LATE TRIASSIC TO MIDDLE JURASSIC (NORIAN TO OXFORDIAN) VOLCANIC AND SEDIMENTARY STRATIGRAPHY AND STRUCTURE IN THE SOUTHEASTERN PART OF THE ISKUT RIVER MAP SHEET, NORTH-CENTRAL BRITISH COLUMBIA.

By

MICHAEL H. GUNNING

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE (HONOURS).

In

DEPARTMENT OF GEOLOGICAL SCIENCES

This thesis conformed to the required standards.

- - - - - - - - - - - - - -

ADVISER

THE UNIVERSITY OF BRITISH COLUMBIA
APRIL 1, 1986

MICHAEL H. GUNNING

LATE TRIASSIC TO MIDDLE JURASSIC (NORIAN TO OXFORDIAN) VOLCANIC AND SEDIMENTARY STRATIGRAPHY AND STRUCTURE IN THE SOUTHEASTERN PART OF THE ISKUT RIVER MAP SHEET, NORTH-CENTRAL BRITISH COLUMBIA.

By

MICHAEL H. GUNNING

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE (HONOURS).

In

DEPARTMENT OF GEOLOGICAL SCIENCES

This thesis conformed to the required standards.

- - - - - - - - - - - - - - -
ADVISER

THE UNIVERSITY OF BRITISH COLUMBIA
APRIL 1, 1986

MICHAEL H. GUNNING

ABSTRACT

The thesis area lies in the northwestern portion of the Bowser Basin, located in the heart of the Intermontane Belt of the Canadian Cordillera. The Bowser Basin is a successor basin formed in Late Bajocian time as a result of the division of the Hazelton Trough by the uplift of the Skeena Arch. Arch upheavals and basin formation occurred throughout the Middle Mesozoic in north-central British Columbia, and were closely related to terrane amalgamation and acoretion events during that time.

The stratigraphy of the area consists of Norian to Late Pliensbachian volcanic sequences that correlate with both the Takla Group and the Toodoggone volcanics. The volcanic sequences are unconformably overlain by Toarcian to Bathonian clastic deposits of coarse sandstone and conglomerate that correlate with the Spatsizi sediments. Locally calcareous siltstone beds indicate that local facies transitions occur across the thesis area. This clastic sedimentary sequence is conformably overlain by ammonite-bearing, Bajocian to Oxfordian, black shale deposits that are correlative with the Ashman Formation of the Bowser Lake Group.

The source region for the clastic sedimentary deposits was the chert-rich Cache Creek Group, located in the uplifted Stikine Arch region directly to the north of the basin. Deep water depositional environments prevailed in the

thesis area from Late Bajocian time onward. A significant facies transition occurs as one moves northward from the thesis area towards the Spatsizi map area and the source region for the northern Bowser Basin. Coarser grained, clastic sequences become more abundant to the north in the Ashman Formation, indicating that a shallower water, higher energy, deltaic environment prevailed in that area.

There are two, non-coaxial phases of deformation evidenced in the thesis area that are orientated at 90° to each other. Megascopic fold structures produced during the first event dominate in the area and trend northeast-southwest. Correlation of the structural synthesis of the thesis area to other areas in the northern Bowser Basin is unclear.

TABLE OF CONTENTS — PAGE

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

INTRODUCTORY STATEMENT

Detailed geologic mapping of the Iskut River map area (104 B) in northwestern British Columbia has been slow in developing with only a few minor projects (Grove, 1971; Donnelly, 1976; Grove, 1981) having been carried out in the past twenty years. However, this is slowly changing as improved logistics help overcome the isolation, rugged terrain, and harsh weather characteristic of the region. Dr. R.G. Anderson of the Geological Survey of Canada in Vancouver is presently co-ordinating the first comprehensive study of the geology of the region, and this report is prepared in support of his continuing work in the area.

The primary objectives of the paper will be to describe in detail the lithology, stratigraphy, and structure of the thesis area. The ages of the various units, both relative and absolute, will be bracketed through the applications of biostratigraphy. The lithologic units described are readily mappable in the field and are useful for correlation with Bowser Lake Group strata in other parts of the Bowser Basin.

In addition, the depositional environment for the sedimentary deposits in the thesis area will be discussed and provenance terranes for these sediments will be evaluated based on ternary diagram applications.

Finally, the stratigraphy observed in the thesis area will be correlated to that of other areas in the Bowser Basin. Rock units based on lithology and age will be described and used for correlation with other regions.

LOCATION AND ACCESS

Field work for this study was done in an area of approximately 25 square kilometers near Tom Mackay Lake located in the Boundary Ranges of the Coast Mountains. The area lies between the Iskut and Unuk rivers, and is approximately 80 kilometers north-northeast of Stewart. The map sheets used for this study are the Snippaker Creek and John Peaks (N.T.S. 104 B/10 and 104 B/9) respectively, with longitudes ranging from W 130° 35′ to W 130° 20′, and latitudes ranging from N 56° 35′ to N 56° 40′.

There is no road access in the area and helicopters are used for traverses and flycamps. Field work was carried out from August 18 to August 27, 1985, and was made possible through a Geological Survey of Canada project under the supervision of Dr. Anderson.

METHODS OF STUDY

Detailed mapping was carried out on five day traverses originating from flycamps established at Tom Mackay Lake and Storie Creek. Hand samples were collected and used for thin section study and several fossil localities were located and sampled for macrofossils.

