacement.

9.7.2.2VICTORIA MOUNTAIN AND MOUNT NANSEN FAULTS

The breaks mapped on Victoria Mountain and on Mount Nansen are inferred because of abrupt juxtapositions across steep dipping contacts. They are comparatively small faults that trend northeast and on which blocks have moved in a dip-slip sense.

The northwestern and northeastern Victoria Mountain faults displace Carmacks Group strata and are therefore inferred to be Tertiary and related to Miller Fault slip; their northern sides fell. The Mount Nansen faults may be related to Mount Nansen Group volcanism. They bring the mid-Cretaceous volcanics against each other and against their basement implying dip-slip.

9.7.2.3MILLER FAULT

The Miller Fault along the north side of Miller Ridge in Carmacks map area is inferred because the Granite Batholith and Carmacks Group are juxtaposed along a straight trace (Figs. 24, 28). The contact presumably dips steeply here and because it is subhorizontal elsewhere a fault is likely. Slip is Tertiary and the southern side fell some hundreds of metres relative to the northern side. The Miller Fault is the same age, scale and sense as the faults along Dark Creek's north side.

9.7.2.4FAULT ON MOUNT PITTS

The northeast trending contact of the Carmacks Group with Nisutlin Assemblage schist a few kilometres northwest of Mount Pitts is interpreted as a pair of faults because of the profound juxtaposition along steep dipping contact. Late Cretaceous volcanic and intrusive rocks abut the ductilely deformed rocks of the detachment zone. Dip-slip of several hundred metres, southeast side down, during the Latest Cretaceous or Tertiary are indicated.

9.7.2.5FAULT WEST OF KLAZA MOUNTAIN

Ten kilometres west of Klaza Mountain is a north trending fault that juxtaposes the upper Carmacks Group against Casino Granodiorite (Fig. 24). Its slip is normal, judging from the trace the fault dips west and the west side dropped relative to the east. Slip occurred in the Latest Cretaceous or Tertiary.

9.7.2.6MINERS FAULT

The Miners Fault northeast of the Miners Range in southwestern Laberge map area (Figs. 24, 28), is hypothesized because marine Nordenskiold Dacite is juxtaposed next to lower Carmacks Group beds without the unconformable relations seen along this contact farther south. Because it displaces Late Cretaceous rocks the fault is Late Cretaceous or Tertiary. As a swarm of Carmacks Group dykes follows the contact just southwest of Richthofen valley slip may have coincided with volcanism. If it is a normal fault it dips to the down-dropped southwest side. A small north trending break offsets the Miners Fault right laterally. This may be a west side down dip-slip; its trace is short for a strike-slip. The Miners Fault could be a caldera-bounding break related to Carmacks volcanism. The faults 15 km north and one and 6 km west of Vowel Mountain (Tempelman-Kluit, 1974) may be relatives. The small faults mapped on Pilot Mountain are small steep dipping normal faults related to Carmacks extrusion.

10.DISCUSSION

The interpretations of the structural data presented here are conjecture. They are offered to inspire questions, and encourage new field work.

10.1WHITEHORSE TROUGH AND YUKON CATACLASTIC TERRANE

Whitehorse Trough is interpreted as the remnant of a volcanic arc basin detached structurally from its own oceanic basement and plutonic roots. The volcanic arc for which Whitehorse Trough is the basin, is the hypothetical Lewes River Arc. Atlin Terrane and the Semenof Block may represent its basement; granodiorite batholiths such as the Tatchun, Granite and Carmacks could be its roots.

Yukon Cataclastic Terrane may represent the subduction complex of the Lewes River Arc and offscraped sediments (Nisutlin Assemblage), slices of oceanic crust (Anvil Assemblage), the deformed plutons of a subducted crustal fragment (Simpson Assemblage), slices of the autochthon (Nasina Formation), and the tectonized base of the Lewes River Arc (Atlin Terrane, Tatchun Batholith et al.)

10.2SPECULATION ABOUT WHITEHORSE TROUGH AND SIMPLE SHEAR

Whitehorse Trough's folds and faults probably formed under simple shear conditions, but fold and fault orientations do not agree with those predicted from a simple shear strain ellipse. Either structures are rotated with respect to each other or the stress field orientation varied. Assuming constancy leads to untenable conclusions about the rotations so it seems that the stress field orientation varied.

Assuming that (a) the faults did form in simple shear, (b) that the stress orientation remained constant and (c) that the main dextral strike-slips, the riedel shears, are not rotated, let us see what rotations will satisfy field relations. The strain ellipse orientation for the folds and faults is then defined by the dextral faults (c above). Thus the main faults correspond to P, Y or R of Figure 34. Extensional connectors, "e" of Figure 34, are expected to strike N20$_{o}$W. The Hootalinqua Fault strikes N10°W, just 10° off that expected; it fits the picture.

Left slip faults such as the Fairview and Open faults, which presumably originated as the R1 or X shears (Fig. 34), should strike N45°E or N70°E. They trend nearly north and must be rotated 45 or 70° anticlockwise under our assumptions. Clockwise rotation is not possible with the Braeburn, Fairview, Chain faults geometry.

Under the assumptions fold trends must also be rotated. If formed in the same simple shear system as the faults they should trend along "f" of Figure 34. In the Teslin system case this is N80°E. In fact none do; they strike between N05°W and N60°W, say N^{35}W on average. Clockwise pivoting of about 55° or anticlockwise rotation of about 125° are required. Clockwise rotation is less, but means that the folds are rotated opposite to the left slip faults - improbable. Counterclockwise rotation means that folds are rotated more than faults, 125° vs 45°. To put this another way, if formed under the same stress orientation and rotated equally left slip faults should trend about 45° counterclockwise of faults - their observed separation is about 45° clockwise. For the folds to be rotated more than the faults implies that they formed and had rotated about 80° before the left-slip faults came into the picture.

The Casca and Aksala faults, two sinistral breaks, subtend an angle of 25°, the same as that between antithetic breaks in a dextral system, i.e. X and Rl of Figure 34. But they trend N70°W and N85°E; if formed with the dextral Teslin system they should strike N45°E and N70°E. They are evidently an antithetic pair pivoted 40° clockwise. Field data provides an independent check. Povoas Anticline between the two faults is rotated 40° clockwise with respect to its extensions outside the wedge, as measured from the map. Casca Fault must have originated as X and Aksala Fault as Rl of Figure 34. These structures rotated opposite to the older ones.

Frank Fault, which trends N45°E, may be an unrotated Rl shear. If so it is sinistral; field relations do not discriminate its sense of slip. It must also be younger than other shears if it is not rotated. Frank Fault postdates northwest trending folds and faults and may be younger than Casca and Aksala faults.

The speculations of tremendous rotations in opposite directions are unreasonable - they imply that the faulted blocks rotated like ball bearings between the dextral faults. Block boundaries, faults and folds should all curve strongly in plan if they evolved during rotation. Counterclockwise rotation is also opposite to that expected in dextral shear. Either simple shear is not the answer or the stress regime was reoriented during deformation. The second alternative of stress reorientations is inescapable. Whether this happened haphazardly or according to some scheme is unknown.

10.3QUESTIONS ABOUT THE DETACHMENT

Whitehorse Trough is separated from the underlying Omineca Belt and Yukon Crystalline Terrane strata by ductilely deformed and sheared rocks, which are interpreted as a detachment zone between them. It absorbed strain during relative displacement. The amount, time and sense of displacement are interesting to speculate about. Some questions are: What do the detachment zone rocks represent - are they the autochthon, the Trough, neither, both? What do the detachment zone boundaries tell us - why are they ductile faults at the base and brittle faults at the top? How thick is the detachment and how much strain has it absorbed? Is all detachment zone strain attributable to relative slip between autochthon and Trough or are there other factors? What is the relative slip between the autochthon and Whitehorse Trough - how allochthonous is Whitehorse Trough? Is the detachment a fundamental zone of decoupling in the crust involving rocks that are fundamentally in place or does it juxtapose different parts of the world? How does the sense of shear in the detachment fit with dextral strike-slip in the upper plate and thrusts in the lower? Are they coeval? How thick is Whitehorse Trough, the upper plate above the detachment? How do upper plate faults, those in Whitehorse Trough, merge with the detachment are they cut by it or the reverse - are they coeval with the detachment's ductile strain - what is their geometry? Most of these questions have ambiguous answers.

We look first at the detachment. It has a distinct bottom and top; the bottom is the several kilometres thick, ductilely deformed part bounded by moderately dipping ductile faults above and below and the top is a weakly sheared zone bounded by steep faults above. The bottom has the three allochthonous assemblages, the Nisutlin, Anvil and Simpson. Measured across the fabric the sheared section is 10 to 15 km thick in the Teslin Suture Zone and thinner elsewhere. For example in the klippen of Finlayson Lake map area they may be only a kilometre or so. The detachment's top includes large blocks of lightly sheared strata, the Semenof Block and the Tatchun, Granite and Aishihik batholiths. This section is also several kilometres thick. The upper part of the detachment zone is locally absent; near Minto, in Carmacks map area, the zone's basal ductile zone abuts directly against northeast Whitehorse Trough. The lower part of the detachment is also absent locally. The southwest contact of Aishihik Batholith is an example where the ductilely deformed rocks are absent. In places, notably at the south end of Lake Laberge, Atlin Terrane is faulted directly against Whitehorse Trough. The Laberge faults are considered the same sorts of structures as the Teslin and Semenof faults and Atlin Terrane is thought structurally analogous to the Semenof Block and the batholiths.

The detachment zone boundaries are faults with lithologic, fabric or metamorphic changes across them. The lower contact is taken as the abrupt, ductile fault between Cassiar Platform and Yukon Cataclastic Terrane beds. It marks a profound lithologic change and although rocks on either side are generally equally metamorphosed footwall beds are less penetratively sheared than hanging wall beds. Under the klippen of Quiet Lake map area the equivalent contact is not only a lithologic and fabric change, but metamorphic as well. The klippen rest on thrusts; their contacts are sharp metamorphic inversions with higher grade, ductilely deformed rocks above lower grade, unstrained strata. The detachment zone base is thus taken as the d'Abbadie Fault on the northeast, the lower contact of Nisutlin Assemblage rocks in Carmacks map area, now intruded by younger granite around Big Creek, and a hypothesized fault along the northeast edge of Aishihik Batholith (not mapped as such in Aishihik Lake map area by Tempelman-Kluit, 1974).

The top boundary of the detachment is drawn between Whitehorse Trough beds and granitic rocks or basalts, strata which are not seen in stratigraphic context. Rocks at this contact have little internal strain or metamorphic contrast. The Teslin and Semenof faults on the northeast and the Selkirk, Hoochekoo and Carmacks faults on the southwest are the surfaces of choice. The Laberge faults are interpreted as equivalent surfaces. The middle boundary of the detachment zone is that between penetratively and weakly sheared rocks, or between allochthonous rocks and possible Whitehorse Trough floor and roots. Northeast of

Whitehorse Trough it is the Big Salmon Fault; on the other side it is the contact between Selwyn Gneiss and the Granite Batholith and that between Aishihik Batholith and Yukon Crystalline Terrane metamorphic rocks. These contacts are not shown as faults on accompanying maps, but relations permit this interpretation.

Detachment zone rocks are mostly unique to the zone and not stratigraphically connected with other elements, but they include a small proportion correlated with the autochthon and some possibly related stratigraphically with Whitehorse Trough. On the northeast the distinctive quartzite correlated with the Nasina Formation forms a small proportion of the detachment zone - it occurs as lenses near the base. Most other strata are distinctive enough to be recognized if present, despite the detachment's strain. Yukon Crystalline Terrane strata are absent in the detachment zone. On the southwest the autochthon is differently strained and metamorphosed than the detachment.

While the lower and upper boundaries of the penetratively sheared rocks dip moderately under Whitehorse Trough from opposite sides the faults at the top of the weakly sheared part seem to dip steeply at surface. Presumably they flatten if Whitehorse Trough is thin, as speculated; it is a puzzle why the gently dipping sections of these faults, surely their most extensive, are not seen - or not recognized.

The steep faults that bound blocks in the detachment's top do not extend into the ductilely deformed rocks as brittle breaks. They may transform downward into ductile faults which merge with the deeper detachment zone fabric or be cut by the detachment.

As visualized and drawn in cross-sections they flatten under Whitehorse Trough, and extend to the top of the ductilely deformed rocks.

Whitehorse Trough is interpreted as a thin sheet above the detachment zone; the cumulative thickness of its strata is no more than 3 or 4 km. Ductilely deformed rocks dip gently or moderately under it from all sides and culminations of structural basement occur in the middle, for example between the Laberge Faults. Projecting the culminations and the detachment zone from the margins suggests that the detachment is only a few kilometres below surface in central Laberge map area.

Whitehorse Trough structures do not reflect the detachment zone culminations. For example the detachment-zone high between the Laberge Faults corresponds to a broad structural low in Whitehorse Trough and Povoas Anticline, an upper plate arch or high block, lies over a depression in the top of the detachment zone as marked by the syncline between basement highs. This means that the depth to detachment, the detachment relief and the subdetachment structure are not predicted by projecting upper plate structures down.

The time of strike-slip in Whitehorse Trough, ductile strain in the detachment and thrusting in the autochthon overlap broadly in the Middle and/or Late Jurassic. Cassiar Platform thrusting and folding is post-Triassic and pre-mid-Cretaceous. Penetrative strain in the detachment is apparently Early or Middle Jurassic and older and the preferred time for strike-slip in Whitehorse Trough is between 165 and 140 Ma - Middle and Late Jurassic.

Unroofing of the granites in the top of the detachment is also Middle or Late Jurassic. Deformation in the autochthon, detachment and upper plate may have proceeded apace.

The amount of strain and its distribution in the detachment zone can be estimated from the fabric and the relations. Judging from fabric penetrativeness and the thickness of the ductilely strained zone hundreds or thousands of kilometres of relative slip may be concentrated in the ductile part of the detachment. The sense of slip suggested by the thrust at the base is that the detachment moved northeast or east over the autochthon. And the strike-slips of Whitehorse Trough suggest that the top moved northwest over the detachment, perhaps 1000 km. The ductilely deformed zone presumably accommodated these displacements; in its base it admitted northeast thrusting, in the top northwest strike-slip.

The strain of both displacements was probably distributed unevenly; the bottom of the detachment zone perhaps admitted most of the northeast slip and the top allowed northwest movement. Whether the strain record in the ductilely deformed rocks is the product of more than one event - for example whether it contains evidence of newer extension unrelated to the events seen here - is unknown. Sense of shear data from the detachment may resolve these questions.

The length of the extension basins measures the local slip along Whitehorse Trough's faults and gives an idea of their scale. The aggregate length of extension basins along the Teslin system is 33 km and that along the Carmacks system is 43 km (in

Whitehorse map area are another 32 km of Tantalus filled basins on the southwest side of Whitehorse Trough). Presumably 75 km is the minimum dextral strike-slip taken up by local structures in the project area. This does not include slip losses by folding or by internal faults. In other words about 75 km of the dextral slip was accomplished by creating openings. An unmeasured amount (probably larger), was accommodated on folds and internal faults. Considering the length of Whitehorse Trough there is plenty of room to accommodate the displacement by internal reorganization.

The amount of strike-slip separation between Whitehorse Trough and its postulated equivalent, the Takla Group across the Teslin Fault system, is about 1000 km. If Whitehorse Trough moved northwest as a block there should be equivalent left hand offset on the opposite side of the Trough. This is not seen. The fault on which the total right hand offset is balanced by equivalent left slip must be outside the area being considered. Also Whitehorse Trough did not move as a block, but as separate, long, northwest trending, dextral fault slivers. These transposed it northwestward and opened extension basins.

The strike-slip of the Trough's bounding and internal faults is presumably gathered in the detachment zone, which is then a gently dipping fault with 1000 km and more top-to-the-northwest slip. The boundary between the base and top of the detachment is the likely strain collector. The detachment zone's base has the same rocks on opposite sides of Whitehorse Trough; so does the zone's top. The granites of Tatchun and Granite, Carmacks and Aishihik batholiths for example are alike and the ductilely deformed rocks across the Trough are similarly indistinguishable. Large strike-slip within the detachment must be between the top and bottom, between the granites and the penetratively sheared rocks. Northeast of Whitehorse Trough the total slip on this collector is equal to that along the Big Salmon Fault. Where the Teslin Fault joins the detachment another 1000 km of slip must be transferred to this surface and under the Carmacks Fault system still more, unknown, displacement is added. The contact between the Granite Batholith and Selwyn Gneiss and its continuation, that between Aishihik Batholith and Yukon Crystalline Terrane, therefore should be a fault on which the slip totalling that on the Big Salmon, Teslin and Carmacks systems is transmitted to the southwest or balanced by equivalent left slip. Most likely the right slip is transferred to the southwest and balanced by left slip in the Coast Mountains.

Large displacement is likely within the autochthon under the detachment; on opposite sides of Whitehorse Trough the autochthon differs. Cassiar Platform and Yukon Crystalline Terrane may include equivalent stratigraphy, but have different metamorphic and deformation histories. The boundary between them could be a Late Paleozoic strike-slip (Fig. 36). It could also be a thrust fault of that vintage. Yet another possibility is that Yukon Crystalline Terrane is a crustal wedge driven into the detachment zone under Whitehorse Trough toward Cassiar Platform. If so the ductilely deformed rocks are the roof and floor of Yukon Crystalline Terrane (Fig. 36).

How fundamental the zone of detachment is remains speculation. The ductilely deformed base may represent the subduction zone under the Whitehorse Trough, that is the ancient North American margin and its offshore edge subducted westward under Whitehorse Trough. The brittle deformed top may be the root and floor of the volcanic arc, which was detached from its superstructure during obduction of Whitehorse Trough over ancient North America. If so the detachment is the zone on which a volcanic arc overrode the ancient North American margin as modelled elsewhere (Tempelman-Kluit, 1979). The overlap of the arc on the autochthon is then even larger than suggested opined earlier and the arc's root must be southwest of Yukon Crystalline Terrane, perhaps in the Coast Ranges. In this case the top of the detachment is presumably part of Whitehorse Trough's stratigraphic basement and the lower part may be the downplated accretionary prism composed of former ocean floor sediments and crust. The boundary between what was fundamentally the ancient North American plate and the accreted arc might then lie about the middle of the detachment zone. In this interpretation the subduction zone under Whitehorse Trough probably dipped gently when it formed; its preserved width is 250 km.

11.AEROMAGNETIC EXPRESSION

Aeromagnetic maps for Carmacks and Laberge map areas (maps 7210G and 7004G) corroborate the geology nicely. They demonstrate the distinctive aeromagnetic expression of rock units and certain rock bodies and emphasize differences between large blocks of country. They do not, by themselves, define the geology.

In Laberge map area the Semenof and Tatchun belts stand out as a single, extensive, magnetically responsive zone between two less magnetic belts, Teslin Suture Zone and Whitehorse Trough. Evidently the two basalt units of the Tatchun and Semenof belts, the Semenof and Povoas formations, have such similar magnetic character that they are magnetically indistinguishable. Teslin Suture Zone has local magnetic highs which correspond, expectably, to the ultramafic rocks of the Anvil Assemblage. The Open Creek volcanics near Boswell River's mouth, which are felsic, are magnetic, but their presumed equivalents at Solitary Mountain, which are basaltic, do not.

Whitehorse Trough has consistently low magnetic response compared to surrounding blocks, but magnetic trends over it reflect the strike of the rocks neatly. This is particularly so between Fox Lake and Lake Laberge. The Povoas Formation of Povoas Anticline is outlined nicely and fairly consistently by moderately magnetic zones, which stand out above the surrounding lower response zones. Even the double bend in the anticline, where it is displaced by the Casca and Aksala faults, shows up nicely. Conglomerate Formation and Nordenskiold Dacite of Ogilvie Valley, west of Coghlan Lake and west of the Fairview Fault are moderately magnetic compared with the remainder of the Laberge Group. Homoclines of these rocks on Mistake Mountain and west of Coghlan Lake are nicely mirrored in the magnetics; were their response more consistent the aeromagnetic maps might be used to map the two formations.

Mount Nansen Group volcanics of Teslin Mountain and Packers Mountain show as relatively responsive strata above the generally unresponsive Whitehorse Trough. Teslin Crossing Stock shows up as a moderately magnetic zone over the intrusion. The small, distinct low over Braeburn is a real anomaly, no explanation is seen for it; could it be the cinnamon buns (see Introduction).

Carmacks volcanics of the Miners Range outline a magnetically responsive zone in southwestern Laberge map area. The magnetic zone's edges correspond nicely with the faulted northeast margin of the Miners Range homocline. The serpentinite just in Whitehorse map area, west and south of Jackfish Bay, evidently continues into Laberge map area under Whitehorse Trough's Laberge Group strata judging from the narrow, high response strip between Lake Laberge and the Miners Range. It can be followed for about 10 km into Laberge map area underneath the northwest trending fold bundle outlined by Laberge Group beds.

The magnetic pattern generally supports the large faults demanded by the rocks, but the magnetics only define the breaks independently where magnetic contrast is high.

In Carmacks map area the Povoas Formation of the Tatchun Belt shows as a consistently high response zone; so do Carmacks Group lavas. But although both are magnetic the shape of the highs differs. Povoas highs are elongated northwestward; those in the Carmacks lack consistent trends and are amorphous. Some Carmacks Group anomalies mark plugs, necks or feeders for the lavas. For example a neat bullseye coincides with the gabbro feeder just northeast of Mount McDade.

The granodiorite in the large intrusions of Carmacks map area generally show up as magnetic lows; the metamorphic rocks do the same. Tatchun Batholith is an example of a low over granodiorite. Interestingly the Granite Batholith, probably equivalent to the Tatchun, is magnetically moderately active; no explanation is seen. The magnetic high over Prospector Mountain is likely a response to the syenite and granite laccolith underneath. The cause of the large active zone west of Fort Selkirk south of Yukon River is not clear. Granodiorite here is correlated with Minto Pluton. Presumably it contains more magnetite near Fort Selkirk than elsewhere. Mount Nansen Group breccias and porphyries have moderate response and stand out indistinctly in the general low of the surrounding metamorphic and intrusive rocks.

The metamorphic rocks of northeastern and southwestern Carmacks map area are generally nonmagnetic, but small bullseyes coincide with known serpentinites. The magnetically active area just west of Granite Canyon lacks outcrop and its cause is unknown. Ultramafics may lie under the cover here.

Magnetite rich gabbro, possibly related to the Povoas Formation, Minto Pluton, Carmacks Group or Selkirk lavas, exposed at the mouth of Wolverine Creek shows up magnificently on the aeromagnetic map as a twin centred high. Volcano Mountain and a large area around it are markedly active magnetically. The rocks are Carmacks Group andesitic basalt with abundant magnetite. The extreme anomaly close to the northwest corner of Carmacks map area has no exposure, but may be underlain by Carmacks Group strata.

12.1INTRODUCTION

Carmacks map area contains a host of mineral occurrences, Laberge map area has few by comparison (Fig. 37). None are being mined, but some such as the Laforma (32) and Freegold (35) deposits in Carmacks map area, have produced in the past. Four main types of showings, each with several representatives, are recognized: gold-silver vein deposits related to the Mount Nansen volcanics, porphyry copper-molybdenite deposits in Mount Nansen Group volcanics, metamorphosed copper deposits in schlieren in granodiorite and coal occurrences in the Tantalus Formation. Less common deposit types include small copper shows, mostly veins in the Povoas and Semenof formations and silver-lead veins near Carmacks Group laccoliths.

The gold-silver veins include several on, and near, Freegold Mountain and a similar number on Mount Nansen. Most occupy steep-dipping faults or shears in Jurassic and older rocks near dykes and plugs of the Mount Nansen Group. The porphyry copper and molybdenite deposits include the Cash (23) and Revenue (26) on the Dawson Range's northern flank. They are large, low grade deposits associated with plutonic phases of the Mount Nansen Group. Unique bornite-chalcopyrite occurrences are seen in biotite rich schlieren in the Granite and Minto intrusions on Williams Creek and near Minto. They are Jurassic deposits which have survived the same ductile strain and recrystallization as their enclosing rocks. Coal occurs at many places in the Tantalus

Formation. The rocks are sufficiently metamorphosed that the coal is coking grade, but the rocks are so badly faulted that seams dip steeply and are difficult to follow.

The following text describes the occurrences briefly; in the text and diagram (Fig. 37) the occurrences are identified by numbers which correspond to those in Yukon Exploration and Geology, (Geology Section, Department of Indian Affairs and Northern Development) the most up to date and comprehensive guide to occurrence data.

This chapter closes with suggestions for exploration. It stresses that the Mount Nansen Group is the economically important host unit, that several possibilities have been neglected and that it warrants concentrated effort on that basis. It suggests a new model for the Big Creek Fault; it points out that the Nordenskiold Dacite has potential that has been overlooked. It examines the implications for coal and gold exploration in the light of the new idea that the Tantalus Formation occupies dextral extension basins and it briefly examines Whitehorse Trough's hydrocarbon potential.

12.2MINERAL EXPLORATION HISTORY

Mineral exploration in the region is closely tied to the region's general development. It occurred in two pulses, the first in the thirties, the second in the late sixties and early seventies. During the first the Dawson Range was the focus of concentrated effort to search out precious metal lodes during the depression. The second pulse, which occurred during economic expansion was stimulated by porphyry copper interest. For a history of the first phase and the influence of some of the personalities the reader is referred to Bostock (1979). The second pulse occurred on the heels of the Casino rush and the interest in Dawson Range porphyry copper possibilities. Still later, in the late seventies and early eighties, the region's precious metal possibilities were reconsidered with the dramatic gold price increases. The closest thing to a large rush, such as those following discovery of Casino and Anvil, was that precipitated by discovery of the Williams Creek showings in 1969. Minto was discovered as a result shortly later in 1971. Results of the seventies and eighties work are detailed in Department of Indian Affairs and Northern Development (DIAND) annual reports.

12.3SUMMARY DESCRIPTION OF DEPOSITS

12.3.1GOLD-SILVER VEIN OCCURRENCES

The gold-silver veins near Freegold Mountain (Fig. 35) include Laforma (34), Rambler, Rambler Hill, Emmons Hill (35), Red Fox (32), Tinta Hill (37), Peerless and Gold Star. Those on Mount Nansen are the Webber-Huestis (40) and Brown-McDade (39). Morin (1981, p. 68-73) described them and referred to earlier descriptions. Summaries are given here to characterize the occurrences, but the reader is referred to the original sources for details.

The Freegold Mountain occurrences are mostly veins in granodiorite of the Granite Batholith. Rhyolite and andesite dykes of the Mount Nansen Group cut the granodiorite. Johnston (1937) mapped the geology in detail. The veins are assumed to be genetically related to the Mount Nansen Group dykes because of their close spatial ties, but the details of the relationship remain to be understood. If related to the Mount Nansen Group mineralization is Late Early Cretaceous.

At Laforma (34) (Sinclair et al., 1976, p. 139-142), originally staked in 1931 and mined in 1939-40, gold occurs in a north-northeast trending vertical quartz vein that cuts massive coarse-grained biotite granodiorite of the Granite Batholith. The granodiorite is strongly altered to argillic facies near the vein. The vein is traced for 800 m in plan and 280 m down dip. In 1966 reserves were estimated as 63,640 tonnes grading 15.1 gm/t gold.

The Red Fox showing (32) is a narrow, vertical, northwest trending vein of galena in a brecciated rhyolite pipe of the Mount Nansen Group, which invades the Granite Batholith. The pipe has anomalously high values of gold, some as high as 160 ppb. The Red Fox (32), Guder (33) and Laforma (34) showings may be part of one gold bearing breccia system (DIAND, 1981, p. 261).

The Rambler vein system (Sinclair et al., 1976, p. 139-142) is a steep dipping, northeast trending break, up to 3 m wide, that is traced for 1100 m. It cuts the granodiorite and follows rhyolite dykes.

At Rambler Hill (near 34) is a plug of rhyolite-quartz porphyry which intrudes the Granite Batholith. It contains disseminated pyrite, is weakly altered, and diamond drilling in 1975 intersected 21 m of 2.3 gm/t gold, 11.6 gm/t silver and 152 m of 0.6 gm/t gold and 2.7 gm/t silver.

On Emmons Hill (35) (Craig and Laporte, 1972, p. 78-79), a spur of Freegold Mountain are lenses of antimony-lead mineralization associated with andesite dykes cutting foliated phases of the Granite Batholith.

Tinta Hill occurrence (37) (Sinclair et al., 1975, p. 120-121), about 6 km east of Freegold Mountain, has quartz sulphide veins in a steep dipping, west-northwest trending, shear zone in granodiorite of the Granite Batholith. The shear zone, open at both ends, is traced for 1200 m. It was discovered in 1930 and has been trenched, drilled and worked underground. Drill indicated reserves in 1975 are 5589 tonnes per vertical metre at 2.6 gm/t gold, 183 gm/t silver, 4.71% lead, 6.0% zinc, 0.37% copper and 0.049% cadmium.

The Mount Nansen veins were discovered in the 1940's. They cut metamorphic rocks of Yukon Crystalline Terrane, the granodiorite and granite that intrudes them and the Mount Nansen dykes and pipes that invade them in turn. The veins carry quartz, arsenopyrite, pyrite, galena, sphalerite and minor silver minerals. Two important vein systems, the Webber-Huestis (40) and Brown-McDade (39), are known.

The Webber and Huestis, also known as the Mount Nansen showings (Morin et al., 1977, p. 167-168), together about 1200 m long, are the northwestern and southeastern extensions of one vein system. During 1968-69 the Webber-Huestis veins were mined and ore reserves after this work were estimated as 182,000 tonnes grading 11.3 gm/t gold, 445 gm/t silver with 91,000 tonnes inferred in addition.

Brown-McDade (39) (Findlay, 1969, p. 23), about 2 km east of the Webber-Huestis, is a steep dipping shear zone, which cuts a small pendant of the coarse grained Big Creek Syenite enclosed in Mount Nansen Group volcanics and subvolcanics and in biotite quartz monzonite that is Cretaceous. The shear zone carries lenses of quartz, arsenopyrite and pyrite. Proven and probable reserves for 1970 are 32,000 tonnes of 12.7 gm/t gold and 202 gm/t silver.

12.3.2PORPHYRY COPPER-MOLYBDENITE SHOWINGS

The porphyry copper occurrences include four examples, all in Carmacks map area (Fig. 37): Cash (23), Revenue (26), Klazan (24) and Cyprus (41). None has proven economic to date. At Cash (23) (Sinclair et al., 1975, p. 111-112) a large zone with disseminated chalcopyrite and molybdenite is known. The grade is about 0.2% copper equivalent over an area 2500 by 800 m. Outcrop is poor, but in drill core the mineralization occurs in the altered Big Creek Syenite; it is genetically associated with Mount Nansen dykes or with subvolcanic intrusions of the Carmacks Group.

Klazan (24) (DIAND, 1983, p. 202) a few kilometres east of Cash, is underlain by felsic breccia and plugs, which constitute a subvolcanic intrusive complex of the Mount Nansen suite, exposed over an area of several square kilometres. Quartz stockworks with minor chalcopyrite, galena and molybdenite and some pyrite, and which grades in the order of 0.15% copper with significant molybdenum values, are exposed in a 200 by 700 m area.

At Revenue Creek (26) (DIAND, 1982, p. 217), a tributary of Big Creek, the next deposit east of the Klazan, which is also poorly exposed, grades reported from 1980 drill holes over nearly 40 m are between 0.3 and 0.4 gm/t gold, 6 to 10 gm/t silver and 0.2% copper. The showings are enclosed in the Big Creek Syenite and Mount Nansen granite; a few light coloured feldspar porphyry dykes of the Mount Nansen Group cut the older rocks.

Cyprus (41) (DIAND, 1981, p. 261) the only known porphyry on Mount Nansen, has a 30 by 50 m quartz-tourmaline breccia pipe, with low grade disseminated copper and molybdenum mineralization. The pipe, a feeder for extrusive Mount Nansen rocks, contains tourmaline cemented fragments of the Mount Nansen volcanics.

In Laberge map area are three small showings that may be classed as porphyry coppers. They are the Bacon (19), Tuv (2) and Lori (17). The first two occur at or near the margins of the Teslin Crossing Stock and may be genetically associated with it. Little is known of these occurrences. The Lori (Sinclair et al., 1976, p. 110) has reported chalcopyrite and molybdenite in fractures in the granodiorite on the south side of Teslin Mountain.

12.3.3MINTO TYPE METAMORPHOSED COPPER DEPOSITS

The metamorphosed copper deposits of Carmacks map area, grouped as Minto type, have been studied in considerable detail and described by Sinclair (1977, p. 68-82) and by Pearson and Clark, 1977 (Fig. 37). The occurrences contain disseminated to massive chalcopyrite and bornite in biotite rich zones or schlieren in foliated hornblende granodiorite. Several mineralized zones, each a few metres wide and 100 or 200 m long, are known at each occurrence. The zones dip steeply at Williams Creek (5) and moderately at Minto (14) and STU (65).

Country rocks are foliated biotite hornblende granodiorite of the Granite and Minto intrusions, probably each other's extensions. The rocks are medium grained, equigranular and contain subhedral hornblende (15%), anhedral biotite (5%), plagioclase (60%) and about 20% quartz. Minerals tend to be aligned so that the rocks appear gneissic; they grade laterally to granitic textures. Foliation trends northwest. The rocks are variably altered; wholesale replacement of plagioclase by pink K-feldspar has changed the rocks to more monzonitic compositions. This is a regional alteration, more locally the rocks are silicified and sericitized and chlorite or biotite partly replaces hornblende.

Alteration began with feldspathization and growth of hydrothermal biotite. Silicification, sericitization and chloritization followed. The first two stages probably coincided with ductile deformation of the granodiorite. All the alteration stages follow biotite growth in the schlieren.

Mineralization, which consists of chalcopyrite and bornite with minor pyrite, coincides with the biotite rich zones, but is locally heavy in silicified zones. Opaque mineral textures are crystalloblastic; the minerals appear metamorphic and coeval with biotite growth in schlieren.

Reserves at Minto (14) are 6.5 million tonnes at 1.86% copper, 3.2 gm/t silver, 0.46 gm/t gold. Those at Williams Creek (5) are 14.5 million tonnes grading 1% copper with low silver and gold values. Other showings of Minto type, principally near Minto are the Pal (15), Comanche (45), Giant (57), and Ori (50); the general relations outlined above hold for them all.

12.3.4COAL IN THE TANTALUS FORMATION

Coal occurs in the Tantalus Formation at a number of localities in Carmacks, Laberge and Aishihik Lake map areas (Fig. 37). Best known are the deposits at Tantalus Butte (3), near Carmacks, from which the host rocks are named and from which coal has been mined intermittently since early this century first to feed boilers on steam boats plying Yukon River, later to dry concentrates at the Faro Mine. Good descriptions of the underground and surface geology are given by Cairnes (1910, p. 59-63) and by Bostock (1936, p. 58-59). The Five Finger occurrence (4), just downstream of Carmacks, is of lower grade coal than at Tantalus and the host rocks are clastics of the Carmacks Group. This coal is Late Cretaceous, significantly younger than the Tantalus coals.

In Laberge map area coal occurs at the Claire (8), Walsh (9) and Hootalinqua (15) showings northeast of Whitehorse Trough and at the Corduroy (14) on Corduroy Mountain in western Laberge map area. At Hootalinqua, Claire Creek and Corduroy Mountain the coal occurs in the Tantalus Formation; as far as known all three are small occurrences of high grade coking coal, but little work has been done on them (Cairnes, 1910). Walsh Creek coal is of lower reflectivity than that in the Tantalus and occurs as seams in much less indurated Pliocene strata. The beds are subhorizontal over large areas and are not disrupted. The occurrence has not been followed far by drilling.