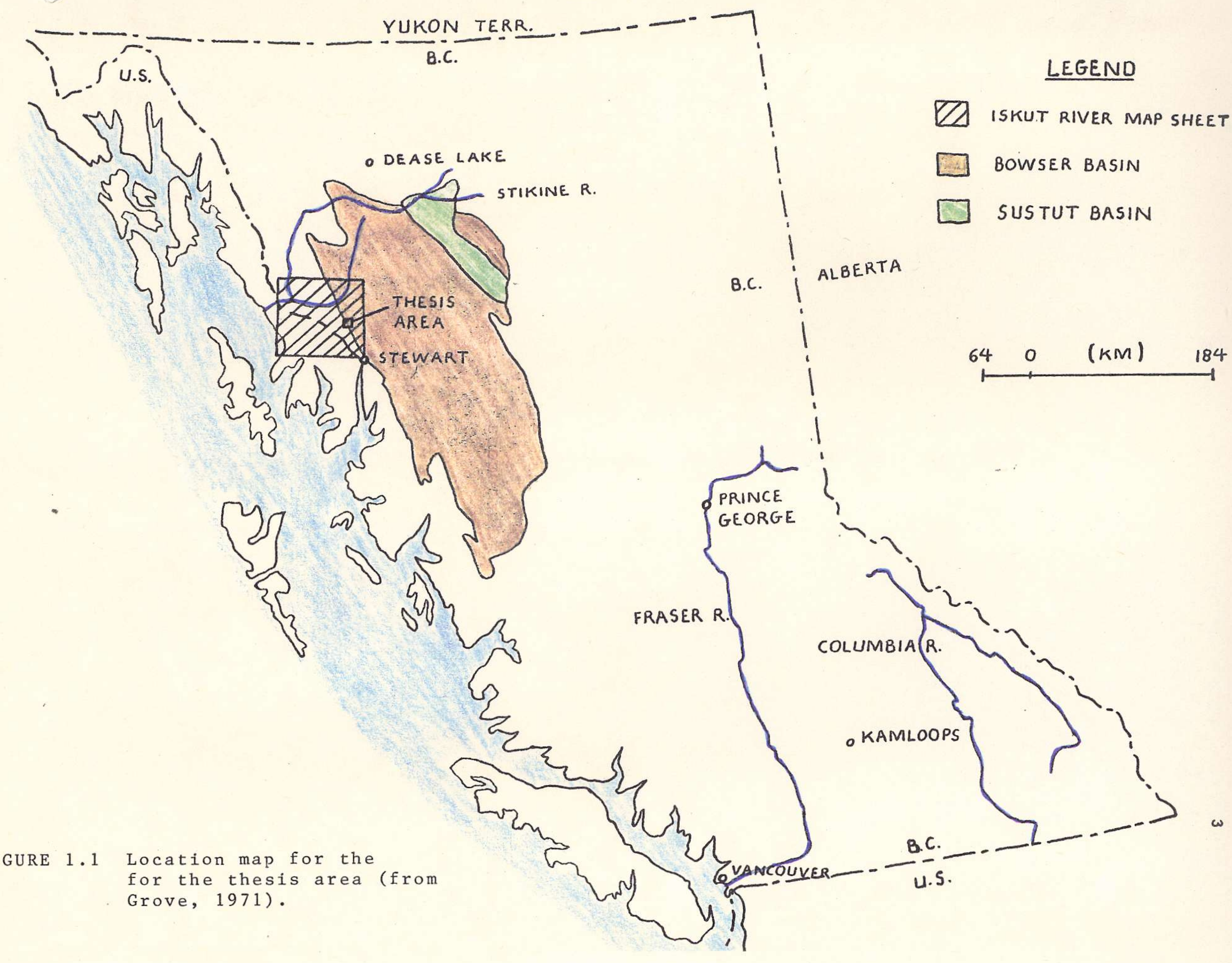


FIGURE 1.1 Location map for the for the thesis area (from Grove, 1971).

ACKNOWLEDGMENTS

Credit for this report is due to many people, however I would like to thank most sincerely Dr. Bob Anderson of the Geological Survey of Canada for his continual guidance and support. Dr. Anderson suggested the area for my thesis during the field season of 1985, and made time available for work on the project. I also thank the Geological Survey of Canada for their financial support and their encouragement of B.Sc. thesis objectives for students such as myself.

I would also like to thank Dr. H. W. Tipper of the Canadian Geological Survey for his time and efforts in fossil identification.

My thesis supervisor at the University of British Columbia was Dr. T. Danner and I greatly appreciated and benefited from both his support and advice during the study. I sincerely thank all those who have helped throughout the duration of the project.

PREVIOUS WORK

The inaccessability of the Iskut River region has greatly hindered the amount of geological study it has received. However, reconnaissance mapping of the region was initiated by G.M. Dawson in 1875 when he explored the southern extent of what is now referred to as the Bowser Basin.

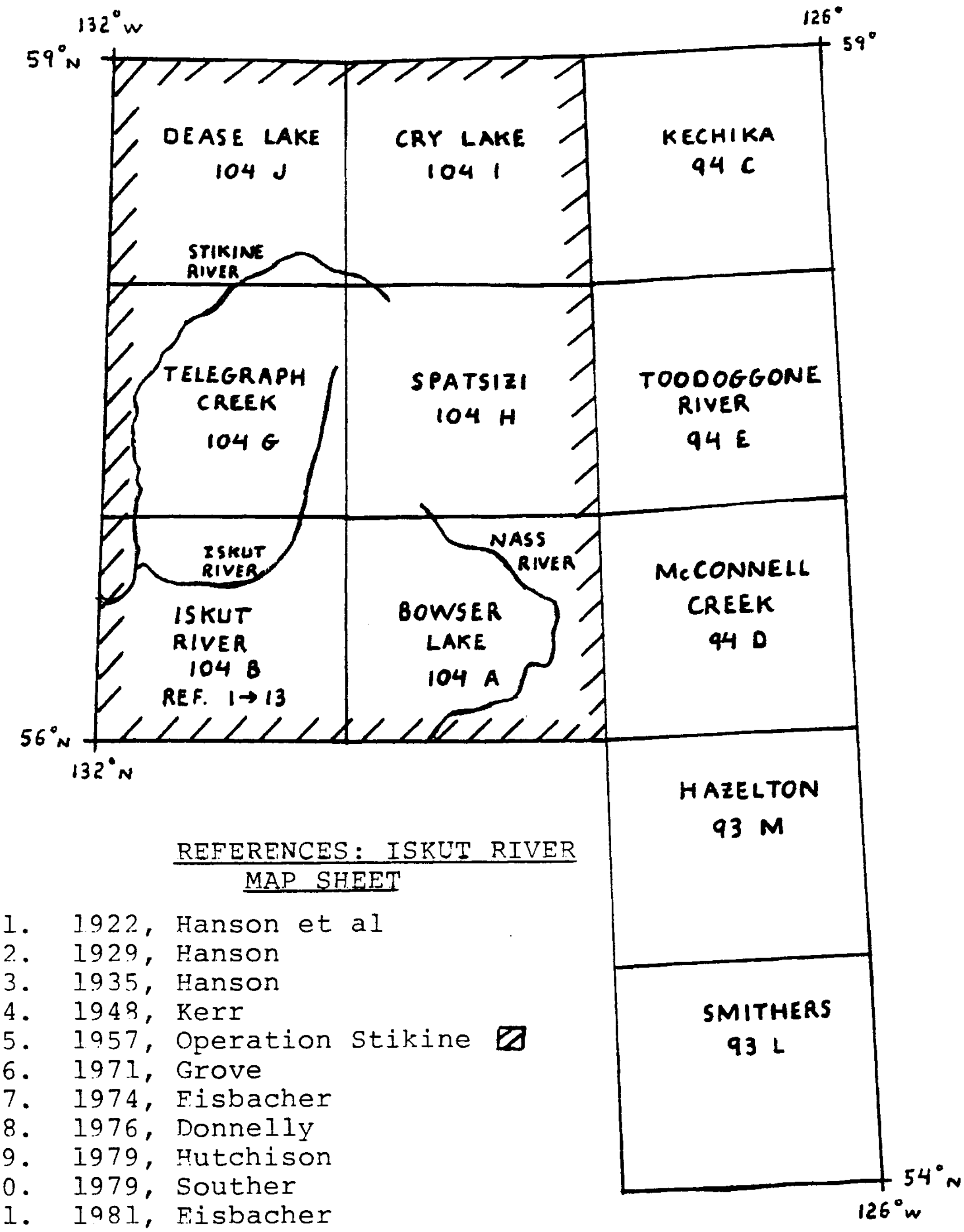
Systematic mapping of the northern Bowser Basin started in 1956 with the advent of "Operation Stikine"; a regional geological study of north-central British Columbia by the Geological Survey of Canada. This study included parts of the Iskut River map sheet. At this time, a 1:250,000 map of the area was published (G.S.C., 1957), and the first reference to Jurassic sediments in the area was made. The Bowser Lake Group sediments were also formally named (Roddick, 1957).

In 1966, Dr. J. Souther (G.S.C.) expanded the extent of the Bowser Lake Group rocks and in that same year, Souther and Armstrong (1966) prepared the first detailed tectonic and geologic model for north-central British Columbia and the Bowser Basin. Detailed stratigraphic and paleontologic studies followed (Frebold and Tipper, 1970), and a detailed study of the Telegraph Creek map sheet (Souther, 1972) located directly to the north of the thesis area was completed.

Although this work greatly accelerated the understanding of the Bowser Basin geology as a whole, the geology of the Iskut River region was still comparatively poorly known. In contrast, the Stewart region to the southwest received a significant amount of geological work during the mid 1900's due in a large part to the area's economic attractiveness. The first report which dealt with the detailed geology of the Iskut River region was prepared by F. A. Kerr in 1948 for the Geological Survey of Canada.

The first detailed geologic map which included the geology of the thesis area was included in a report by Edward Grove (1971) on the Sterwart area. Grove has also published an updated version of this map (1981) for a report on the Stewart and Iskut River region that he is presently completing. In 1976, D. Donnelly completed a B.Sc. undergraduate thesis for Texasgulf that dealt with the geology of the Kay Claims just 5 kilometers east of Tom Mackay Lake. In 1979, maps made by Hutchison et al and Souther et al were released that focused on the geology of the Iskut River region. These maps, together with those of Grove, represent the most recent work in the area.

In 1976, Dr. H. Tipper and Dr. T. Richards completed the most comprehensiva study to date on the Mesozoic stratigraphy of north-central British Columbia. In 1984, L. Currie completed a study on the stratigraphy of the northern Spatsizi map area, and in 1985, R. Thomson completed a detailed study on the stratigraphy of the Spatsizi Plateau area which followed his previous work in the area with Dr. P. Smith (1984) of the University of British Columbia. In 1986, I. Moffatt completed a study on the structure of the Groundhog Coalfield area in the northeastern Bowser Basin which followed his previous work in the area with Dr. M. Bustin (1983, 1984) of the University of British Columbia. The work of Tipper and Richards, Currie, Thomson, Smith et



<u>REFERENCES: ISKUT RIVER MAP SHEET</u>

1. 1922, Hanson et al
2. 1929, Hanson
3. 1935, Hanson
4. 1948, Kerr
5. 1957, Operation Stikine ▨
6. 1971, Grove
7. 1974, Eisbacher
8. 1976, Donnelly
9. 1979, Hutchison
10. 1979, Souther
11. 1981, Eisbacher
12. 1981, Grove
13. 1985, Anderson

FIGURE 1.2 A map of the Iskut River map sheet and surrounding map areas, and a list of references of previous studies which have included some aspects of the geology of the Iskut River map sheet (modified from Thomson, 1985).

al, Moffatt and Bustin, and that of Donnelly will be referred to throughout the paper.

GEOLOGIC SETTING

The Bowser Basin lies in the heart of the Central Cordillera in British Columbia. The Canadian Cordillera is composed of five parallel and physiographically distinct belts that trend northwest-southeast (Fig. 1.3a). Two of these belts comprise orogenic zones; the Coast Plutonic Complex (Coast Belt) of the Cretaceous to Early Tertiary Pacific Orogeny to the west, and the Omineca Crystalline Belt of the Middle Jurassic to Tertiary Columbian Orogeny to the east. Both of these orogenic belts are composed of granitic and medium - to high-grade metamorphic rocks and are bordered and separated by three belts characterized by essentially unmetamorphosed sedimentary and volcanic rocks. The Omineca Crystaline Belt is bordered to the east by the Rocky Mountain Fold and Thrust Belt, and is bordered to the west by the Intermontane Belt. The Coast Plutonic Complex is bordered to the west by the Insular Belt and to the east by the Intermontane Belt which forms much of central British Columbia.

The thesis area lies within the Intermontane Belt and figure 1.3b shows the configuration of the allocthonous or "suspect" terranes that amalgamated to form the tectono-stratigraphic belt. The Stikine Terrane makes up most of the western half of the Intermontane Belt and is of