12.3.5COPPER OCCURRENCES IN VOLCANICS

At several places in Carmacks map area are small occurrences of chalcopyrite in the Povoas Formation. The Bonanza King (7), Merrice (6), Crossing (48) and McCabe (54) are examples (Fig. 37). Green (1966, p. 42-44) described the occurrences at the Bonanza King, the most interesting showing, as quartz lenses up to a metre and a half wide, carrying chalcopyrite and bornite. They lie in the plane of a steep northwest trending foliation in altered greenstone. A composite sample containing some copper minerals assayed about 20 gm/t silver and 1.6% copper. The Bonanza King, Merrice and Crossing are all close to the Hoochekoo Fault and are thought genetically related to it. McCabe is a small occurrence of chalcopyrite in altered Povoas Formation greenstone.

The Tuf (47) (Sinclair et al., 1975, p. 95) on the Yukon River's south side at Carmacks map area's west boundary is a small showing of chalcopyrite in granodiorite of the Minto Pluton. Chalcopyrite is disseminated and in veinlets. It's mineralogy is similar to that of the Bonanza King (7), but the host rocks differ; it also resembles Minto type metamorphosed copper occurrences, but lacks the mafic schlieren found with them. Most likely the showing is related to the bounding faults on the southwest side of Whitehorse Trough, Selkirk Fault in this case, just as the Bonanza King is connected with the Hoochekoo Fault.

An interesting occurrence of chalcopyrite in Povoas Formation was noted on the ridge northeast of Rink Rapid. The sulphide is disseminated in the volcanics.

No copper occurrences are known in the Lewes River Group in Laberge map area, but one interesting showing of veins of chalcopyrite is the Semenof (10), an occurrence of chalcopyrite in small veins in the Semenof Formation in the canyon of a small east draining tributary of Big Salmon River. Little work has been done on this showing.

The Loon showing (3) (Craig and Laporte, 1972, p. 119-120) near Loon Lakes in southeast Laberge map area is a copper occurrence in sheared rocks at the edge of the Teslin Suture Zone. Chalcopyrite occurs in veinlets and is disseminated in a 30 to 40 m wide, west dipping zone in cherty quartzite of the Boswell Formation. The showing is difficult to classify with any of the others as its host rocks differ. It and the Semenof are both near the Big Salmon Fault and they may be localized by that fault.

12.3.6SILVER LEAD VEINS

In the western part of Carmacks map area are several silver-lead veins on the Frog (21), Lilypad and Newt claims (DIAND, 1982, p. 216) (Fig. 37). They occupy an area about 11 km by 6 km. The veins occupy several metres wide, recessive weathering zones in tuffs of the lower Carmacks Group close to the syenite laccolith on Prospector Mountain; they are only followed for short distances. They occur in two sets: northeast and north striking and steep dipping. Vein material is oxidized and includes cockade and ribbon quartz with goethite, jarosite, scorodite, malachite and anglesite. Galena, pyrite, arsenopyrite and chalcopyrite are primary sulphides seen locally.

12.4REGIONAL GEOCHEMISTRY

Geochemical data on stream and surface waters in Carmacks map generalized in moving average maps (Geological Survey of Canada, 1986) generally correlates with certain features of the bedrock geology, but also defines some anomalies. For example several elements define the Big Creek Fault. High arsenic and antimony values follow it and gold outlines the Big Creek Syenite fault block and defines the Fault and its partner the Dawson Range Fault. Lead also shows up the fault block of Big Creek Syenite defining the Big Creek Fault and its relatives. Gold also pinpoints the edges of the Tatchun Batholith, a relationship which is difficult to explain from the bedrock. Interestingly the gold response from the Carmacks Group is low - are the chances for other Panther and Rainbow showings small? The high gold and silver concentrations around Carmacks (and lead and zinc nearby along the Chain Fault) may support the idea that the Tantalus is an exploration target for precious metals as speculated below.

Expectably the cobalt and nickel concentrations reflect the distribution of Carmacks Group flood basalts in the Miller Ridge and Mount Pitts and Wolverine Creek outliers. Silver is uniformly low except around Prospector Mountain and just north of Carmacks. The first may reflect silver occurrences such as the Lilypad on Prospector Mountain, but the second has no known reason. Expectably the copper concentration reflects the distribution of the Povoas Formation of the Tatchun Belt. It is the high copper background unit in this region (Tempelman-Kluit and Currie, 1978). Copper also shows up the Coffee Creek granite, which is not known for its mineralization and certainly not for copper occurrences. In fact the Coffee Creek Granite shows up as a high background unit in cadmium, zinc and tungsten. Copper also outlines the Big Creek Fault faintly. Are the several known porphyry copper-molybdenum occurrences along this break the cause? Molybdenum does not reflect the Big Creek Fault, but does show up the Coffee Creek Granite and also the Tatlmain Batholith. Neither are expected from known showings or high backgrounds. Cadmium and zinc also show up the Coffee Creek Granite, again surprising from the paucity of known showings. Tin and tungsten, which might be expected to be related to the same rocks, reflect different units. Tin is concentrated in areas underlain by the Granite Batholith and orthogneiss of the Yukon Crystalline Terrane southwest of Lonely Creek, tungsten along Big Creek, perhaps in the Coffee Creek Granite and in the Casino Granodiorite. Around Braden's Canyon is an area anomalous in barium, lead, zinc, cadmium, copper, arsenic, antimony and mercury. Perhaps this reflects the showing (12), but it seems insignificant compared to the exciting geochemical response here. Alternatively the amphibolite here, part of the Anvil Assemblage, has high backgrounds in a range of elements, but this is also unique - no similar response is seen in Anvil strata elsewhere.

12.5MINERAL EXPLORATION TARGETS

Mineral exploration in the project area has naturally focussed on rock units with known metal concentrations; among these the Mount Nansen Group, one of the overlap units, stands out above the others. Older rock units of the main tectonic subdivisions are largely devoid of metal concentrations and appear discouraging as prospecting targets. Thus Whitehorse Trough and Yukon Crystalline Terrane strata lack important known metal occurrences in the project area and Yukon Cataclastic Terrane only has a few showings in its granitic top. Reconsideration reveals some neglected possibilities and a particularly interesting target associated with the Tantalus Formation in the extension basins.

Laberge and Lewes River Group strata are largely uninspiring as targets for exploration, but the copper skarns at Whitehorse indicate caution in writing the Lewes River Group off. Near intrusions such as the stock on Teslin Mountain, Lewes River Group skarns are possible. The Povoas Formation is an important unit with many small occurrences of copper and high copper backgrounds (Tempelman-Kluit and Currie, 1978). Copper-gold concentrations are possible if not likely.

Nordenskiold Dacite has plenty of disseminated, fine-grained pyrite. No showings are known in the project area, but the unit is the time and lithologic equivalent of the Toodoggone volcanics in northern British Columbia, which host many intriguing epithermal gold deposits (Panteleyev, 1983). The Toodoggone has the same relations to the Hazelton Group as the Nordenskiold to the Laberge Group.

Teslin Suture Zone's sheared rocks appear as unexciting as those of Whitehorse Trough; they have few occurrences, none inspiring. The Loon (3) and Semenof (10) are two which may be genetically connected to the host rocks, but they may also be related to the Big Salmon Fault. The only metallic mineral occurrence in Yukon Cataclastic Terrane is at Bradens Canyon (12), a small copper show.

Yukon Crystalline Terrane's metamorphic rocks are barren as far as known; asbestos may occur in the serpentine, but no showings are known. Presumably the high metamorphism means that hydrothermal fluid circulation, if it occurred, was localized higher, in the now eroded part. Later intrusion of the Casino Granodiorite in these dehydrated rocks inhibited extensive hydrothermal fluid generation.

Of the granitic rocks the most attractive for exploration are the mid-Cretaceous relatives of the Mount Nansen Group, the Casino Granodiorite and Coffee Creek Granite. They are barren as far as known, but their spatial connection with Mount Nansen mineralization makes them interesting. The Coffee Creek Granite along the Big Creek Fault is stongly saussuritized and may be worth a concentrated search for mineral showings. The older granites, those in the top section of Yukon Cataclastic Terrane, have Minto type metamorphosed coppers whose genetic relationship to the rocks is unclear. It is surprising that Minto type occurrences are only known from the Minto and Granite batholiths; the Tatchun and Aishihik batholiths occur in the same structural position, but lack showings as far as known. Similarly the extension of the Minto host rocks northwestward beyond Fort Selkirk merits prospecting. In each instance search should be concentrated near the structural base of the intrusions where the rocks have the same fabrics as are seen at the known showings. The northeastern side, not just the edge, of Tatchun Batholith, and the southwestern side of the Aishihik Batholith are seen as favourable.

The Mount Nansen volcanics and Casino Granodiorite are speculated to be coeval and genetically related to the Big Creek Fault. Apparently the Big Creek Syenite fell as a block while Casino Granodiorite was intruded and while subvolcanic dykes and plugs of Mount Nansen Group invaded it and propylitized it strongly. The Big Creek Syenite may be the collapsed roof above a Mount Nansen magma chamber with Mount Nansen subvolcanics intruded through and around it. This can explain the concentration of porphyry and precious metal occurrences around it and the extensive propylitic alteration of the Big Creek Syenite; it suggests that this block and its margins merit a deeper look.

The Big Creek Fault, though not exposed, should also be worth looking at for fossil hydrothermal systems. Mineral occurrences clustered along it (Fig. 37) include porphyry copper occurrences such as the Cash (23), Klazan (24), Revenue (26) and Zit (69) and gold-silver vein systems such as the Caribou Creek (30), Red Fox (32), Guder (33), Laforma (34) and Emmons Hill (35). A corollary of the collapsed roof hypothesis is that the Big Creek block should have a faulted southeastern margin. It may lie along the extension of the Miller Fault or the other northeast trending faults of Victoria Mountain and Mount Nansen, under the Carmacks Group on Miller Ridge. This boundary holds promise for concentrations.

Although the mid-Cretaceous Mount Nansen Group is an important mineralization control the Late Cretaceous Carmacks Group, also a volcanic suite, appears unimportant in this respect judging by the paucity of known showings. Few occurrences can be linked spatially or genetically with the unit's lower extrusive tuffs or with its upper flood basalt. The Panther and Rainbow along upper Big Creek (Sinclair et al., 1976, p. 142-143) are possible exceptions. Showings like them are worth looking for. The granite laccolith in the lower Carmacks Group at Prospector Mountain localizes several silver bearing galena veins at the Lilypad (21) (DIAND, 1982, p. 216). The veins are fairly wide, but short and the intrusion was relatively dry. Skarn possibilities around the laccolith and its relatives on Mount Pitt are not exhausted. If the Dawson Range Fault, the Victoria Mountain faults and the fault southeast of Prospector Mountain continued as fluid channels into Carmacks Group time the places where they are covered by the Carmacks Group may be worth close study.

The Carmacks-Hoochekoo-Selkirk Fault system may be a more important control on mineralization than the host rocks. Copper-silver veins like the Bonanza King (7) lie in the shear zone and Minto-type metamorphosed copper deposits are also close. The zone of ductile strain probably had high fluid pressure during deformation and metamorphism and water may have been released to faults tapping the zone. That only this fault acted as a fluid conduit is unlikely; other strike-slips may be worth considering in this light, but no specific targets are seen.

The Semenof showing (10), opposite the mouth of Big Salmon River, has same spatial relationship to the Big Salmon Fault as the Minto (14) and Williams Creek (5) to the lower structural contact of the Granite Batholith. They all occur just above the structural surface bounding the top and bottom of the detachment. Perhaps the Big Salmon Fault and the eastern edge of the Semenof block are worth close scrutiny, but outcrop is poor.

Implications for coal and for epithermal mineral possibilities in the Tantalus filled extension basins are exciting. The fault controlled basins are deep; they presumably bottom on the detachment under Whitehorse Trough. This suggests that known coal showings may be thick and that their down dip extension may be substantial. They indicate potential for deep coals. Also several of the Tantalus basins along the southwest bounding faults of Whitehorse Trough may be much larger than their exposed area. For example if the basin just west of Carmacks is tectonically controlled by the Carmacks fault system, as speculated, it may extend to the hypothesized connection fault between the Carmacks and Hoochekoo faults. The Vowel Mountain, Mount Cooper and Corduroy Mountain Tantalus occurrences may similarly extend under their Carmacks Group cover.

The extension basins and their faults are also likely sites where hydrothermal fluid was released from the detachment. Whitehorse Trough's detachment zone likely operated under fluid overpressured conditions; the extension faults and their basins are escape conduits that end in the overpressured shear zone. With the Tantalus deposited right on it where extending faults intersect the Tantalus basins warrant careful prospecting. Precious metal concentrations in altered zones along the faults bounding and flooring the basins, or in the fault walls are particular targets. Mineralization may be deep; there is little evidence for it at the surface in the Tantalus Formation although reported placer gold at Hootalinqua may derive from a source such as this and although the extensive silica cement of the Tantalus itself may derive from hydrothermal systems. The porphyry dykes intruded in extended zones along the fault system may also be good targets for precious metal occurrences although the several large, mapped dykes look barren upon cursory inspection. The strike-slips, which also bottom on the detachment, are transpressional and little fluid may have escaped along them. In any case they lack known mineral occurrences.

12.6HYDROCARBON POSSIBILITIES

Hydrocarbon possibilities in the interior of the Canadian Cordillera have been considered poor because the grade of metamorphism is generally too high for hydrocarbon preservation and because the deformation is too intense for hydrocarbon trapping. Nevertheless Koch (1973) in a review of Cordilleran possibilities considered that Whitehorse Trough and its extensions in the remainder of the Intermontane Belt warrant closer study for their hydrocarbons. The present work supports his contention. The metamorphic grade of Whitehorse Trough strata is certainly not excessive, the stratigraphy includes potential hydrocarbon source rocks and stratigraphic and structural traps. Whitehorse Trough is Mesozoic volcanic arc basin emplaced structurally on the North American margin. Elsewhere in the world such basins have proven productive. Unfortunately Whitehorse Trough is strongly deformed; if hydrocarbon was generated most of it probably escaped during deformation.

Thermal maturation indices indicate that the entire Whitehorse Trough sequence falls in the "oil window"; conditions were ideal for hydrocarbon generation given proper source rocks. The colour alteration index of conodonts, which reflects the rocks' thermal maturation, falls between 2 and 3 in Aksala Formation limestones. It means that the rocks attained temperatures near 150°C and have about 70% fixed carbon; the equivalent vitrinite reflectance is between 1.1 and 1.3. This places them near the high end of the "oil window". The highest determined index (4, M.J. Orchard, written comm., 1983) indicates that temperatures reached to between 190 and 300°C and that about 90% of the rock's carbon is fixed. These indices derive from the deepest part of the stratigraphic sequence; no conodonts occur higher in the sequence, but the degree of maturation at the top of the succession is approximated by the vitrinite reflectance and grade of Tantalus Formation coals. The first averages .78 (the range is .75-.81), low in the "oil window", and the coal rank is high volatile bituminous, about the middle of the "window" (P. Hacquebard, pers. comm., 1985).

Source rocks which may contain enough biogenic material to generate hydrocarbons are limestone and calcareous shale in the Aksala Formation and shale in the Richthofen Formation. Both are marine units; potentially better sources than equivalent terrestrial rocks. The Aksala Formation is a reefal carbonate with fossil sponges, algae, corals and bivales. Pyrobitumen, which occurs locally in fractures and cavities in Aksala Formation limestone, shows that some hydrocarbon was generated. The amount of potential source rock and its biogenic content remains to be studied.

Beside potential source rocks and suitable thermal conditions, strata and structures in which hydrocarbons might accumulate are required for oil and gas reservoirs. Although most of the rocks are are well indurated and probably "tight" some units are locally porous. Possible reservoir rocks are parts of the Lewes River carbonate, much of the Tanglefoot Formation and part of the Nordenskiold Dacite. Impermeable barriers to prevent escape once hydrocarbons are generated are further requirements.

The thoroughly indurated Nordenskiold Dacite ash sheets with interstratified normal marine sandstone represent one possible reservoir-trap combination.

Whitehorse Trough's structural complexity suggests that most hydrocarbon that was generated probably escaped during the strike-slip. The steep dipping panels of strata abutting faults have many potential escape conduits. Study of Whitehorse Trough's possible source and reservoir rocks and analysis of the structure may reveal structural traps that preserved small hydrocarbon pools, but large reservoirs are unlikely.

FOSSIL LIST

Collection identified by T.P. Poulton, Geological Survey of Canada
G.S.C. Loc. No.
91776

Locality and Fauna

Southeast Carmacks map area N62° 21'30", W136° 25'00"
In a gravel pit beside the Mayo road 3.8 km east-northeast of Yukon Crossing. Map Unit; Laberge Group, Tanglefoot Fm. Rock type; Yellow brown weathering, medium-grey sandstone interbedded with dark calcareous argillite.

Pelecypods: ?*Goniomya* or *Pleuromya* sp.
?*Modiolus* sp.
other undetermined pelecypods

Gastropods, undetermined, fern leaves

Age

Not determinable, but one of the undetermined pelecypod species is the same as in loc. 91780 (locality 9), suggesting a similar, possibly Middle Bajocian age.

Collection identified by W.S. Hopkins, Geological Survey of Canada
G.S.C. Plant Loc. No. 1A
9297

Age

Maceration resulted in very small quantity of heavy, black, carbonized residue. No palynomorphs were present.

Collection identified by H.W. Tipper, Geological Survey of Canada
G.S.C. Loc. No. 2
91783

Locality and Fauna

Southeast Carmacks map area N62° 21'20", W136° 24'00"
Beside Mayo road close to gravel pit, 1.5 km south of Hill 3770. Map Unit; Laberge Group, Nordenskiold Dacite Rock Type; Conglomerate interbedded with massive, green-grey "sandstone" and thin shale beds.

Lioceratoides? *propinquum* (Whiteaves)
Weyla acutiplicata (Hyatt)
fragments of dactylioceratid

large coleoid, Atractites?
bryozoa?
Weyla sp.

Age

If the Lioceratoides? is a correct specific identification then the collection is almost certainly Late Pliensbachian in age; same as loc.4.