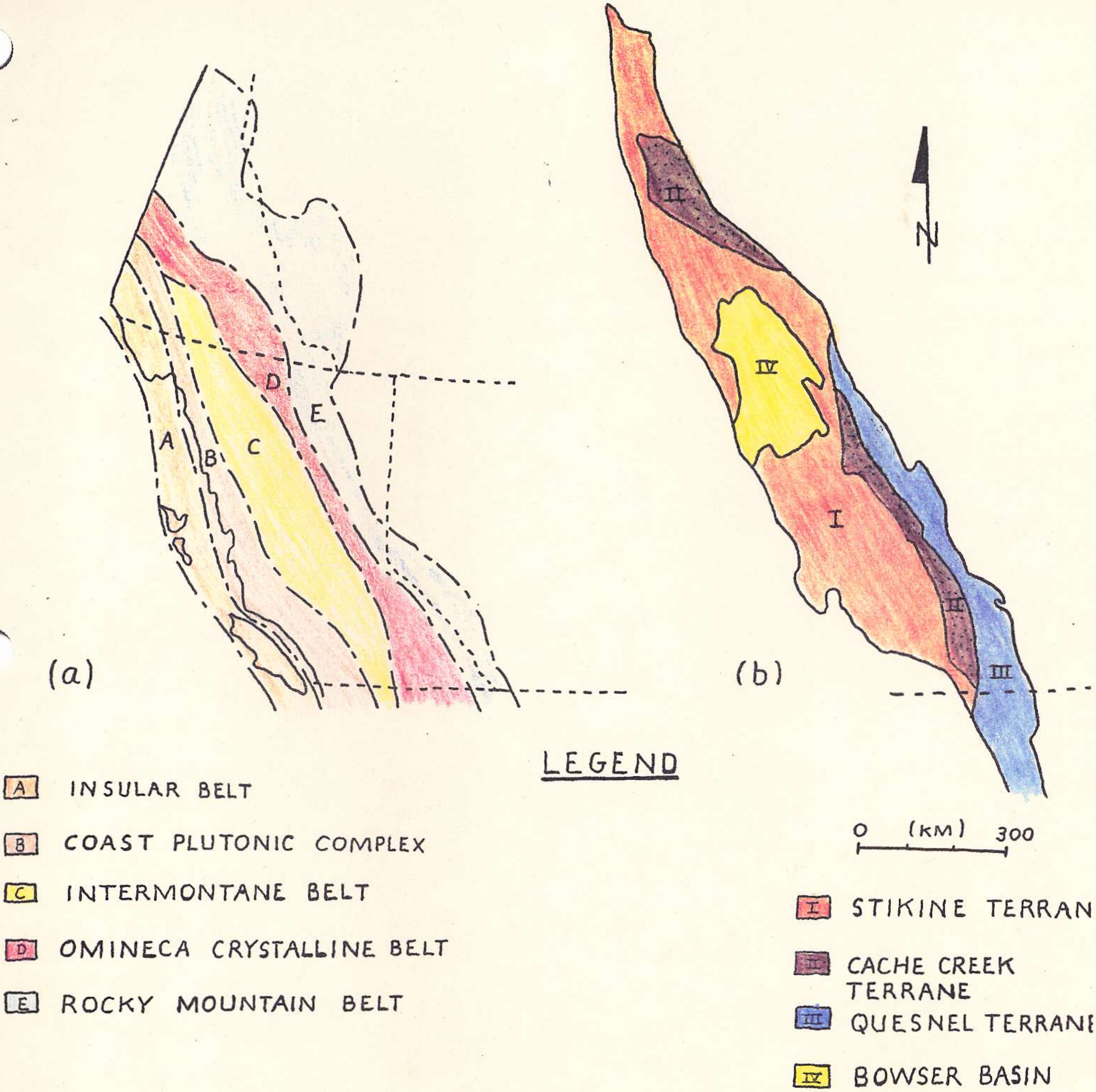


FIGURE 1.3 Distribution of the tectonic belts of the Canadian Cordillera (1.3a) and the position of the allocthonous terranes that make up the Intermontane Belt (1.3b) (modified from Thomson, 1985)

primary interest to this study as it is the terrane onto which the sediments of the Bowser Basin were deposited.

The Bowser Basin lies in the central area of the Intermontane Belt in a region that is dominated by unmetamorphosed lithologies. Its boundaries are well defined by arches or by intrusive bodies (Fig. 1.4). To the north and to the south, the basin is bordered by the Stikine Arch and Skeena Arches respectively. To the east, it is bordered by the metamorphic and plutonic bodies of the Omineca Crystalline Belt while intermediate to basic intrusions which make up much of the Coast Plutonic Complex form the formidable western border of the basin.

The sediments which have filled in the Bowser Basin are primarily marine and were deposited during Middle to Late Jurassic time. In most areas, they are underlain by the Late Paleozoic - Early Mesozoic sediments and volcanics that filled in the previously formed Hazelton Trough.

REGIONAL GEOLOGY AND TECTONICS

During the Late Triassic, the Stikine Terrane was the site of very active volcanism which resulted in the deposition of calc-alkaline volcanic sequences rich in plagioclase. This volcanism was also accompanied by granitic intrusions that may have been co-magmatic with the volcanic events (Souther, 1977). The sequences of volcanic rocks deposited at this time are now referred to as the Stuhini

Group (correlative with the Takla group found in the southern part of the basin). At the end of Late Triassic time, this volcano-plutonic complex was uplifted to form the Stikine Arch possibly as the result of the collision (i.e. amalgamation) of the Stikine and Cache Creek Terranes.

The Cache Creek Terrane, located along the boundary between the Intermontane and Omineca Crystalline Belts, was also uplifted in Late Triassic time and this uplifting event divided north-central British Columbia into three separate basins. The Hazelton Trough formed to the west and southwest, the Whitehorse Trough formed to the north, and the Quesnel Trough formed to the east and southeast. The Whitehorse Trough was filled primarily with sediments while the Hazelton Trough became the site of considerable accumulations of Early Jurassic volcanic rocks that are now referred to as the Hazelton Group.

The rocks of the Hazelton Group are exposed over a very large area in north-central British Columbia, and in many areas directly underlie the Bowser Lake Group (Fig. 1.5). They form a succession of both marine and non-marine rocks dominated by rhyolitic to basaltic flows and tuffs with lesser amounts of clastic sediments and limestone. This primarily volcanic sequence is divided into three major formations (Tipper and Richards, 1976) : the Telkwa, Nilkitwa, and Smithers Formations. Of these three, the Telkwa is the most extensive. The age of these volcanic sequences ranges from Sinemurian to Early Callovian. The earlier successions suggest a subaerial environment while the upper strata suggest a shallow marine, back-arc setting (Tipper and Richards, 1976).

In Early Bajocian time, the Skeena Arch, cored by granitic bodies, was uplifted as a result of the emplacement of the Topley Intrusions. This event divided the Hazelton Trough into two "successor basins" (i.e. basins that form as the result of the breakup or division of a larger basin); the Nechako Basin to the south of the Skeena Arch, and the Bowser Basin to the north. This event also initiated the Middle to Late Jurassic "molasse" sedimentation of the Bowser Basin.

The Bowser Basin was filled with the detritus from the erosion of the surrounding uplifted belts (i.e. primarily the Stikine Arch to the north and northwest,and the Skeena Arch to the south and southeast), from Late Bajocian to Middle Kimmeridgian time (Tipper and Richards, 1976). The resulting sedimentary sequences are now referred to as the Bowser Lake Group. Its aerial extent is considerable (Fig. 1.4), and the Bowser Lake Group is composed of both marine and non-marine rocks. Shales, silstones, sandstones, and conglomertes were deposited with little or no limestone to form the Late Bajocian to Early Oxfordian Ashman Formation; the lowermost and most extensive unit in the Bowser Lake Group. The environments of deposition were characterized by