Collection identified by T.P. Poulton, Geological Survey of Canada
G.S.C. Loc. No. 3
91777

Locality and Fauna

Southeast Carmacks map area N 62° 19'30", W136° 22'00"
On east side of Yukon River at Rink Rapids. Map Unit; Laberge Group, Richthofen Fm. Rock Type; Sandstone, pebbly sandstone, minor shale.

Pelecypods: Weyla sp.
Lima sp.
Entolium sp.
other undeterminable pelecpods

Brachiopods: undetermined rhynchonellids.

Age

Lower Jurassic. Sinemurian or Pliensbachian preferred according to H. W. Tipper.

Collection identified by H.W. Tipper, Geological Survey of Canada
G.S.S. Loc. No. 4
91782

Locality and Fauna

Southeast Carmacks map area N62° 19'30", W136° 22'30"
West bank of Yukon River at Rink Rapids. Map Unit; Laberge Group, Nordenskiold Dacite. Rock Type; Massive quartzo-feldspathic sandstone.

cf. Lioceratiodes (?) propinquum (Whiteaves)
indeterminate harpoceratid ammonite

Age

Possibly very Late Pliensbachian.

Collection identified by Hans Frebold, Geological Survey of Canada

<u>G.S.C. Loc. No.</u> 5

91784

<u>Locality and Fauna</u>

Southeast Carmacks map area N62° 18'30", W136° 13'00"
3 km north of west end of Tatchun Lake. Map Unit; Laberge Group, Nordenskiold Dacite. Rock Type; Shale in massive dacite ash flows.

Very poorly preserved fragments of ammonites including Dactylioceratinae gen. et sp. indet., Harpoceratinae gen. et sp. indet. Similar to <u>Dactylioceras</u>, <u>Hildaites</u>, and <u>Harpoceras</u>.

<u>Age</u>

Probably Early Toarcian.

Collection identified by T. P. Poulton, Geological Survey of Canada

<u>G.S.C. Loc. No.</u> 6

91779

<u>Locality and Fauna</u>

Southeast Carmacks map area N62° 16'30", W136° 21'30"
Close to Five Finger Rapids, east bank of Yukon River. Map Unit; Laberge Group, Richthofen Fm. Rock Type; Shaly pod pebbly sandstone.

Pelecypods: ? '<u>Posidonia</u>' sp.
? '<u>Corbula</u>' sp.

<u>Age</u>

Undetermined, presumably Jurassic.

Collection identified by H.W. Tipper, Geological Survey of Canada

<u>G.S.C. Loc. No.</u> 7

91778

<u>Locality and Fauna</u>

Southeast Carmacks N62° 16'00", W136° 21'30"
1 km upstream from Five Finger Rapids. Map Unit; Laberge Group, Richthofen Fm. Rock Type; Interbedded shale and slate.

Fragments of ammonites, possibly Asthenoceras boreale Frebold
small pelecypods as in loc. 7a.

<u>Age</u>

indeterminate, possibly the same as loc 7a.

Collection identified by H.W. Tipper, Geological Survey of Canada

G.S.C. Loc. No. 7A

91781

Locality and Fauna

Five Finger Rapids, immediately below conglomerate. Rock Type; Shale directly below conglomerate, probably Richthofen Formation.

Asthenoceras boreale (Frebold)
fragment of a stephanoceratid ?
belemnite
wood fragments
plant imprint- fern
small pelecypods like Posidonia?
fragment of small ammonite, possibly a sonninid

Age

Lower Bajocian.

A collection made by Lees from this same locality was reexamined by H.W. Tipper, Geological Survey of Canada, who reported as follows.

G.S.C. Loc. No.

C-090646

Fauna

Asthenoceras boreale (Frebold)
fragment of a strongly ribbed broad, rounded venter

Comment

Asthenoceras boreale Frebold was originally identified as Grammoceras (?) boreale by Frebold from a specimen taken from this collection (G.S.C. Bull.16, plate VII). Recently David Taylor, Portland State Univ. has recorded the species from Eastern Oregon and was able to correct the generic identification and the age. He has found it to be Middle Jurassic, (range is upper part of the Concavum zone, through the Discites zone and most of the Laeviuscula zone in terms of the Northwest European Standard).

Age

Latest Aalenian (?) to middle Early Bajocian, probably the latter.

Collection identified by H.W. Tipper, Geological Survey of Canada.

G.S.C. Loc. No. 8

91774

Locality and Fauna

Southeast Carmacks map area N62° 14'00", W136° 20'30"

On the east bank of Yukon River, 4 km south of Five Finger Rapids. Map Unit; Laberge Group, Nordenskiold

Dacite. Rock Type; Brown weathering thin bedded, shale and siltstone interbedded with thick massive ash flows.

Amaltheus stokesi (J. Sowerbyi)
cf. Leptaleioceras pseudoradians (Reynes)
Arieticeras cf. A. algovianum (Oppel)
fragment of a dactylioceratid
Arieticeras aff. A. gerardi Monestier
ammonite gen. & sp. indet.

Age

Late Pliensbachian, older than loc 4.

Collection identified by T.P. Poulton, Geological Survey of Canada.
G.S.C. Loc. No. 9
91780

Locality and Fauna

Southeast Carmacks N62°04'45:, W136° 07'00"
On south side of Yukon River, 2 km northwest of Mt Daoust. Map Unit; Laberge Group, Tanglefoot Fm. Rock Type; Coarse brown feldspathic sandstone. Black medium grey sandstone. Shale, slates.

Pelecypods: Myophorella sp.
?Pleuromya sp.
?Camptonectes sp.
?Gryphaea sp.
?Corbula sp.
other undetermined pelecypods.
Gastropods, undetermined.
Wood fragments.

Age

The specimens of Myophorella are very close to, or conspecific with those from collection GSC C-18179 (Reported in Tempelman-Kluit 1974, p96) and a similar age is suggested - possibly Middle Bajocian, almost certainly Middle Jurassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 10
C. 086430

Locality and Fauna

Southwest Glenlyon map area N62°0'10", W135°49'00"
Map Unit; Aksala Fm, Hancock Member. Rock Type; Limestone.

Epigondolella bidentata Mosher sensu lato

Age

Latest Middle or Late Norian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.

G.S.C. Loc. No. 11

C. 086429

Locality and Fauna

Southwest Glenlyon map area N62°0'10", W135°49'00" Map Unit; Aksala Fm., Hancock Member. Rock Type; Limestone.

Epigondolella sp indet. ramiform elements

Age

Probably Early Norian, Late Triassic. Very small specimens, all of them incomplete.

Collection identified by M.J. Orchard, Geological Survey of Canada.

G.S.C. Loc. No. 12

C. 086428

Locality and Fauna

(TOR 79.20-12)

Southwest Glenlyon map area N62°0'10", W135° 47'30" Yukon River, 4 miles north of Mandanna Lake. Map Unit; Aksala Fm. Rock Type; Limestone.

Neogondolella cf. N. polygnathiformis (BUDOROV & STEFANOV)	(2)
ramiform element	(1)

Age

Pobably Carnian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.

G.S.C. Loc. No. 12A

C. 086427

Locality and Fauna

(TOR 79.20-13)S

Southwest Glenlyon map area N62°0'10", W135°47'30" Yukon River, 4 miles north of Mandanna Lake. Map Unit; Hancock Member Rock Type; Limestone.

Neogardolella cf. N. polygnathiformis (Budorov & Stefanov)	(3)
ramiform element	(1)

Age

Probably Carnian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 13
C. 086437

Locality and Fauna

(TOR 79-161A)N Northwest Laberge map area N61°53'40", W135°50'50" 4 km northeast of East Mountain. Map Unit; Aksala Fm., Hancock Member. Rock Type; Limestone.

Neogondilella cf. N. polygnathiformis (Budonov & Stefanov) (1)

Age

Probably Carnian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 14
C. 086435

Locality and Fauna

(TOR 79.16-4) Northwest Laberge map area N61°53'20", W135°53'10" 1.5 km northeast of East Mountain. Map Unit; Aksala Fm, Hancock Member. Rock Type; Limestone.

Ichthyoliths

Age

Not specified.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 15
C. 086436

Locality and Fauna

(TOR 79.16-3) Northwest Laberge map area N61°53'20", W135°52'42" 2 km northeast of East Mountain. Map Unit; Aksala Fm., Hancock Member. Rock Type; Limestone.

Ichthyolith

Age

Not specified.

Collection identified by H.W. Tipper, Geological Survey of Canada.
G.S.C. Loc. No. 17
C-86700

Locality and Fauna

Northwest Laberge map area N61°51'50", W135°49'30" On small creek 4.5 km northeast of Fairview Mountain. Map Unit; Aksala Fm., Mandanna Member. Rock Type; Red greywacke and shale.

Halobia? sp.
Tropites? sp.

Age

Upper Triassic, possibly Upper Carnian. This collection has several *Tropites* - like ammonites as well as fragmentary pelecypods that resemble *Halobia*. The preservation is such that definite identification is difficult.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 18
97034

Locality and Fauna

Northwest Laberge map area N61°49'00", W135°43'30" Lewes River Group between Packers Mountain and Mandanna Creek 2.5 km east of Mandanna Creek. Map Unit; Aksala Fm., Mandanna Member. Rock Type; Bioclastic sandy grey limestone between green sandstone and thick bedded limestone.

"*Variamussium*" sp.
Lima? sp.

Age

Upper Triassic, probably Upper Norian.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 19
97037

Locality and Fauna

Northwest Laberge map area 61°49'00", W135°42;15" Between Packers Mountain and Mandanna Creek. 3.5 km east of Mandanna Creek. Map Unit; Laberge Group, Nordenskiold Dacite. Rock Type; Limy siltstone (orange weathering) below ash flow and above conglomerate.

Ammonites (*Acanthopleuroceras* ?? or *Crucilobiceras* ??)

Age

Probably Jurassic.

Collection identified by H.W. Tipper, Geological Survey of Canada.
G.S.C. Loc. No. 19A
97037

Locality and Fauna

Northwest Laberge map area 61°49'00", W135°42;15" Between Packers Mountain and Mandanna Creek. 3.5 km east of Mandanna Creek. Map Unit; Laberge Group, Nordenskiold Dacite. Rock Type; Limy siltstone (orange weathering) below ash flow and above conglomerate.

Tropidoceras? sp.
Metaderoceras sp venter of an ammonite very close to the distinctive venter of Acanthopleuroceras (Luningiceras) pinnaforme Smith, numerous pelecypods closely packed.

Age

Earliest Pliensbachian. The Tropidoceras? and Metaderoceras favor the lower half of the Lower Pliensbachian. If Luningiceras is correctly suggested then the collection is probably from the equivalents of the European Jamesoni zone, ie. the lowest part of the Lower Pliensbachian. This ammonite has been identified in Spatsizi map area (104H) and in the Gabbs Range, Nevada, the type area.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 20
C. 086434

Locality and Fauna

(TOR 79.17-8)N

Northwest Laberge map area N61°48'55", W135°32'10" 3.2 km east of Chain Lakes. 2.2 km south of Packers Mountain. Map Unit; Povoas Fm. Rock Type; Limy siltstone/ sandstone.

Epigondolella? sp. indet. (1)
Ichthyoliths

Age

Probably Late Triassic. Blade fragment resembles epigondolellid in profile.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 20A
97042

Locality and Fauna

Northwest Laberge map area N61°48'55", W135°32'10" 2.2km south of Packers Mountain, 3.2 km east of Chain Lakes. Povoas Fm. Rock Type; Limestone.

"Pecten" cf. yukonensis Lees.

Age

Upper Triassic, probably Upper Norian.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 21
C. 086432

Locality and Fauna

(TOR 79.17-12) Northwest Laberge map area N61°48'25", W135°33'35" 3.2 km east of Chain Lakes, 3.8 km south-southwest of Packers Mountain. Map Unit; Povoas Fm. Rock Type; Limestone.

Epigondolella bidentata MOSHER, 1968 (1)

Age

Late Norian, Late Triassic. This sample was partly mixed with that from locality 22. This specimen may have come from either sample.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 22
C. 086433

Locality and Fauna

(TO 79.17-9B)N Northwest Laberge map area N61°48'45", W135°31'50" 3.2 km east of Chain Lakes, 3.0 km south of Packers Mountain. Map Unit; Povoas Fm. Rock Type; Bioclastic limestone.

Age

Not specified (but see locality 21).

Collection identified by T.P. Poulton, Geological Survey of Canada
+.S.C. Loc. No. 23
C-86808

Locality and Fauna

Northwest Laberge map area N61°47'00", W135°28;00" 6.2 km southwest of Packers Mountain Map Unit; Tanglefoot Fm. Rock Type; Arkose.

Bivalves: *Myophorella* sp.
Myophorella yellowstonensis
Imlay (?)
other bivalves, indet.
Scaphopods (?)

Age

Middle Jurassic

Collection identified by J.A. Jeletzky, Geological Survey of Canada.
G.S.C. Loc. No. 24
C-086807

Locality and Fauna

Northwest Laberge map area
6.5 km southeast of Packers Mountain on the north side of the canyon of a small creek. Rock Type; Red sandstone.

Atractites sp. indet. (? a new species)
(a representative of the order Aulacocerida Stolley 1919)
(To index collection)
Small keeled ammonites closely resembling *Protogrammoceras* or ?*Arieticeras* (to be referred to one of our Jurassic specialists for a more detailed identification and dating-see 24A below)

Age

The genus *Atractites* s. str. is know to range right through the Upper Triassic, Lower, Middle and Lower Upper (Oxfordian) Jurassic. In the Jurassic the genus *Atractites* s. str. appears to be restricted to the Tethyan Realm and the adjacent marginal parts of the Boreal Realm (i.e. mid-western and western but not the Arctic basins of Canada). In the Jurassic of western Canada (i.e western British Columia and southern Yukon) *Atractites* s. str. appears to be restricted to the Lower Jurasic rocks. If # C-086807 is a late Pliensbachian as seems likely, this age would fall well within the already known regional time range of *Atractites* s. str. This collection was reexamined by H.W. Tipper who identified *Arieticeras* and who assigned the collection a Late Pliensbachian age on that basis.

Collection identified by H. Frebold, Geological Survey of Canada.
G.S.C. Loc. No. 24A
C-86806

Locality and Fauna

Northwest Laberge map area N61°47'00", W135°28'00"
6.5 km southeast of Packers Mountain on the north side of the canyon of a small creek. Map Unit; Laberge Group, Conglomerate Fm. Rock Type; Red medium grained sandstone.

Metadoceras sp.
Faciniceras ? sp.
Arieticeras sp.
unidentified hildoceratids

Age

Early Pliensbachian.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 25
97040

Locality and Fauna
Northwest Laberge map area N61°45'30", W135°45'00"
1.8 km east of Mandanna Creek. Map Unit; Mandanna Member Rock Type; Limestone corals and bivales

Age
Upper Triassic, probably Upper Norian.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 26
C. 086446

Locality and Fauna
Northwest Laberge map area N61°43'00", W135°43'45"
5.5 km east-northeast of Cone Hill. Map Unit; Mandanna Member. Rock Type; Limestone.

Neogondolella polygnathiformis (BUDOROV & STEFANOV) sensu lato (2)
Epigondolella sp.

Age
Late Triassic. Two small growth stages appear to the same species as in Collection 26a.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 26A
C. 086445

Locality and Fauna
Northwest Laberge map area N61°43'00", W135°43'45"
Map Unit; Mandanna Member Rock Type; Limestone.

Neogondolella polygnathiformis (BUDOROV & STEFANOV) sensu lato (2)

Age
Carnian, Late Triassic

Collection identified by C.A. Ross, University of Texas
G.S.C. Loc. No. 27
C-82673

Locality and Fauna
North central Laberge map area N61°53'00", W135°01'30"
5.5 km west of Big Salmon. Map Unit; Semenof Fm. Rock Type; Small limestone lens in greenstone.

Fusulinella cf. F. pulchra Rauser-Chern.
Wedekindellina sp.
Fusulinella spp. (at least 2 in addition to above)
Nankinella spp.
Bartramella sp.
Bradyina sp. (v. large)
Tetrataxis sp.
biserial forams

Age

Middle Carboniferous, Moscovian, upper part, younger than collection 56.

Collection identified by W.S. Hopkins, Geological Survey of Canada.
G.S.C. Loc. No. 28
C-60050-C-60053

Locality and Fauna

North central Laberge map area N61°58'30", W134°48'30" Tributary of Walsh Creek; 5 km from mouth of tributary. Map Unit; Walsh Creek Fm. Rock Type; Mud or clay.

Age

These samples were all taken from a cut bank along a tributary of Walsh Creek. Lithology could best be described as near mud or clay. All four samples yielded abundant uncarbonized woody kerogen ut only the first yielded playnomorphs. This poorly preserved microflora included Lycopodium, cf. Cyathidites, cf. Pinus, Sequoiapollenites, Glyptostrobus, Inaperturopollenies, ?Ulmus, ?Carpinus, ?Betula and unrecognizable triparate grains. Although I would be hard pressed to prove it, I would suggest a ?Miocene or Pliocene age for this assemblage.

Collection identified by W.S. Hopkins, Geological Survey of Canada.
G.S.C. Loc. No. 29
C-76925

Locality and Fauna

North central Laberge map area N61°55'30", W134°41'30" 3.5 km southwest of where Lokken Creek joins Walsh Creek. Map Unit; Walsh Creek Fm. Rock Type; Claystone.

Age

This sample contained only a very small and very poorly preserved microflora, nevertheless, results were interesting. Identified taxa include

Laevigatosporites, cf. Osmunda, Lycopodium, Sphagum, Pineaceae, Glypostrobus, cf. Carpinus, ?Alnus, unidentified tricolpate and triporate angiosperm pollen grains. According to the literature the Tantalus Formation is considered to be Upper Jurassic and/or Lower Cretaceous in age. This small assemblge of palynomorphs indicates a still younger age; at least Upper Cretaceous or younger. If ?Alnus is correctly identified the age is probably Tertiary. I feel examination of other samples would be warranted.

Collection identified by W.S. Hopkins, Geological Survey of Canada.
G.S.C. Loc. No. 29A
C-60044
C-60045
C-60046
C-60047
C-60048
C-60049

Locality and Fauna

Locality as above.