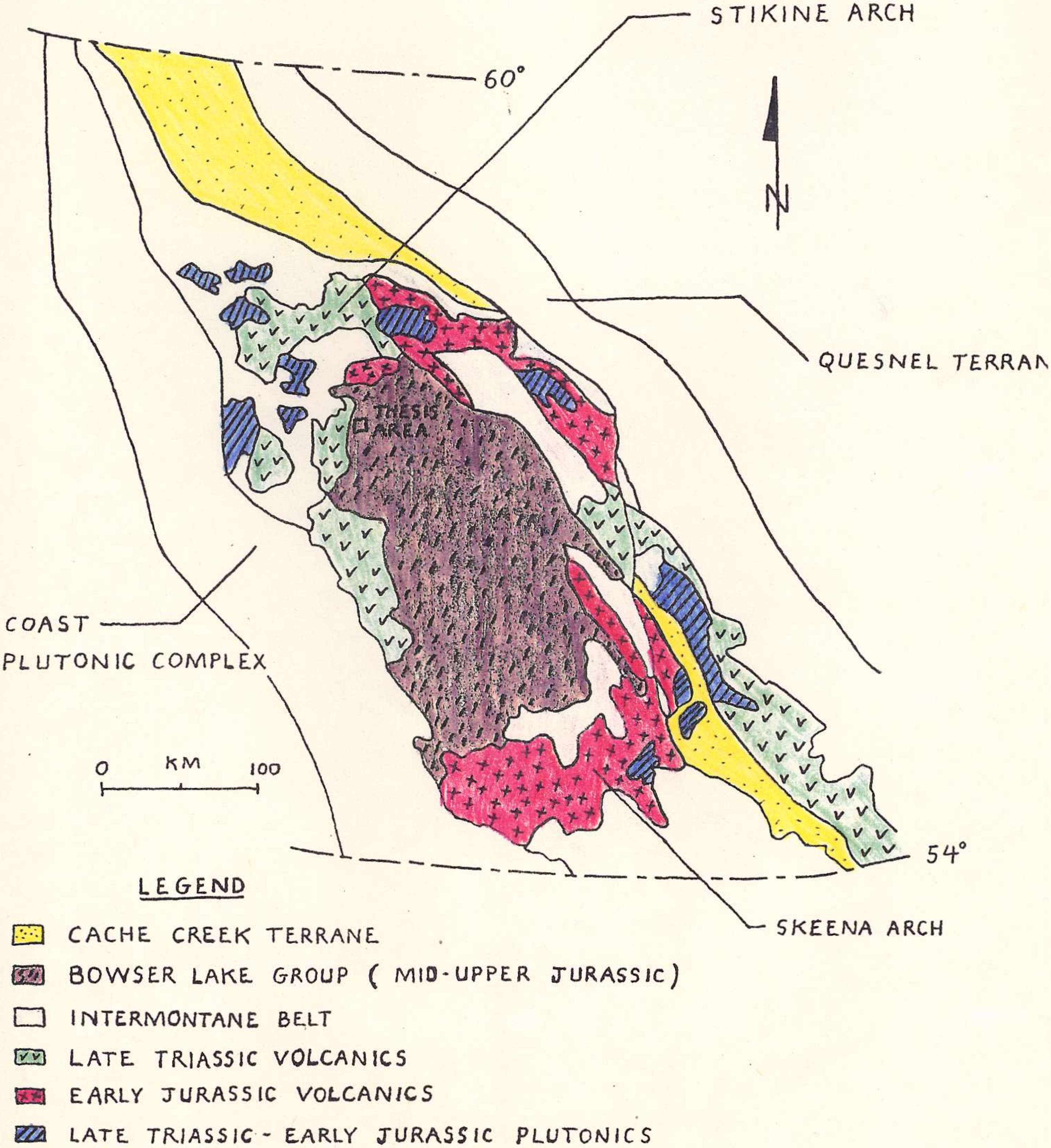


FIGURE 1.4 Regional geology of the Bowser Basin of northwestern British Columbia outlining the terrane boundaries and major rock groups of the Jurassic and Triassic (modified from Thomson, 1985).

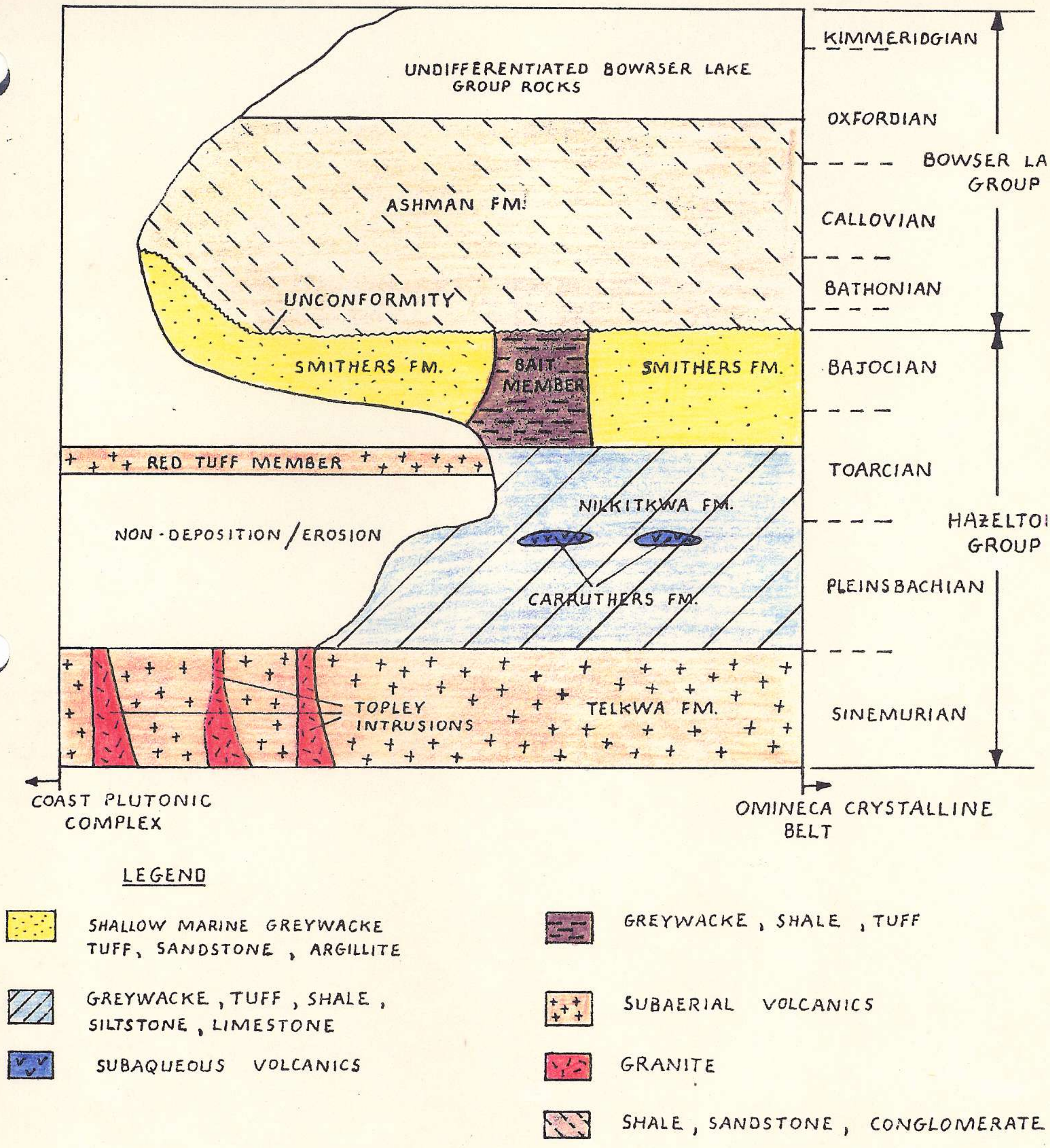


FIGURE 1.5 Stratigraphic section of the Mesozoic rocks that form much of the Intermontane Belt in north-central British Columbia (modified from Tipper and Richards, 1976).

high levels of energy with deltaic, pro-deltaic, and continental slopes being the primary depositional sites. The coarser clastic sediments are moderately compositionally mature, and texturally mature with little matrix and well rounded grains.

The structure of both the Hazelton Group volcanic rocks and the Bowser Lake Group sedimentary rocks is characterized by "passive", or flexural-slip dominated folds that trend northeast-southwest. Folds vary from upright to overturned, and thrusting in the fold cores is common. Evidence of cross folding is inconsistent throughout the basin and the weaker shales show much of the deformation characteristic of this region.

The structural features of the Bowser Basin may in part be due to the collisions of allocthondus terranes as they were being brought together off the west coast of North America prior to the formation of the Canadian Cordillera. These processes of terrane amalgamation occurred from Early Triassic time to as recent as Late Tertiary time.

In Late Triassic time, the Quesnel, Cache Creek, Eastern Assemblage, and Stikine "suspect" terranes were brought together off the west coast of North America to form the allocthonous "superterrane I" (Monger et al, 1983; Fig. 1.6). This event may have produced the Late Triassic arch upheavels (i.e. the Stikine Arch) and the structural style observed in many of the Triassic volcanic rocks in central

British Columbia.

In Late Jurassic time, the Alexander and Wrangellia terranes were amalgamated off the continental craton to form the allocthonous "superterrane II" (Monger et al, 1982; Fig. 1.6).

The formation of the Omineca Crystalline Belt occurred from Middle Jurassic to Early Tertiary time. The formation of this belt took place both during and after the accretion of superterrane I with the continental margin of North America (Monger et al, 1982). This event may have imparted a significant structural grain on the eastern margin of superterrane I during Middle to Late Jurassic time.

The formation of the Coast Plutonic Complex occurred from Middle Cretaceous to Early Tertiary time and may have been closely related to the amalgamation, or "welding together" of superterrane II with the western edge of North America. This event produced a major structural grain on the Mesozoic rocks along the western margin of the Central Cordillera.

The final major structural event in the Canadian Cordillera occurred primarily in Tertiary time in the form of strike-slip movements along faults such as the Tintina and Teslin Faults (Fig. 1.7). These processes may have transported the terranes up to 500 kilometers in a northwest-southeast direction as shown by Monger et al (1978), to place the terranes into their present positions in the Canadian Cordillera.

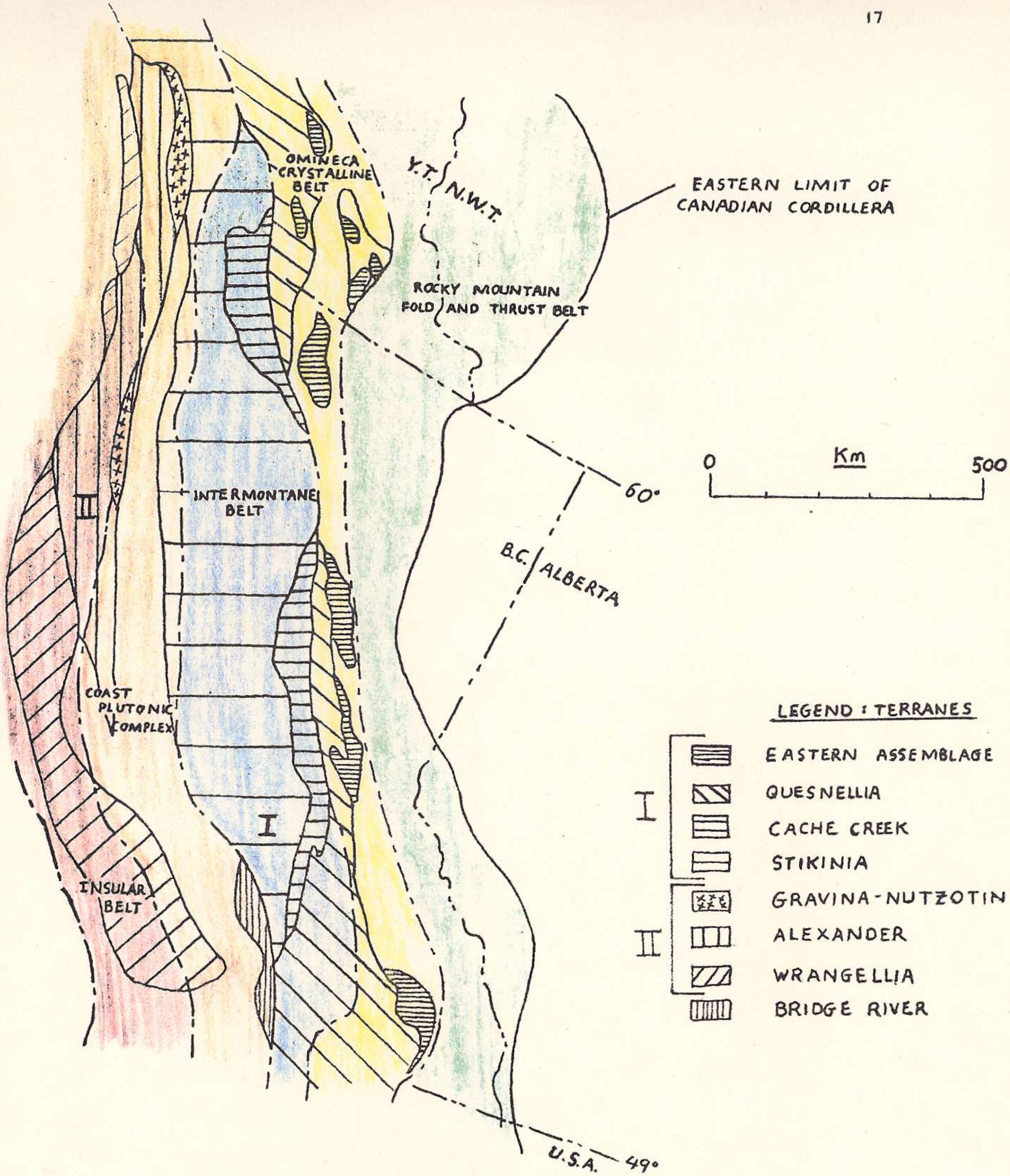


FIGURE 1.6 Distribution of the allocthonous terranes which make up the tectono-stratigraphic belts of the Canadian Cordillera (modified from Monger et al, 1982).