Age

With the exception of C-60045 all samples contained abundant carbonaceous material, generally not highly carbonized, but no palynomorphs. Samples were collected from extremely thin films of shale layered within the predominantly conglomeratic sequence. It would appear that the depositional environment precluded incoroporation of pollen or spores into even the finer elements of the stratigrahic pile. No age interpretations possible, although the fresh appearance of the organic material suggests the sequence is not particularly old.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 30
C. 086443

Locality and Fauna

North central Laberge map area N61°50'00", W134°58'30" 3 km southeast of peak 4534, 3km north-northeast of Cassiar bar. Map Unit; Boswell Fm. Rock Type; Limestone.

Ramiform fragments (2)

Age

Ordovician - Triassic

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 31
C. 086444

Locality and Fauna

North central Laberge map area N61°46'30", W134°42'40" 4 km south-southwest of mouth of Headless Creek. Map Unit; Boswell Fm. Rock Type; Grey limestone and yellow dolomite.

Idiognathoides noduliferous ELLSION & GRAVES, (1)

Age

Probably Morrowan, Early Pennsylvanian, possibly Atokan, early Middle Pennsylvanian.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 32
97043

Locality and Fauna

Western Laberge map area N61°36'10", W135°40'40" 10.4 km southeast of Conglomerate Mountain. Map Unit; Hancock Member Rock Type; Limestone.

Corals indet.

Age

Probably Upper Triassic.

Collection identified by W.S. Hopkins, Geological Survey of Canada.
G.S.C. Loc. No. 33
C-60057

Locality and Fauna

West central Laberge map area N61°35'40", W135°51'00" 4.2 km south of Conglomerate Mountain, just east of the highway Map Unit; Tantalus Fm. Rock Type; Chert bearing gritty sandstone.

Age

Much black kerogen. Only identifiable palynomorph was *Cicatricasisporites* which idicates an age of Lower Cretaceous or younger.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 34
97038

Locality and Fauna

West central Laberge map area N61°33'30", W135°46'00" 8 km southeast of Conglomerate Mountain. Map Unit; Aksala Fm, Casca Member Rock Type; Argillaceous limestone.

Hexacorals indet.
Spiriferids indet.

Age

Upper Triassic, probably Upper Norian.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 35
97041

Locality and Fauna

West central Laberge map area N61°33'30", W135°46'00" 8 km southeast of Conglomerate Mountain. Map Unit; Aksala Fm, Casca Member Rock Type; Shaly limestone.

"Pecten" cf. yukonensis Lees

Age

Upper Triassic, probably Upper Norian.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 36
97045

Locality and Fauna

Central Laberge map area N61°34'30", W135°25'00" 4 km southeast of north end of Coghlan Lake. Map Unit; Upper Hancock Member of Aksala Fm. Rock Type; Limestone.

Corals indet.

Age

Probably Upper Triassic.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 37
97046

Locality and Fauna

Central Laberge map area N61°34'25", W135°24'10"

4.3 km southeast of north end of Coghlan Lake. Map Unit; Upper part of Hancock Member. Rock Type; Limestone.

Coral indet.

Age

Probably Upper Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.

G.S.C. Loc. No. 38

C. 086431

Locality and Fauna

Central Laberge map area N61°33'55", W135°09'10"
2.7 km west of mouth of Frank Creek. Map Unit; Hancock Member. Rock Type; Limestone.
Ichthyolith

Age

Upper Palaeozoic/Triassic.

Collection identified by T.P. Poulton, Geological Survey of Canada.

G.S.C. Loc. No. 39

C-108107

Locality and Fauna

Central Laberge map area N61°35'05", W134°54'05"
500 m northwest of Hootalinqua. Exposure in bank of small creek draining into Yukon River. Map Unit; Povoas Fm. Rock Type; Greywacke.

Marine bivalves: Pleuromya sp.
Wood fragments

Age

Triassic to Early Cretaceous, Undiff.

Collection identified by M.J. Orchard, Geological Survey of Canada.

G.S.C. Loc. No. 40

C. 086440

Locality and Fauna

Western Laberge map area N61°32'10", W135°48'20"
3 km northeast of north end of Little Braeburn Lake. Map Unit; Casca Member. Rock Type; Limestone.

Inarticulate brachiopod, dorsal valve?

Age

Phanerozoic!

Collection identified by E.T. Tozer, Geological Survey of Canada.

G.S.C. Loc. No. 41

97044

Locality and Fauna

Western Laberge map area N61°32'00", W135°46'00"
2.5 km northeast of north end of Little Braeburn Lake.
Map Unit; Aksala Fm, Mandanna Member Rock Type; Limestone.

Terebratulid and spiriferid brachiopods indet.

Age

Triassic ?

Collection identified by H.W. Tipper, Geological Survey of Canada.

G.S.C. Loc. No. 41A

97044

Locality and Fauna

Locality and Fauna as above.

Many fragmentary terebratelid brachiopods.
Framents of unidentifiable pelecypods.

Age

Indeterminate, Late Triassic?? The brachiopods are similar to forms in many Triassic collections, particularly the Upper Norian, but aside from this comment they are not diagnostic. They are unlike any forms seen in Jurassic beds. The lithology favours, in general, the Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.

G.S.C. Loc. No. 42

C. 086441

Locality and Fauna

Western Laberge map area N61°31'30", W135°53'00"
12.8 km south of Conglomerate Mountain, near Braeburn.
Map Unit; Hancock Member. Rock Type; Lewes River limestone.
Ichthyoliths

Age

Upper Palaeozoic/Mesozic

Collection identified by H.W. Tipper, Geological survey of Canada.

G.S.C. Loc. No. 43

C-86698

Locality and Fauna

West central Laberge map area, N61°25'45", W135°40'00" 2.5 km southeast of Braeburn Mtn. Map Unit; Richthofen fm. Rock Type; Shale.

Ammonite, indeterminate

Age

Jurassic. This specimen is not identifiable even to genus. There are several Lower Jurassic forms that it could be, or even a Middle Jurassic sonninid.

Collection identified by H. Frebold, Geological Survey of Canada.

G.S.C. Loc. No. 44

C-86811

Locality and Fauna

Western Laberge map area N61°26'00", W135°38'00", 3.6 km southeast of Braeburn Mountain. Map Unit; Richthofen Formation . Rock Type; shale with interbedded marine ash flows of dacite.

Metaderoceras sp.
Tropidoceras sp.
ammonite indet.

Age

Early Pliensbachian, lower half.

Collection identified by H. Frebold, Geological Survey of Canada.

G.S.C. Loc. No. 45

C-86801

Locality and Fauna

Western Laberge map area N61°23'15", W135°41'00" On unnamed creek between Little Fox Lake and Braeburn Lake. 3.2 km east of St. Hilary Mountain. Map Unit; Nordenskiold Dacite (Marine). Rock Type; Black siltstone, "punky" sandstone.

1) Metadoceras spp. indet. Impressions and fragments. Poorly preserved.
2) Tropidoceras sp. indet.
3) Reynescoeloceras sp.
4) Tropidoceras cf. T. actaeon

Age

Early Pliensbachian

Collection identified by H.W. Tipper, Geological Survey of Canada.
G.S.C. Loc. No. 46
C-86697

Locality and Fauna

West central Laberge map area N61°22'00", W135°47'30"
5.5 km northeast of Belleview Mountain. Map Unit; Richthofen Fm. Rock Type; Thin bedded siltstone.

pelecypod fragment indet.
Paltechioceras? sp.

Age

Lower Jurassic (probably Upper Sinemurian) This loosely coiled ammonite resembles Paltechioceras very closely but because of preservation, it could also be one of several echioceratids. The keel is low and indistinct and is unlike most arietitids. The ribs are fairly straight and fade near the venter.

Collection identified by H.W. Tipper, Geological Survey of Canada.
G.S.C. Loc. No. 47
C-102951

Locality and Fauna

West central Laberge map area N61°21'55", W135°39'00"
3 km east of north end of Little Fox Lake. Map Unit; Nordenskiold Dacite, marine facies. Rock Type; Punky sandstone.

Phylloceras sp.
Arieticeras cf. A. algovianum
Leptaleoceras sp.
Fuciniceras? sp.
Protogrammoceras paltum
lytoceratids as in C-86695 above harpoceratid-like ammonite but ribs bifurcate belemnoid.

Age

Late Pliensbachian. The assemblage is similar to Late Pliensbachian faunas throughout western British Columbia, southern Alaska, and Oregon.

Collection identified by H.W. Tipper, Geological Survey of Canada.
G.S.C. Loc. No. 48
C-86549

Locality and Fauna

West central Laberge map area N61°21'20", W135°50'00"
3.8 km northwest of Bunker Hill. Map Unit; Richthofen Fm. Rock Type; Interbedded sandstone and shale.

harpoceratid ammonites - possibly Protogrammoceras,

Age

Late Pliensbachian. These are common genera in Tulsequah, Telegraph Creek and Spatsizi areas. Their stratigraphic position has not been fully established but in Queen Charlotte Islands and northeastern Siberia faunas containing these specific genera are thought to be near the Pliensbachian - Toarcian boundary.

Collection identified by H.W. Tipper, Geological Survey of Canada.

G.S.C. Loc. No. 49

C-86695

Locality and Fauna

West central Laberge map area N61°20'30", W135°38'00"

Gravel Pit near Little Fox Lake. Map Unit; Laberge Group, Tanglefoot Fm. Rock Type; Sandstone

lytoceratid ammonite with constrictions?

Age

Jurassic?, possibly Lower or Middle. The single imprint of a loosely coiled ammonite with possibly of a few constricttions suggests forms such as Nannolytoceras or Audaxlytoceras but must be considered indeterminate.

Collection identified by H.W. Tipper, Geological Survey of Canada.

G.S.C. Loc. No. 50

C-86550

Locality and Fauna

West central Laberge map area N61°18'30", W135°33'00"

1.5 km north of North end of Fox Lake. Map Unit; Laberge Grup, Tanglefoot Fm. Rock Type; Greywacke and shale.

Dorsetensia sp.

fragment of a coarse ribbed ammonite

Age

Lower Bajocian. No specific identification possible but similar forms to those of Collection 50A.

Collection identified by H.W. Tipper, Geological Survey of Canada.
G.S.C. Loc. No. 50A
C-86699

Locality and Fauna

As above.

Dorsetensia aff. D. liostraca liostraca S. Buckman
fragment of a phylloceratid ammonite
Dorsetensia sp.

Age

The age indicated is Lower Bajocian. Although the species in this collection have not been identified in the Canadian Cordillera before there are many species that are similar and these are invariably low in the Lower Bajocian. In the Yukon this genus or any sonniniid genus has not been found previously. Stephanoceras, a slightly younger L. Bajocian genus has been found in the Whitehorse area in the Fish Lake syncline and T.P. Poulton identified Tmetoceras from the Laberge area (collected by Reid) indicating an age of Early Aalenian, the stage below the Bajocian. This collection is from almost the youngest marine rocks of the Whitehorse Trough. The material collected is generally quite well preserved but has been somewhat compressed. Except for one fragment of phylloceratid, all specimens resemble the genus Dorsetensia. This genus has been studied by Wolfgang Huf in Germany (1968) and the specimens in this collecion resemble some of his species such as Dorsetensia liostraca liostraca S. Buckman except that the specimens in questions are coarser ribbed, ribs are more distant, the keel is less prominent and some have finer secondary ribs, particularly near the venter. Some of these differences could be explained by secondary deformation, but the generic assignment seems reasonable. These may be new species.

The specimen for which no specific name is suggested is poorly preserved but could be related to one of several species particularly D. deltafalcata (Quenstedt).

Collection identified by J.A. Jeletzky, Geological Survey of Canada.
G.S.C. Loc. No. 51
C-086809

Locality and Fauna

West central Laberge map area N61°19'40", W135°20'20"
7.0 km east-southeast of Mt. Edith, 3.5 km from mouth of Delta Creek. Map Unit; Conglomerate Fm. Rock Type; Siltstone.

Atractites sp. indet. (a rolled fragment) (To Index Collection)

Age

The same as for the locality 24A and lot C-081508, excepting the evidence of ammonites in the former lot.

Collection identified by M.J. Orchard, Geological Survey of Canada.

G.S.C. Loc. No. 52

C-086438

Locality and Fauna

(TOR 79.15-2) Central Laberge map area N61°8'15", W135°5'1" 8 km east of Mt. Lewes. Map Unit; Aksala Fm. Rock Type; shaly sandstone.

Ichthyoliths (2); micro-brachiopod

Age

None specified.

Collection identified by E.T. Tozer, Geological Survey of Canada.

G.S.C. Loc. No. 53

97035

Locality and Fauna

Central Laberge map area N61°27'30", W134°54'00" 11 km north of Miller Lake. Map Unit; Casca Member, Aksala fm. Rock Type; Limy sandstone.

Pinna sp.
Pectenids indet.

Age

Upper Triassic, probably Upper Norian

Collection identified by E.T. Tozer, Geological Survey of Canada.

G.S.C. Loc. No. 54

97036

Locality and Fauna

Central Laberge map area N61°27'15", W135°02'30" 1.3 km north of Donville Creek, 6 km south of Maunoir Butte. Map Unit; Aksala Fm. Hancock Mbr. Rock Type; Limestone

Spondylospira lewesensis (Lees)

Age

Upper Norian

Collection identified by T.P. Poulton, Geological Survey of Canada.
G.S.C. Loc. No. 55
C-86803

Locality and Fauna

Central Laberge map area N61°24'00", W134°53'00" 7 km northeast of Miller Lake. Map Unit; Tanglefoot Fm. Rock Type; Limy arkose to limestone.

Bivalves: *Trigonia* sp.
Myophorella sp.
"*Astarte*" sp.
Camponectes sp.
other bivalves; indet.
Scaphods(?)

Age

Probably Middle Toarcian to Bajocian but a younger Middle Jurassic age cannot be ruled out.

Collection identified by T.P. Poulton, Geological Survey of Canada.
G.S.C. Loc. No. 55A
C-81320 and C-81321

Locality and Fauna

Central Laberge map area N61°24'00", W134°53'00" 7 km northeast of Miller Lake. Map Unit; Tanglefoot Fm. Rock Type; Arkose.

Ammonites: *Tmetoceras* sp.
Bivalves: *Myophorella* spp.
Trigonia sp.
Thracia sp.
Placunopsis (?) sp.
Astarte spp.
Corbula(?) sp.
Perna(?) sp.
Gryphaea(?) sp.
"*Ostrea*"(?) sp.
Lima(?) sp.
Entolium sp.
Grammatodaon sp.
other bivalves, indet.
Gastropods, indet.
Serpulid worm burrows(?)
Belemnites(?), indet.

Age

Aalenian

Collection identified by E.W. Bamber, Geological Survey of Canada
G.S.C. Loc. No. 56
C-82677

Locality and Fauna

East central Laberge map area N61°25'15, W134°28'10"
11km northwest of Livingstone Creek. Map Unit; Boswell Fm. Rock Type; Light grey limestone, grainstone and packstone.

Age

None specified

Collection identified by C.A. Ross, University of Texas
G.S.C. Loc. No. 56A
C-82677

Locality and Fauna

As for 56.

Profusulinella sp.
Fusulinella sp.
Fusiella sp.
Eoschubertella sp.
Wedekindellina? sp.
Bradyina sp.
Kornia (algae)
biserial forams

Age

Middle Carboniferous, Moscovian, lower part of Upper Moscovian.

Collection identified by C.A. Ross, University of Texas
G.S.C. Loc. No. 57
C-82675

Locality and Fauna

Southeast Laberge map area N61°22'00", W134°25'00"
4.5 km northwest of Livingstone Creek. Map Unit; Boswell Fm. Rock Type; Basalt with limestone lenses.

Fusulinella sp.
Fusiella sp.
Pseudoendothyra ("Endostaffella") sp.
Nankinella sp.

Age

Middle Carboniferous, Moscovian, lower to middle part.

Collection identified by H.W. Tipper, Geological Survey of Canada.
G.S.C. Loc. No. 58
C. 86696

Locality and Fauna

Southeastern Laberge map area N61°18'00", W134°41'30"
8.2 km northwest of Teslin Crossing. Map unit; Lewes River Group? Casca Member? Rock Type; Black argillaceous limestone, thinbedded. This fossil lot is at the centre of a discrepancy. Its assigned age is Jurassic, but the rocks are unlike any Jurassic strata in the project area and resemble parts of the Casca Member.

one flattened and poorly preserved ammonite strongly resembling Phlyseogrammoceras or possibly Haugia. A safe identification is not possible.

Age

Probably Toarcian, possibly Late Toarcian.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 59
C. 086439

Locality and Fauna

(TOR 79-9.7) South central Laberge map area N61°18'4", W135°08'45"
6.5 km southeast of Goddard Pt., Lake Laberge. Map Unit; Lower Hancock Member, Aksala Fm. Rock Type; Limestone.

Epigondolella aff. E.postera (Kozur & Mostler)	(1)
Epigondolella sp. indet.	(3)

Age

Late Middle or Late Norian, Late Triassic.

Collection identified by H. Frebold, Geological Survey of Canada.
G.S.C. Loc. No. 60
C-86804

Locality and Fauna

Southeast Laberge map area N61°14'30", W134°45'00"
Small creek 7,5 km west of Teslin Crossing. Map Unit; Richthofen Fm. Rock Type; Shale.

Very poorly preserved specimens and fragments of small wide-umbilicate keeled ammonites with undivided straight ribs, one impression of part of ammonite with falcoid ribs. The specimens are probably hildoceratids such as Protogrammoceras and Arieticeras.

Age

Early Jurassic, probably Late Pliensbachian.

Collection identified by H. Frebold, Geological Survey of Canada.

G.S.C. Loc. No. 61

C-86805

Locality and Fauna

Southeast Laberge map area N61°14'30", W134°44'00" Small creek 6.5 km west of Teslin Crossing. Map Unit; Richthofen Fm. Rock Type; Shale

Impression of very small wide-umbilicate ammonite with undivided ribs and ventral keel. Gen. et sp. indet.