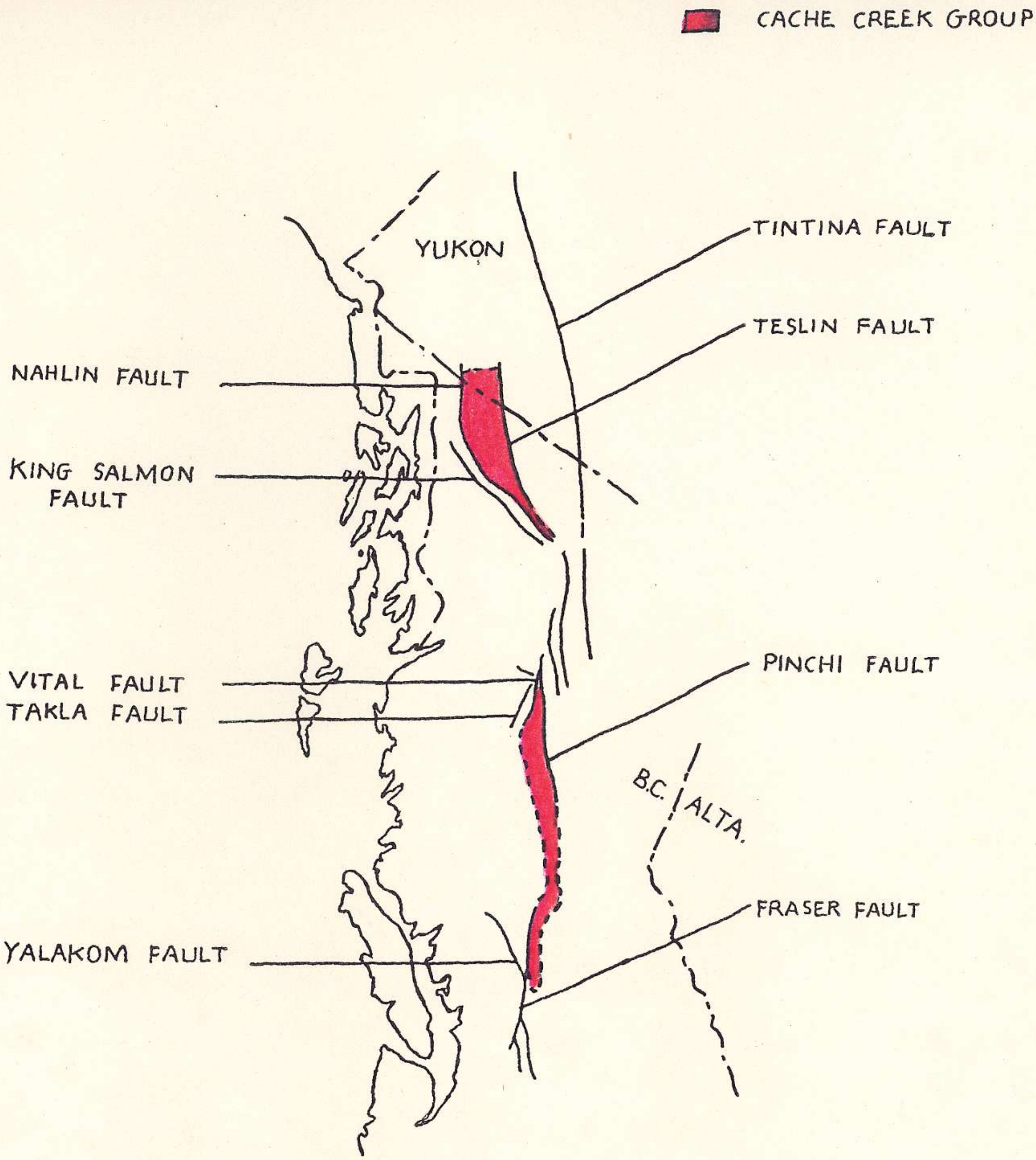


FIGURE 1.7 Major fault patterns active during early Tertiary time throughout the Canadian Cordillera. Displacement of the Cache Creek Group can be inferred from the map (modified from Monger, 1978).