Age

Probably Early Jurassic

Collection identified by T.P. Poulton, Geological Survey of Canada.

G.S.C. Loc. No. 62

C-86802

Locality and Fauna

Southeast Laberge map area N61°14'00", W134°44'00" Small Creek 6.5 km west of Teslin Crossing Map Unit; Laberge Group, Tanglefoot Fm. Rock Type; Arkose.

Ammonites(?): Aptchi
Bivalves: Posidonia(?) sp.

Age

Probably Toarcian or Lower Bajocian judging by the most common occurrenc of similar Posidonia(?) in rocks of these ages in Canada. Younger or older Mesozoic, or even Late Paleozoic ages cannot be ruled out.

Collection identified by M.J. Orchard, Geological Survey of Canada.

G.S.C. Loc. No. 63

C. 086447

Locality and Fauna

SE Laberge map area N61°12'00", W134°33'30" 5 km south of Teslin Crossing. Map Unit; Hancock Member. Rock Type; Limy layer in orange weathering clastic rocks - argillite mudstone.

Ramiform element (1)
Ichthyolths

Age

Permo - Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 64
C. 087001

Locality and Fauna

South central Laberge map area N61°10'00", W135°01'00"
Northeast side of Hill 4308, near Laurier Creek. Map Unit; Hancock Member Rock Type; Massive dark grey limestone.

Epigondolella bidentata (Mosher) sensu lato (5)

ramiform elements (2)

Age

Late Middle or Late Norian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 65
C. 086450

Locality and Fauna

South central Laberge map area N61°10'00", W135°01'00"
East side of Hill 4308, near Laurier Creek. Map Unit; Hancock Mbr. Rock Type; Limestone

Epigondolella bidentata (Mosher) sensu lato (6)
Ramiform element
Ichthyoliths

Age

Late Middle or Late Norian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 66
C. 087002

Locality and Fauna

South central Laberge map area N61°10'00", W135°01'00"
Hill 4308, northwest of Laurier Creek. Map Unit; Hancock Mbr. Rock Type; Limestone.

Epigondolella bidentata (Mosher) sensu lato (22)
Ramiform elements (5)
Ichthyoliths

Age

Late Middle- Late Norian, Late Triassic

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 66A
C. 087003

Locality and Fauna

South central Laberge map area N61°10'00", W135°01'10"
Hill 4308, near Laurier Creek. Map Unit; Hancock Mbr.
Rock Type; Algal rich, white weathering, grey biomicrite limestone.

Epigondolella bidentata (Mosher) sensu lato. (12)

Age

Late Middle - Late Norian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 66B
C. 087004

Locality and Fauna

South central Laberge map area N61°10'10", W135°01'01"
Hill 4308, near Laurier Creek. Map Unit; Hancock Mbr.
Rock Type; Medium - dark grey limestone, biomicrite.

Epigondolella bidentata (Mosher) sensu lato (4)

Age

Late Middle - Late Norian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 66C
C. 087005

Locality and Fauna

South central Laberge map area N61°10'10", W135°01'01"
1 km northwest of Hill 4308, near Laurier Creek Map Unit; Hancock Mbr. Rock Type; Coralline, grey biomicrite.

Epigondolella bidentata (Mosher) sensu lato (85)
Ramiform elements (5)

Age

Late Middle - Late Norian, Late Triassic. This is the largest faunule containing elements referred to *E. bidentata* s.l., a species that occurs in many of the other faunules reported herein. Although this species falls into a broad concept of *E. bidentata*, there are significant differences from *E. bidentata* sensu stricto. The species is probably new, but its precise age, within the upper half of the Norian, is unknown.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 66D
C. 087006

Locality and Fauna

(TOT 79.11-20) South central Laberge map area N61°10'10", W135°01'10"
1 km north of top of section, Hill 4308, near Laurier Creek. Map Unit; Hancock Mbr. Rock Type; Coralline, grey biomicrite.

Epigondolella bidentata (Mosher) sensu lato (4)

Age

Late Middle - Late Norian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 67
C. 086449

Locality and Fauna

South central Laberge map area N61°10'00", W135°0'00"
Southeast side of Hill 4308, near Laurier Creek. Map Unit; Hancock Mbr. Rock Type; Grey, algal rich biomicrite.

Epigondolella bidentata (Mosher) sensu lato (2)
Ramiform element (1)

Age

Late Middle - Late Norian, Late Triassic.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 68
C. 086448

Locality and Fauna

South central Laberge map area N61°10'00", W135°01'00"
Southeast side of Hill 4308, near Laurier Creek. Map Unit; Hancock Mbr. Rock Type; Algal biomicrite.

Epigondolella bidentata (Mosher) sensu lato (2)

Age

Late Middle Norian - Late Norian,Late Triassic. The suffix sensu lato is used for these specimens pending further investigation of intraspecific variablity of similar populations.

Collection identified by J. Jenkins, Geological Survey of Canada
G.S.C. Loc. No. 69
95320

Locality and Fauna

South central Laberge map area N61°04'00", W134°53'00"
From Triassic reef at Lime Peak. Map Unit;Upper Hancock Member Rock Type; Limestone

Diplodella?
Juvenile platform - *Epigondolella* or *Neogondolella*
Epigondolella bidentata Mosher - 4 excellent specimens.

Age

Late Triassic, Late Norian. *Epigondolella bidentata* Mosher has a very limited stratigraphic range and is thus and important guide in the Upper Triassic. It is limited to rocks of Late Norian age.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 69A
C. 086442

Locality and Fauna

South central Laberge map area N61°04'00", W134°53'00"
Lime Peak. Map Unit; Upper Hancock Member Rock Type; Limestone.
Ramiform fragment

Age

Conodont fragment: Ordovician - Triassic

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 70
C. 087007

Locality and Fauna

South central Laberge map area N61°03'30", W134°54'00"
On shore of Thomas Lake; 2 km southwest of Lime Peak. Map Unit; Upper Hancock Member Rock Type; Limestone.

Epigondolella cf.*E. bidentata* MOSHER, 1968 (3)

Age

Possibly Late Middle, probably Late Norian, Late Triassic.

Collection identified by T.P. Poulton, Geological Survey of Canada.
G.S.C. Loc. No. 71
C-107856

Locality and Fauna

South central Laberge map area N61°07'30", W134°42'00"
3 km east of west end of Long Lake. Map Unit; Lower Tanglefoot Fm. Rock Type; Conglomerate

Ammonites: *Tmetoceras* sp. aff. *T. scissum* (Benecke)
Hammatoceratinae gen. et sp. indet.

Bivalves: *Entolium* sp.
Gresslya(?) sp.
Astarte(?) sp.
other bivalves, indet.

Wood fragments.

Age

Lower or possibly Middle Aalenian (Lower Middle Jurassic boundary). This collection comes from the same outcrop figured by Tempelman-Kluit (GSC Paper 78-A, p.63, fig. 14.5)

Collection identified by E.W. Bamber, Geological Survey of Canada
G.S.C. Loc. No. 72
C-82676

Locality and Fauna

Southeast Laberge map area N61°10'30", W134°19'00"
7 km west of Loon Lake. Map Unit; Boswell Fm. Rock Type; Limestone.

?Bothrophyllum sp. - incomplete specimen.

Age

Late Carboniferous or Permian. Thin-sectioned for fusulinaceans - none present.

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 73
C. 087010

Locality and Fauna

Southeast Laberge map area N61°08'10", W134°24'30"
11 km west of south end of Boswell Mtn. 16 km southeast of Teslin Crossing. Map Unit; Lewes River Group? Hancock Member? Rock Type; Massive light grey weathering, meium grey crinoidal lime mudstone.
Ichthyoliths

Age

Not specified

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 74
C. 087008

Locality and Fauna

Southeast Laberge map area N61°07'00", W134°13'00"
South end Boswell Mountain. Map Unit; Boswell Fm.
Rock Type; Limestone.
Ramiform fragments

Age

Ordovician - Triassic

Collection identified by M.J. Orchard, Geological Survey of Canada.
G.S.C. Loc. No. 74A
C 087009

Locality and Fauna

Southeast Laberge map area (lat. and long. as above)
South end Boswell Mountain Map Unit; Boswell Fm.
Rock Type; Limestone

Idiognathodus cf. *I. sinuosus* ELLISON & GRAVES (1)
Idiognathodus sp. indet. (3)

Age

Pennsylvanian through Early Permian, probably Pennsylvanian. Sweet (1975: Cat-of conodonts II) gives the range of *I. sinuosus* as Morrowan. LANE & STRAKA (1974: GSA Sp. pap.) record the range as mid Morrowan through unspecified post-Morrowan strata. In mind in the absence of good material determinable to species, the range of the genus is given.

Collection identified by E.W. Bamber, Geological Survey of Canada
G.S.C. Loc. No. 75
C-79700

Locality and Fauna

Southeast Laberge map area N61°06'40", W134°13'50"
South end of Boswell Mountain. Map Unit; Boswell Fm.
Rock Type; Lime mudstone.

echinoderm columnals
chonetid brachiopods
? prodctoid brachiopods (very poorly preserved)

Age

Probably Carboniferous or Permian

Collection identified by T.P. Poulton, Geological Survey of Canada.
G.S.C. Loc. No. 76
C-81315

Locality and Fauna

Northwest Laberge map area N61°44'30", W135°40'45"
10 km southeast of Birch Mtn. Map Unit; Nordenskiold Dacite Rock Type: Sandstone in a conglomerate lens between Nordenskiold Dacite sheets.

Ammonites and a bivalve, indet.

Age

The Toarcian age suggested in the field cannot be supported by detailed study because the specimens are too poorly preserved. nevertheless, this collection clearly represnts a different fauna than that represented more or less uniformly in collection C-81308 to C-81311 collected below it and in C-81322 and C-81323.

Collection identified by T.P. Poulton, Geological Survey of Canada.
G.S.C. Loc. No. 77
C-81308

Locality and Fauna

Northwest Laberge map area N61°44'00", W135°4'00"
10 km southeast of Birch Mtn. Map Unit; Nordenskiold Dacite Rock Type; Shale and sandstone beds in conglomerate below Nordenskiold Dacite.

Ammonites: 2 poor small fragments -
Arnioceras (?) sp.
Bivalves: Weyla acutiplicata
Chlamys sp.
Lima sp.
Meleagrinella sp.
Frenguelliella sp. (B of Pulton, 1979)
"Ostrea" sp.
Astarte sp.
Pinna(?) sp.
Protocardia sp.
Pleuromya(?) sp.
other bivalves, indet.
Terebratulid brachiopod(?), indet.

Age

Sinemurian (mid lower to lower middle)

Collection identified by T.P. Poulton, Geological Survey of Canada.

G.S.C. Loc. No. 77A

C-81309

Fauna

Bivalves:
- *Modiolus* sp.
- *Weyla alata*
- *Weyla acutiplicata* (?)
- other bivalves, indet.

Age

Sinemurian

Collection identified by T.P. Poulton, Geological Survey of Canada

G.S.C. Loc. No. 77B

C-81310

Fauna

Ammonites: a small undeterminable fragment that could well represent *Arnioceras*, *Asteroceras*, or similar forms.

Bivalves:
- *Weyla acutiplicata* and cf. *acutiplicata*
- *Chlamys* sp.
- *Lima* sp.
- *Entolium* sp.
- *Placunopsis*(?) sp.
- *Terquemia*(?) sp.
- *Modiolus*(?) sp.
- *Perna* sp.
- *Pinna*(?) sp.
- "*Ostrea*" sp.
- *Astarte*(?) sp.
- *Coelastarte*(?) sp.
- *Pleuromya*(?) sp.
- *Goniomya* sp.
- *Pholadomya* sp.
- *Frenguelliella* sp. (B of Poulton, 1979)
- *Cardinia* sp.
- *Corbula*(?) sp.
- *Protocardia* sp.
- other bivalves, indet.

Gastropods, indet.

Decapod(?) fragment, indet.

Age

Sinemurian

Collection identified by T.P. Poulton, Geological Survey of Canada.
G.S.C. Loc. No. 77C
C-81311

Fauna

Ammonites: 2 very poor small fragments - *Arnioceras*(?) sp.

Bivalves:
Weyla acutiplicata
Lima sp.
Meleagrinella sp.
Pinna sp.
Modiolus(?) sp.
Pleuromya(?) sp.
Coelstarte(?) sp.
Frenguelliella sp. (B of Poulton, 1979)
Thracia(?) sp.
Cardinia(?) sp.
other bivalves, indet.

Gastropods, indet.

Age

Sinemurian

Collection identified by T.P. Poulton, Geological Survey of Canada.
G.S.C. Loc. No. 78
C-81323

Locality and Fauna

Central Laberge map area N61°38'30", W135°11'30" 5.8 km southeast of southeastern end of Frank Lake. Map Unit; Conglomerate Fm. Rock Type; Rusty medium grained sandstone.

Ammonites: Poor, very small juveniles - Arnioceras(?) and possibly another genus.

Bivalves:
Weyla acutiplicata
Weyla alata
Frenguelliella sp. (B f Poulton, 1979)
Meleagrinella sp.
Lima sp.
Entolium sp.
"Ostrea" sp.
Modiolus sp.
Perna(?) sp.
Pinna sp.
Corbula(?) sp.
Pleuromya(?) sp.
Coelastarte(?) sp.
Isocyprina(?) sp.
other bivalves, indet.

Gastropod, indet.
Echinoid spine indet.

Age

Sinemurian

Collection identified by T.P. Poulton, Geological Survey of Canada.

G.S.C. Loc. No. 79

C-81322

Locality and Fauna

Central Laberge map area N61°38'00", W135°12'00" 5.8 km southeast of southeastern end of Frank Lake. Map Unit; Conglomerate fm. Rock Type; Massive sandstone.

Bivalves: *Weyla acutiplicata* and aff. *acutiplicata*
Weyla alata
Entolium spp.
Lima spp.
Chlamys sp.
Pseudomonotis(?) sp.
"*Pteria*" ap.
Pinna sp.
Perna sp.
Coelastarte(?) sp.
Gryphaea(?) sp.
Pleuromya(?) sp.
Pholadomya sp.
"*Ostrea*" sp.
Modiolus(?) sp.
Cyprina(?) sp.
other bivalves, indet.
Gastropods, indet.
Crinoid(?) columnals, indet.
rhynchonellid brachiopods(?), indet.
Terebratulid brachiopods(?), indet.

Age

Sinemurian

Collection identified by E.T. Tozer, Geological Survey of Canada.

G.S.C. Loc. No. 101

23395 Tozer's (1952) locality 1

Locality and Fauna

Central Laberge map area N61°26'45", W135°07'40" About 500m above the mouth of Donville Creek. Map Unit; Hancock Member. Rock Type; Grey limestone.

Myophoria sp.
Ostrea? sp.

Age

Upper Triassic

Collection identified by E.T. Tozer, Geological Survey of Canada.

G.S.C. Loc. No. 102

23438 Tozer's (1952) locality 2

Locality and Fauna

Central Laberge map area N61°26'40", W135°07'30" Approximately 650m from the mouth of Doville Creek. Map Unit; Hancock Member Rock Type; Interbedded greywacke and dark-grey limestone.

Halobia or *Daonella*

Trachyceratids resembling *Trachceras aonsides* (Mojsisovics)

Age

Upper Triassic, probably Lower Carnian.

Collection identified by E.T. Tozer, Geological Survey of Canada.

G.S.C. Loc. No. 103

23394 Tozer's (1952) locality 3

Locality and Fauna

Central Laberge map area N61°26'30", W135°07'40" At foot of small waterfall; about 950m above the mouth of Donville Creek. Map Unit; Hancock Member Rock Type; Light grey limestone.

Poorly preserved-
corals
Brachiopods
Pelecypods
Arinoid columnals, large echinoid radioles and an occasional echinoid test.

Age

Upper Triassic

Collection identified by E.T. Tozer, Geological Survey of Canada.

G.S.C. Loc. No. 104

23450 & 23423 Tozer's (1952) locality 4

Locality and Fauna

Central Laberge map area N61°30'30", W135°04'30" South end of Maunoir Butte. Map Unit; Casca Member Rock Type; greywacke.

Halobia pr *Daonella*
Mentzeliopsis? sp.

Age

Middle or Upper Triassic, probably Carnian.

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 105
23427 & 23447 Tozer's (1952) locality 5

Locality and Fauna

Central Laberge map area N61°28'30", W135°04'50" 1.5 km east of Thirty Mile River, 2 km south of Aksala Creek. Map Unit; Hancock Member Rock Type; Bioclastic limestone.

"cf. Dielasma julicum Bittner"
Gastropods & pelecypods including Mysidisptera cf. poyana (McLearn)

Age

Carnian (early Upper Triassic)

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 106 & 107
23389, 23406, 23422, 23424 Tozer's (1952) localities 6 and 7

Locality and Fauna

Central Laberge map area N61°30'45", W135°06'00" West side of Maunoir Butte. Map Unit; Casca Member Rock Type; Black argillaceous limestone, shale and siltstone

Monotis subcircularis
Halobia sp.
H. rugosa Gumbell
Juvavites sp.
other poorly preserved ammonites

Age

Norian

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 108
23410 Tozer's (1952) locality 8

Locality and Fauna

Central Laberge map area N61°30'30", W135°03'30" Southeast side of Maunoir Butte. Map Unit; Casca Member Rock Type; Grey calcareous shale.

Halobia

Age

Possibly early Norian

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 109
23457, 23459 Tozer's (1952) locality 9

Locality and Fauna

Central Laberge map area N61°25'00", W135°04'00"
5.5 km southeast of the mouth of Donville Creek. Map Unit; Casca Member Rock Type; Black argillaceous limestone

Monotis Subcircularis Gabb
Rhacophyllites sp.
Halorites sp. indet.
Rhabdoceras suessi Hauer

Age

Norian

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 110
23462 Tozer's (1952) locality 10

Locality and Fauna

South central Laberge map area N61°14'40", W135°11'30"
East shore of Lake Laberge, 16.6 km south of Lower Laberge Map Unit; Mandanna Member Rock Type; Limestone

Cerioid corals
Dielasma suttonensis Lees (non Clapp and Shimer)
Spondylospira lewesensis (Lees)
"Trigonia" textilis Lees
Palaeocardita sp.

Age

Late Norian (mid-Upper Triassic)

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 111-116
Tozer's (1952) localities 11-16

Locality and Fauna

Unknown except 23407 (Tozer's locality 115)

Locality and Fauna

South central and central Laberge map area
Localities 111 and 112 are on the east shore of Lake Laberge, 15 and 14 km, respectively, south of Lower Laberge. Localities 113 and 114 are also on the east shore of Lake Laberge, 8,2 and 5.4 km south of Lower Laberge. Loc. 115 is 10.4 km east-northeast of Lower Laberge. Locality 115 is 104.4 km east-northeast of Lower Laberge. Locality 116 is 4.0 km southeast of Maunoir Butte. Map Unit; Mandanna Member

A very varied fauna was collected at these localities and includes;

Spondylospira lewesensis (Lees)
Dielasma suttonensis Lees (non Clapp and Shimer)
"Variamussium" yukonensis Lees
Mysidea shulapsensis (McLearn)
Trigonia textilis Lees
Astarte cf. appressa Gabb
Paracochlocerds sp.
"Megalodus sp. nov"

Age
Late Norian (mid-upper Triassic)

From locality 115 the following conodonts were collected and identified by M.J. Orchard (GSC Loc. No. 23407)

Fauna
Epigondolella bidentata Mosher sensu lato

Age
Late Middle or Late Norian, Late Triassic

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 117
23434 Tozer's (1952) locality 17

Locality and Fauna
South central Laberge map area N61°19'00", W135°13'00"
8.6 km south of Lower Laberge, on east shore of Lake Laberge. Map Unit; Hancock Member Rock Type; Massive medium grey limestone.

Spondylospira lewesensis (Lees)
Dielasma suttonensis Lees (non Clapp and Shimer)

Age
Late Norian (mid-Upper Triassic)

Collection identified by E.T. Tozer, Geological Survey of Canada.
G.S.C. Loc. No. 118
23421 Tozer's (1952) locality 18

Locality and Fauna
Central Laberge map area N61°28'00", W135°02'30"
5.6 km northeast of the mouth of Donville Creek. Map Unit; Hancock Member Rock Type; Massive grey limestone.

Spondylospira lewesesois (Lees)
Dielasma suttonensis Lees (non Clapp and Shimer)
Ostrea ("*Alectryonia*") sp.

Age

Late Norian

Collection identified by E.T. Tozer, Geological Survey of Canada.

G.S.C. Loc. No. 119

23419 Tozer's (1952) locality 19

Locality and Fauna

South central Laberge map area N61°15'20", W135°12'30" On east shore of Lake Laberge, 15.4 km south of Lower Laberge. Map Unit; Hancock Member Rock Type; Grey massive limestone.

Poorly preserved ammonites (mainly inner whorls or arcestids)

Posidonia

Age

This assemblage represents a different faunal facies from that of localities 17 and 18 but no age determination is possible owing to poor preservation of the fossils.

From locality 119 the following conodonts were collected and identified by M.J. Orchard (GSC Loc. No. 23419)

Fauna

Neogondolella cf. *N*. *polygnathiformis* (Budorov & Stefanov)
Epigondolella aff. *E*. *primitia* Mosher

Age

Carnian (probably Late) - Basal Norian, Late Triassic

G.S.C. Loc. No. 201

10245 (Lees' lot 74)

Locality

Northwest Laberge map area N61°45'20", W135°45'45" Laberge area: 10 miles south of Mandanna Lake on the higher hills on the east side of the west branch of Mandanna valley.

G.S.C. Loc. No. 201A
10246 (Lees' locality)

Locality

One half mile west of lot 74 and stratigraphically lower.

G.S.C. Loc. No. 201B
10247 (Lees' locality)

Locality

Same locality as lot 74 (10245) 15ft. above it.

G.S.C. Loc. No. 202
10243 (Lees' locality)

Locality

Laberge area: 3 miles southeast of the southern end of Frank Lake and on higher hill west of the limestone belt.

G.S.C. Loc. No. 202A
10244

Locality

Central Laberge map area N61°38'40", 135°13'00"
3 miles southeast of the southern end of Frank Lake on higher hills west of the limestone belt.

G.S.C. Loc. No. 203
10239 (Lees' locality)

Locality

Laberge area: 4 miles southeast of the southern end of Frank Lake, in sandstone west of contct with limestone belt.

G.S.C. Loc. No. 203A
10240 (Lees' locality)

Locality

Laberge area: 4 miles southeast of the southern end of Frank Lake, in sandstone west of contact with limestone belt.

G.S.C. Loc.No. 203B
10241 (Lees' locality)

Locality

Central Laberge map area
3.5 miles south of Miller Lake, 4 miles southeast of the southern end of Frank Lake, in sandstone west of contact with limestone belt.

About this collection Frebold and Poulton (1977, p.98-99) wrote: "In the Laberge area of southern Yukon marine beds of Early Hettangian age are present. Lees described some poorly preserved ammonites as "cf. Psiloceras erugatus Bean" from this area. The locality (GSC loc. 10241) is 3.5 miles (5.6 km) south of Miller Lake, in limestone conglomerate well up in the basal member of the Laberge Series. This and other related species belong in Europe to the Planorbis Subzone of the Planorbis Zone."
Poulton reexamined the collection in 1984 and reported as follows " Regarding Lees (1934) identifications, only his locality can be confidently dated as Lower Sinemurian by the Ammonte Arnioceros. The Hettangian locality 55 is probably also correctly dated (Frebold and Poulton, 1977). The only revision to systematic names that can be suggested at present is revision of Trigonia aff. Costatula of Lees, to Frenguelliella, as done by Poulton, 1979."

G.S.C. Loc. No. 203C
10242 (Lees' locality)

Locality

Laberge map area N61°37'50", W135°1'30"
Same locality as lot 55 (1041, but stratigraphically lower in sandstone. Fragmentary plant remains.

G.S.C. Loc. No. 204
10250 (Lees' locality)

Locality

East central Laberge map area N61°21'10", W134°38'30"
9.8 km east of Teslin River, 8.5 km south of Masons landing.

LP80/1 = C.116317

Locality and Fauna

Lime Peak
Epigondolella bidentata Mosher

Age

Late Norian, Late Triassic

LP80/3 = C.116318

Locality and Fauna

South of Lime Peak, overlooking Thomas Lake
Epigondolella sp.

Age

Norian (probably Early or Middle), Late Triassic

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FIGURE CAPTIONS

Fig 1) Sketch maps to show the location of the project area in relation to the Belts and Terranes of the Canadian Cordillera. The first map shows the area in relation to the five tectono-physiographic "belts" into which the Canadian Cordillera is divided. Laberge and Carmacks map areas at the northern end of the Intermontane Belt also cover parts of the adjacent Omineca belt and Yukon Crystalline Terrane. The inset map shows the project area in relation to the terranes of southern Yukon. Cassiar Platform, Whitehorse Trough, Yukon Cataclastic Terrane and Yukon Crystalline Terrane are represented in the project area.

Fig 2) Sketch map of the project area showing where previous geological studies have concentrated. Areas delimited by boundaries are identified by author and year. Spot localities where specific descriptions are given are referred to by author, subject and page number. For example BL lr 12 means that Bostock and Lees, 1938 described Lewes River Group rocks specifically from this place on page 12 of their report.

For Laberge map area authors are as follows: Bostock, 1936 (B), Bostock and Lees, 1938 (BL), Cairnes, 1910 (C) Lees, 1934 (L). Tempelman-Kluit, 1978 (T-K). For Carmacks map area unless specified the author is Bostock, 1938. MIR refers to annual Mineral Industry reports of GSC and are identified by year

Lower case letters refer to rock types or rock units as follows: ai- acid intrusives: b-Braeburn Limestone: bi-basic in trusives: c-Carmacks Group: cl-Tertiary clastics: d-diorite: g-granite gneiss: gd-granodiorite: gr-granites: h-Hutshi Group: ki-Klusha intrusives: l-Laberge Group: lr-Lewes River Group: nd-Nordenskiold Dacite: n-Mt Nansen Group: p-porphyries: pv-Povoas Formation: q-quartz monzonite: s-syenite: sa-Schwatka andesite: sv-Selkirk Volcanics: t-Tantalus Formation: v-Tertiary volcanic rocks: y-Yukon Group

Fig 3) Map of southern Yukon showing the project area in relation to adjacent areas and to the most recent Geological Survey of Canada compilations of those areas. Map areas are identified by name NTS number author and year of publication.

Fig 4) Laberge map area showing the where ground observations were made during the present project The area between the Big Salmon River and its southern tributary was studied from Quiet Lake map area before the present project and by Erdmer during the present work.

Fig 5) Carmacks map area showing where ground observations were made during the present project.

Fig 6) Sketch map of the project area showing settlements, highways, seasonal roads, main drainages and the highest peaks Access is from the Klondike Highway, which transects the project area from north to south.

Fig 7) Map showing the project area in relation to Bostock's (1948) main physiographic subdivisions. Lewes Plateau, the upland between the Dawson Range and the Pelly Mountains, dominates the project area.

Fig 8) Map simplified from Hughes et al. (1969) to show the project area in relation to the maximum extent of late Pleistocene continental ice during the McConnell (youngest) and Reid (older) glacial advances. Outwash channels formed during deglaciation are shown for reference.

Fig 9) Map showing the main project area's fault bounded tectonic subdivisions. Cassiar Platform and Yukon Crystalline Terrane are the autochthon; Yukon Cataclastic Terrane and Whitehorse Trough rest above them structurally. Whitehorse Trough is bounded on the northeast and southwest by dextral strike-slips. Ductile faults separate Yukon Crystalline Terrane and the autochthon. Tatchun Belt is a subdivision of Whitehorse Trough and the Semenof Block and Teslin Suture Zone are subdivisions of Yukon Cataclastic Terrane.

Fig 10) Sketch map of the geology of the project area and its surroundings showing distribution of the main rock units and structures. Units are labelled following the scheme used in accompanying maps and diagrams and patterns separate large areas. The autochthon and the upper plate are separated by a thick detachment zone and the whole is covered by several "overlap" units. The autochthon has two elements, Cassiar Platform and Yukon Crystalline Terrane, the detachment also has two parts, Yukon Cataclastic Terrane and a top of granites and related rocks. Whitehorse Trough represents the brittle deformed upper plate.

Fig 11) Map of the the project area and suroundings showing the structure of Yukon Cataclastic Terrane, the detachment between Whitehorse Trough and the autochthon. Yukon Cataclastic Terrane includes ductilely deformed base and a weakly sheared top. The base has the Nisutlin, Anvil and Simpson Assemblages and the top has the Semenof Block and the Tatchun, Minto, Granite and Aishihik Batholiths. The structure of the southwestern autochthonous element, Yukon Crystalline Terrane is also shown. Trend lines and strike and dip symbols show the fabric orientation. Yukon Crystalline Terrane fabrics are discordant to those of Yukon Cataclastic Terrane; the first strike northeast the last to the northwest. Radiometric age determinations are shown by dots with numbers which represent the age in Ma. Localities where fossils were discovered in the Semenof Block are indicated by dots; these numbers refer to Appendix I where the fossils and their determination are listed.

Fig 12) Map of the project area and surroundings to show the distribution of granitic bodies around Whitehorse Trough. Rock types are identified by the symbols used in accompanying maps. Radiometric age determination localities are shown by dots with numbers to represent the age in Ma. The inset range plot shows

K/Ar ages and error limits determined for the intrusive bodies.

Fig 13) K/Ar ages of samples form Aishihik, Long Lake and Carmacks Batholiths reflect a complex thermal history. Aishihik Batholith may be intruded about the Late Paleozoic as indicated by the 268 Ma age or if the Povoas Formation is its extrusive daughter it may have been emplaced about the Late Triassic. Its 144 and 164 Ma ages likely reflect uplift possibly related to the strike-slip. Carmacks and Long Lake Batholith K/Ar dates are interpreted as uplift not intrusive, ages. If they, or intrusions like them, were the root for the Nordenskiold Dacite they were intruded about 195 Ma.

Fig 14) Table to show the postulated stratigraphic relations of the Lewes River Group subdivisions as visualized in the present work and according to earlier students of the group. Correlations between the Lewes River Group and the Stuhini and Takla Groups are shown for comparison.

Fig 15) Shematic north south cross sections of the relations of Lewes River Group strata (Povoas and Aksala Formations) on opposite flanks of Povoas anticline to show that the Casca and Hancock Members are lateral equivalents in the Aksala Formation. The upper sketches (A and B) shows the relations on the east and west flanks of the anticline between Laurier Creek and Povoas Mountain. The bottom sketch (C) shows the relations of Lewes River strata between Casca and Aksala Creeks

Fig 16) Map of Whitehorse Trough fossil localities, K/Ar age determinations and locations of stratigraphic columns of Fig. 17. Shading outlines the Trough and numbered symbols represent the fossil localities; numbering is according to the scheme of Appendix I. Triangles represent K/Ar age determinations on Laberge Group rocks, indicated by the age in Ma. Numbers in circles give the localions of the columns of Fig. 17 and the reconstructed stratigraphy of Figs. 20 and 21.

Fig 17) Stratigraphic columns for fault blocks in Whitehorse Trough. Complete sequences are rare and the columns represent composites for the respective blocks some more speculative than others. Columnns are identified by topographic names; the numbers at the top refer to the localities shown on Fig. 16. Numbers in the bottom right of units represent unit thicknesses (in km). Fossil localities, projected into the columns, are located on Fig. 16; the numbers match those of Appendix I and of Fig. 18. Radiometric age determinations are given by the initials KA with numbers representing the age in Ma.

Fig 18) Range plot of fossils from the project area collected during this and earlier work. Localities are identified by numbers corresponding to those in Appendix I; the first hundred numbers refer to collections made during the present work, the second hundred to Tozer's (1958) collections and the third hundred to collections of Lees (1934). The kind of fossils and the rock unit from which they derive are shown by symbol.

Fig 19) Diagram of the inferred relations of Laberge Group strata The unit is divided into four formations, a lower shale, overlain by laterally equivalent conglomerate and dacite and a by an upper unit of arkose.

Fig 20) Schematic east-west (cross) section of Whitehorse Trough in Laberge map area to show the inferred lateral relations of Lewes River and Laberge Groups subdivisions. The cross section is keyed to the columns of Fig. 16. Fossil localities are shown by numbers which refer to those of Appendix I. Thicknesses are roughly to scale. Hypothetical time lines are indicated by dotted lines. The wavy lines (top and bottom) indicate the limits of data.

Fig 21) Schematic northwest-southeast (longitudinal) section of Whitehorse Trough from southeastern Carmacks to south central Laberge map areas to show the inferred lateral relations of Lewes River and Laberge Groups subdivisions. Numbers at the top refer to the columns of Fig. 17. Fossil localities are shown by numbers which refer to those of Appendix I Thicknesses are roughly to scale. The dotted lines represent hypothetical time lines. The wavy lines (top and bottom) indicate the limits of data.

Fig 22) Sketch map of the distribution of the Tantalus Formation "overlaps" in relation to Whitehorse Trough's bounding faults. The Tantalus Formation occurs at, or near, releasing double bends of the bounding strike-slips. The lightly shaded area represents that underlain by Laberge and Lewes River Group beds; dark shading represents the Tantalus basins. General bedding attitude, average thickness (in km- square boxes) and relevant age determinations and fossil localities are shown. The topographic names identifiy the outliers for discussion in the text.

Fig 23) Sketch map of the distribution of Mount Nansen Group extrusive and intrusive "overlaps" and their hypothesized equivalents in relation to Whitehorse Trough. The shaded area represents that underlain by Laberge and Lewes River Group beds. Relevant radiometric age determinations are shown by numbers which give the age in Ma. The outliers are identified by the topographic names used in the text.

Fig 24) Sketch map of the distribution, facies, average thickness age determinations and general orientation of the area's two Late Cretaceous volcanic "overlap" units, the Carmacks Group and Open Creek volcanics. The faulted southwest boundary of Whitehorse Trough, shown for reference, is overlapped by the Carmacks Group in the Miners Range and west of Carmacks. Boxed numbers represent average thicknesses in km; K/Ar age determinations are shown in Ma with their experimental uncertainty. Light shading represents the lower volcaniclastics and andesite of the Carmacks Group; darker shading represents upper Carmacks Group flood basalt. The "v" pattern represents areas with the welded felsic tuff, low in the Group. Lower Carmacks Group tuffs are represented by small dots for relatively fine-grained tuffs, larger dots for coarser-grained varieties. Subvolcanic intrusives are shown by the granitic pattern. Open Creek volcanics are shown by vertical ruling. The histogram is a summary of the radiometric age determinations for the unit.

Fig 25) Composite stratigraphic columns for the four main areas where the Carmacks Group is exposed to show the inferred internal relations. The unit has a lower andesitic formation dominated by pyroclastics in Carmacks map area and by porphyries in the Miners Range. The Group's top is the characteristic flood basalt. Granitic laccoliths occur between the Carmacks Group and its basement on Prospector Mountain and Mount Pitts. Pipes and plugs of syenite, trachyte or gabbro, which occur locally are thought to be feeders for the top of the unit. Thicknesses are shown in km and K/Ar age determinations, projected into the columns, are shown in Ma.

Fig 26) Distribution of Pliocene and Pleistocene "overlap" units in the project area. The Selkirk Volcanics around Fort Selkirk were extruded from four centres (stars)- Volcano Mountain, Wolverine cone, Minto centre and one on Wolverine Creek- indicated by stars. The inset map shows changes in the Yukon River's course since extrusion of the Selkirk Lavas. Solid lines show the pre-Selkirk Yukon River route; the dashed outline is of today's course. Walsh Creek beds are Pliocene fanglomerate derived from the Pelly Mountains and laid along a fault scarp that is a precursor to Big Salmon River. Possible equivalents fo these beds are seen along the Campbell Highway at km 539.5.

Fig 27) Schematic structure sections without vertical exaggeration across the project area show the inferred relations between the autochthon (Cassiar Platform and Yukon Crystalline Terrane), detachment (Yukon Cataclastic Terrane) and upper plate (Whitehorse Trough). Section A is diagonally across Carmacks map area and section B is across Laberge map area. Structural styles of the slices are as different as their stratigraphy. The thin upper plate is deformed by strike-slip faults which end in the detachment zone; the autochthonous rocks are cut by roughly coeval, northeast directed thrusts which can't be traced upward. The detachment zone between them apparently absorbed the differential slip through penetrative shear in the basal part and through spaced faults higher up. Boundaries between elements are faults, ductile ones low in the structural sequence and brittle breaks higher up. Granite batholiths and basalt in the top of the detachment zone are weakly sheared and may represent Whitehorse Trough's structurally detached roots and floor.

Fig 28) Sketch map to show the project area's main structures. Note that the large strike-slips, all part of the Teslin dextral strike-slip system, are confined to, or along the margins of, Whitehorse Trough (not shaded). The Teslin Fault has two branches; a northeastern one with releasing double bends and a southwestern one with constraining bends. The northeastern one, at the edge of the Trough, is the Semenof, Hootalinqua, Boswell, Mason system along which small extension basins are localized. The southwestern system, in the Trough, includes the Open, Chain, Fairview, Breaburn Faults. The Selkirk, Hoochekoo and Carmacks Faults along the Trough's southwest margin are also dextral slips with releasing double bends that localized extension. Faults and folds in Whitehorse Trough are thought to be Late Jurassic to Early Cretaceous. The breaks southwest of Whitehorse Trough are Late Cretaceous normal faults; they "overlap" Whitehorse Trough's strike-slips and are related to Mount Nansen and Carmacks Groups volcanism.

Fig 29) Transfer of slip from the Teslin to the Boswell and from there to the Semenof Fault through the Mason and Hootalinqua connector faults defines two "releasing double bends" where extension was localized. This created tectonic basins which filled with the Tantalus Formation during strike-slip. Beside dating the slip this also shows that the sense of slip was dextral. Releasing double bends also localized the Tantalus basins on the southwest side of Whitehorse Trough showing that faults on that margin are also dextral.

Fig 31) Sketch map and schematic cross-section of the area around southern Lake Laberge across the Laberge-Whitehorse map areas boundary to show the relations of the Laberge Faults. The faults juxtapose serpentinite and basalt of the Late Paleozoic Cache Creek Group next the Early Jurassic Laberge Group omitting the intervening Lewes River Group. They also truncate folds in Laberge Group strata obliquely. The Laberge Faults are interpreted as the opposite dipping flanks of the detachment's arched upper surface. It plunges northwest under Whitehorse Trough at about the map area boundary. They show that Whitehorse Trough is not only detached at the edges, but under the middle as well and they show that structures above and below this surface do not match.

Fig 32) Map of the structures between the Chain and Braeburn Faults. Short dashes indicate the strike of bedding. The

Fairview Fault is interpreted as the left-slip connector between two right-slip master faults. The amount of slip is unknown, but could be many km. Note the symmetrical map pattern of faults and folds in the wedges which is idealized in the inset. Mandanna Syncline is the analogue of the Tanglefoot Syncline and the Mandanna Fault and its partner are matched by the two Twin Lakes Faults. Structures in the two wedges may be products of constriction between the bounding faults. If the Fairview Fault is dextral and coeval with the Chain and Braeburn Faults it should trend northeast. But it strikes nearly north and could be rotated. This may explain the constricted wedges but the rotation is counterclockwise- opposite to that expected with dextral slip.

Fig 33) Sketch map of Whitehorse Trough structures southwest of Povoas Anticline. Folds are generally truncated by faults and may be rotated. For example if the Surprise and Ptarmigan Synclines are the same fold cut by the Edith Fault one is rotated with respect to the other. The relations show that the folds generally predate the faults. The latest large structures, the Frank, Aksala and Casca Faults, cut and displace all other structures.

Fig 34) Diagram to show the ages of Whitehorse Trough's stratigraphic units and those of the "overlap" strata. The dates show that dextral strike-slip on Whitehorse Trough's bounding faults probably occurred in the Late Jurassic and Early

Cretaceous. Ages on the ductilely deformed rocks (YCT= Yukon Cataclastic Terrane) show that their strain precedes strike-slip, but may have overlapped about 160 Ma.

Fig 35) Strain ellipse for Whitehorse Trough strike-slips. The ellipse is oriented by dextral faults, such as the Teslin (R), and by extension faults, such as the Hootalinqua (e). The diagram predicts that the folds should strike east (f). Instead they trend northwest implying that the folds, the stress field or both rotated with time.

Fig 36) Hypothetical cross section across the northern Intermontane Belt (not to scale, northeast on right). Whitehorse Trough is interpreted as an upper plate separated from the autochthon by a detachment zone. The detachment includes a ductilely deformed base, Yukon Cataclastic Terrane, and a weakly sheared top that is not named (it includes the Semenof Block and several batholiths). The autochthon also has two elements, Cassiar Platform and Yukon Crystalline Terrane, presumably separated by a fault (shown here as a southwest dipping thrust). They were presumably juxtaposed before Whitehorse Trough was thrust over them both during the Jurassic.

Fig 37) Map of the project area showing the general geology and the mineral occurrences. Mineral showings are indicated by dots and numbers which refer to the text; the numbers are the same as those used in Department of Indian and Northern Affairs publications on Yukon Exploration and Geology Most showings are associated with the Mount Nansen Group, a mid-Cretaceous "overlap" unit in southwestern Carmacks map area. The Big Creek Fault is considered a Mount Nansen-related break- it probably controls the distribution of the porphyry copper and gold showings along Big Creek.

NEW NAMES PROPOSED FOR ROCK UNITS

To accompany all manuscripts and maps submitted for publication

1. Proposed names: SEMENOF FORMATION and BOSWELL FORMATION

2. Reasons for proposing names: to formalize descriptions

3. Summary definition: The Semenof Hills are a subdivision of Teslin Suture Zone with Carboniferous basalt and limestone, partly correlative with the Taku and Cache Creek Groups.

4. Lithology:
SEMENOF FORMATION - Resistant, massive dark green altered basalt, volcanic breccia, tuff and greenstone; includes minor undifferentiated BOSWELL FORMATION

   BOSWELL FORMATION - Recessive, dark weathering, slate, phyllite greywacke, chert, chert conglomerate and breccia, volcanic breccia, greenstone and limestone. White weathering, massive to thick bedded, resistant, grey, micritic limestone. Resistant massive, dark green, altered basalt, volcanic breccia and greenstone; distinguished from SEMENOF FORMATION by stratigraphic context. Massive dark weathering, coarse to medium grained, hornblendite-gabbro.

5. Contact relations: The BOSWELL and SEMENOF FORMATIONS are time equivalent and resemble the Cache Creek Group.

6. Thickness and distribution: BOSWELL FORMATION - 1100 m thick; southwestern Boswell Mountain and the Semenof Hills' northeast flank. SEMENOF FORMATION - 800 m. thick; distribution restricted to the Semenof Hills.

7. Index fossils: BOSWELL/SEMENOF - 27, 56, 57, 74;

8. Age: BOSWELL/SEMENOF - Pennsylvanian;

9. Locality of type sections if applicable: N/A

10. Origin of name: BOSWELL FORMATION - named for Boswell Mountain where there are good exposures. SEMENOF FORMATION - name taken from the low mountain range to which their outcrop is restricted.

11 Proposed publication: Terminal Report - Laberge map area

12. Have you checked the availability of proposed name? Yes

13. Remarks:

Signed ____________________

Critical Reader ____________________

NEW NAMES PROPOSED FOR ROCK UNITS

To accompany all manuscripts and maps submitted for publication

1. Proposed names: LEWES RIVER GROUP includes AKSALA FORMATION with MANDANNA, CASCA AND HANCOCK MEMBERS; and POVOAS FORMATION

2. Reasons for proposing names: to formalize descriptions

3. Summary definition: The LEWES RIVER GROUP includes four generally superposed, laterally interfingered facies deposited during the Carnian and Norian From the base up are basalt-andesite breccia, reefal limestone calcareous shale and greywacke and red greywacke

4. Lithology: AKSALA FORMATION - MANDANNA MEMBER: red weathering, moderately resistant, medium bedded, green and red greywacke and pebble conglomerate; red shale partings, minor interbedded red shale and siltstone. CASCA MEMBER: recessive, brown and rusty weathering, brown shale and greenish, calcareous greywacke and sandstone; interbedded bioclastic limestone and argillaceous limestone; minor conglomerate and agglomerate. HANCOCK MEMBER: resistant, white weathering, massive limestone and thick bedded limestone; minor thin bedded argillaceous limestone.

   POVOAS FORMATION - Massive resistant, dark weathering, dark green andestic basalt, volcanic breccia, tuff and agglomerate; minor augite porphyry and massive flow rocks; massive resistant, dark green, volcanic breccia, tuff, agglomerate and augite porphyry in Tatchun Belt; includes- chlorite-amphibole schist, the sheared and metamorphosed equivalents in Carmacks map area; massive, red weathering, dacitic volcanic breccia and tuff; includes minor limestone; resembles Nordenskiold Dacite.

5. Contact relations: POVOAS FORMATION - overlain by and intertongued with, carbonate of the HANCOCK MEMBER; no strata are seen below those of the POVOAS FORMATION but the unit may rest on the BOSWELL and SEMENOF FORMATIONS or on their time equivalents AKSALA FORMATION - ovelain conformably by the CONGLOMERATE FORMATION

6. Thickness and distribution: LEWES RIVER GROUP - occupies central Whitehorse Trough in Laberge map area,

largely between the Chain Fault and the Fairview and Goddard Faults. POVOAS FORMATION - 500 m. thick; crops out in the core of Aksala anticline, an open fold east of Lake Laberge; other exposures are northeast of Mandanna-Chain Lakes west of Conglomerate Mountain and between Mandanna Creek and Birch Mountain; AKSALA FORMATION - 1000 to 1500 m. thick; occurs on the flanks of the Povoas Anticline

7. Index fossils: 10, 12, 17, 20, 21, 22, 25, 26, 32, 36 37 41, 54, 59, 64, 65, 66 67, 68, 69, 70, 101, 102, 103, 104, 107, 109, 110, 111, 112

8. Age: LEWES RIVER GROUP - Upper Triassic (Carnian and Norian) POVOAS FORMATION - Middle? and Upper Triassic; AKSALA FORMATION - Upper Triassic

9. Locality of type sections if applicable: N/A

10. Origin of name: LEWES RIVER GROUP - Bostock (1936); POVOAS FORMATION - taken from Povoas Mountain where large outcrops occur; AKSALA FORMATION - named for Aksala Creek

11 Proposed publication: Terminal Report - Laberge map area

12. Have you checked the availability of proposed name? Yes

13. Remarks:

Signed ____________________

Critical Reader ____________________

NEW NAMES PROPOSED FOR ROCK UNITS

To accompany all manuscripts and maps submitted for publication

1. Proposed names: LABERGE GROUP includes TANGLEFOOT FORMATION, NORDENSKIOLD DACITE, CONGLOMERATE FORMATION RICHTHOFEN FORMATION

2. Reasons for proposing names: to formalize descriptions

3. Summary definition: The LABERGE GROUP is a succession of shale, conglomerate, dacite, greywacke and arkose that ranges through the Lower and into the Middle Jurassic

4. Lithology: TANGLEFOOT FORMATION - Moderately resistant, pale yellow to buff weathering, thick to medium bedded gritty, coarse grained arkose and feldspathic sandstone; interbedded granite-pebble conglomerate; interbedded brown shale.

   NORDENSKIOLD DACITE - Resistant, reddish brown weathering, massive, medium blue grey, mauve green or reddish dacite dacite tuff and breccia with fresh plagioclase, hornblende and biotite; interbedded conglomerate; Resistant, reddish brown weathering, massive, khaki-green dacite tuff with fresh plagioclase, hornblende and biotite; grades locally to pale green, punky weathering, salt and pepper textured, massive sandstone, the weathered equivalent; interbedded conglomerate and shale

   CONGLOMERATE FORMATION - Resistant, massive to very thick bedded, red brown weathering, well-indurated, matrix- and clast- supported, boulder, cobble and pebble conglomerate; clasts of andesite-basalt, subvolcanic dacite porphyry and granodiorite; minor interbedded greywacke and shale.

   RICHTHOFEN FORMATION - Recessive, dark brown weathering, thin bedded, dark brown to greenish, silty shale; minor interbedded conglomerate; gradational to, and interbedded with, massive dacite .

5. Contact relations: LABERGE GROUP - generally considered to rest unconformably or disconformably on the LEWES RIVER GROUP and disconformably below the TANTALUS FORMATION. The NORDENSKIOLD DACITE rests on, and is intertongued with, the CONGLOMERATE FORMATION.

6. Thickness and distribution: LABERGE GROUP - is exposed in the northern Intermontane Belt, an area referred to as Whitehorse Trough, Wheeler (1961). TANGLEFOOT FORMATION - 200 - 1500 m. thick; occurs mainly in northwestern Laberge map area and in southeastern Carmacks map area; well developed north of Twin Lakes east of Coghan Lake and on Anticline Mountain; NORDENSKIOLD DACITE - 600 - 800 m. thick; occurs west of Lake Laberge Coghlan Lake and Chain Lakes; the main outcrops are on both sides of the Mandanna valley. CONGLOMERATE FORMATION - 200 - 1200 m. thick; exposed discontinuously from the west shore of Lake Laberge to Mandanna valley RICHTHOFEN FORMATION - 600 M. thick; vicinity of Lake Laberge and southeastern Carmacks map area just upstream of Five Finger Rapids on Yukon River.

7. Index fossils: TANGLEFOOT FORMATION - 9, 23, 50, 55, 71; CONGLOMERATE FORMATION - 19, 76, 77; RICHTHOFEN FORMATION - 3, 7 ,8, 43, 44, 45, 46 60, 61.

8 Age: TANGLEFOOT FORMATION - Toarcian-Bajocian; NORDENSKIOLD DACITE and CONGLOMERATE FORMATION - Pliensbachian to Toarcian; RICHTHOFEN FORMATION - Hetangian to Pliensbachian.

9. Locality of type sections if applicable: N/A

10. Origin of name: LABERGE GROUP - the rocks were studied west of Lake Laberge and named the Laberge Series by Cairnes (1910); they are here raised to Group status; TANGLEFOOT FORMATION - named for the mountain in northwest Laberge map area; NORDENSKIOLD DACITE - named by Cairnes (1910) and is treated here as a Formation of the LABERGE GROUP; CONGLOMERATE FORMATION - named for Conglomerate Mountain just east of the Klondike Highway; RICHTHOFEN FORMATION - Richthofen Island in southwest Lake Laberge has good outcrop;

11 Proposed publication: Terminal Report - Laberge map area

12. Have you checked the availability of proposed name? Yes

13. Remarks:

Signed ____________________

Critical Reader ____________________

NEW NAMES PROPOSED FOR ROCK UNITS

To accompany all manuscripts and maps submitted for publication

1. Proposed names: OPEN CREEK VOLCANICS

2. Reasons for proposing names: to formalize description

3. Summary definition: colourful Late Cretaceous volcanics

4. Lithology: reddish, white, green and bluish dacite flows and flow breccia; brown basalt flows on Solitary Mountain.

5. Contact relations: probably overlie the Nisutlin and Anvil Allochthonous Assemblages unconformably northeast of Baker Lake and north of Teslin Mountain; north of Hootalinqua rest unconformably(?) on massive POVOAS FORMATION Greenstone.

6. Thickness and distribution: 300 - 400 m. thick; occur around Open Creek and on Solitary Mountain in southeastern and northeastern Laberge map area; the largest area is northeast of Baker Lake on both sides of Boswell River;

7. Index fossils: N/A

8. Age: Late Cretaceous (Campanian)

9. Locality of type sections if applicable: N/A

10. Origin of name: named for Open Creek where there are colourful volcanics

11 Proposed publication: Terminal Report - Laberge map area

12. Have you checked the availability of proposed name? Yes

13. Remarks:

Signed ____________________

Critical Reader ____________________

NEW NAMES PROPOSED FOR ROCK UNITS

To accompany all manuscripts and maps submitted for publication

1. Proposed names: WALSH CREEK FORMATION

2. Reasons for proposing names: to formalize descriptions

3. Summary definition: nearly flat lying beds of moderately indurated conglomerate

4. Lithology: resistant, thick bedded to massive, moderately-indurated conglomerate with minor interbedded sandstone. Recessive white claystone to mudstone with interbedded gritty sandstone and minor coal. Resistant, white weathering, massive rhyolite.

5. Contact relations: rests unconformably on older strata; in the northeast the conglomerate is faulted against BOSWELL FORMATION limestone.

6. Thickness and distribution: 30 - 500 m. thick; north central Laberge map area, along Walsh Creek and its tributaries;

7. Index fossils: 28, 29

8. Age: Tertiary (Miocene or Pliocene);

9. Locality of type sections if applicable: N/A

10. Origin of name: named for Walsh Creek where beds are exposed;

11 Proposed publication: Terminal Report Laberge map area

12. Have you checked the availability of proposed name? Yes

13. Remarks:

Signed ____________________

Critical Reader ____________________

FAULT NAMES

D'Abbadie
Big Salmon
Teslin
Tatchun
Semenof
Chain
Braeburn
Fairview
Mandanna
Open
Goddard
Ogilvie
Miller
Thomas
Surprise
Edith
Richtofen
Coghlan
Casca
Aksala
Frank
Carmacks
Hoochekoo
Ingersoll
Selkirk
Laberge
Big Creek
Miners
Mason
Tanglefoot
Crossing?
Laurier
WALSH

FOLDS

Poroas Anticline
Surprise Syncline
Edith Syncline
Anticline Syncline
Mandanna Syncline

New Names units

Boswell
Semenof
Open Creek
Walsh Creek
Poroas
Aksala
Hancock
Casca
Mandanna
Richthofen
Conglomerate
Tanglefoot
Teslin Crossing