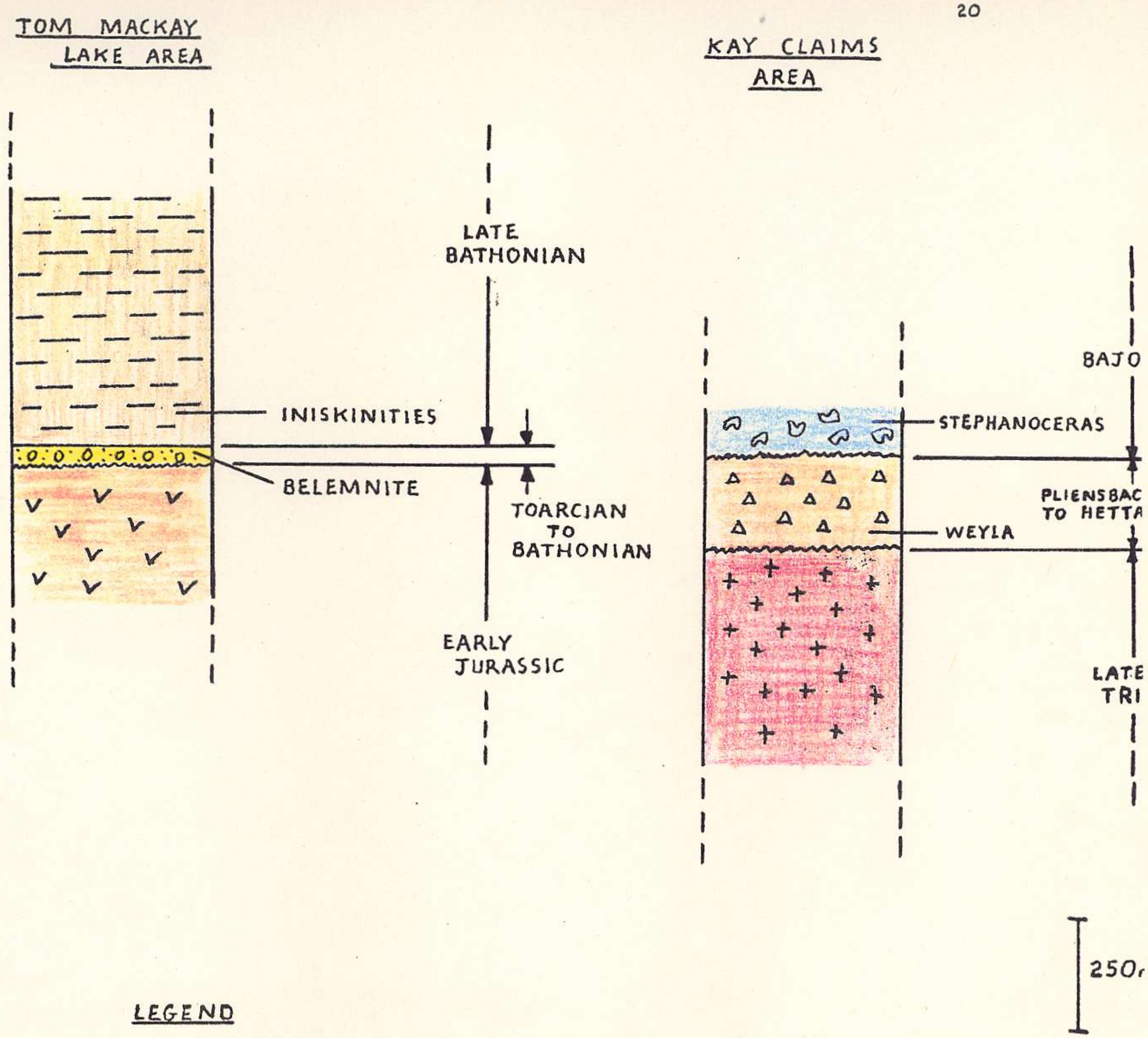
STRATIGRAPHY

TOM MACKAY LAKE AREA

The stratigraphy of the Tom Mackay Lake area ranges from Hettangian to Late Bathonian in age, and consists of sedimentary and volcanic strata that comprise three distinct units that are mappable in the field: a lower unit of volcanic rocks (Unit B) dominated by silicified and lapilli-lithic tuffs, a middle unit of coarse grained conglomerates and arenites (Unit C), and an upper unit of laminated black shales and siltstones (Unit E).

In 1976, D. Donnelly studied the stratigraphy of the Kay Claims located 5 km to the east of Tom Mackay Lake. The strata are composed primarily of intermediate to basic volcanic flows and tuffs, and are correlated with the lower volcanic sequences of the Tom Mackay Lake area in this section.

Descriptions of the units in the Tom Mackay Lake area are given on the following pages based on field, hand sample, and thin section observations. A stratigraphic section of the area (including the stratigraphy of the Kay Claims) is shown in figure 2.1. The ages of the units are based on fossil identification by Dr. H. W. Tipper of the Geological Survey of Canada (March, 1985).



LEGEND

- UNIT E : AMMONITE-BEARING BLACK SHALE AND SILTSTONE
- UNIT C : LITHIC ARENITES AND COARSE POLYMICT CONGLOMERATE
- UNIT B : SILICIFIED AND LAPILLI-CRYSTAL-LITHIC TUFF
- KAY CLAIMS : PILLOW BASALTS INTERBEDDED IN MUDSTONE
- KAY CLAIMS : RHYOLITE BRECCIA, SILICIFIED AND LITHIC TUFF
- KAY CLAIMS : ACIDIC CRYSTAL TUFF, LAPILLISTONE, MARINE SEDIMENTS

FIGURE 2.1 Stratigraphic section of the Tom Mackay Lake area including the stratigraphy of the Kay Claims (Donnelly, 1976) located approximately 5 km east of Tom Mackay Lake.

TABLE 2.1 Biostratigraphy of the Tom Mackay Lake area.

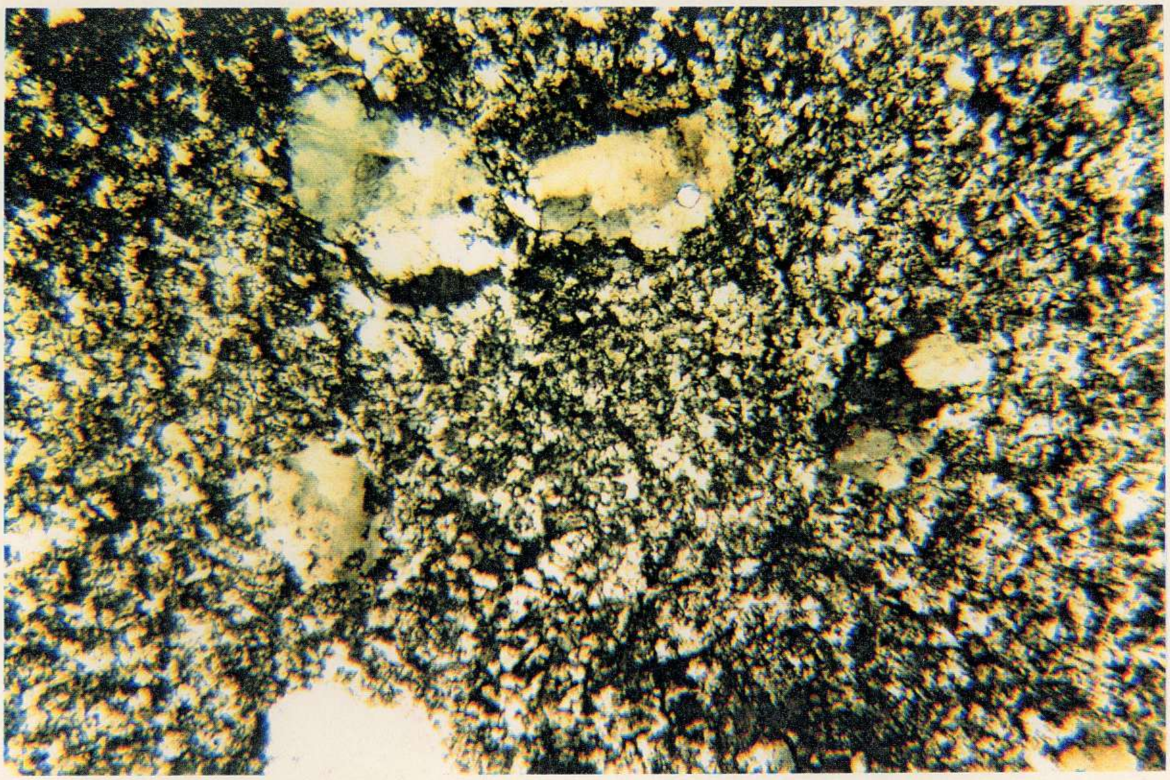
MAP UNIT	FOSSIL IDENTIFICATION	AGE PERIOD	AGE STAGE	LITHOLOGY
E	Iniskinites,sp.	Middle Jurassic	Late Bathonian	Laminated black shale
C	Belemnite	Early Jurassic to Middle Jurassic	Toarcian to Late Bathonian	Medium grained lithic arenites
B	Paltarpites,sp.	Early Jurassic	Late Pliensbachian	Volcanic sequences from the Kay Claims (D. Donnelly, 1976)
	Weyla,sp.	Early Jurassic	Hettangian to Toarcian	

UNIT B: Silicified and lapilli-crystal-lithic tuffs

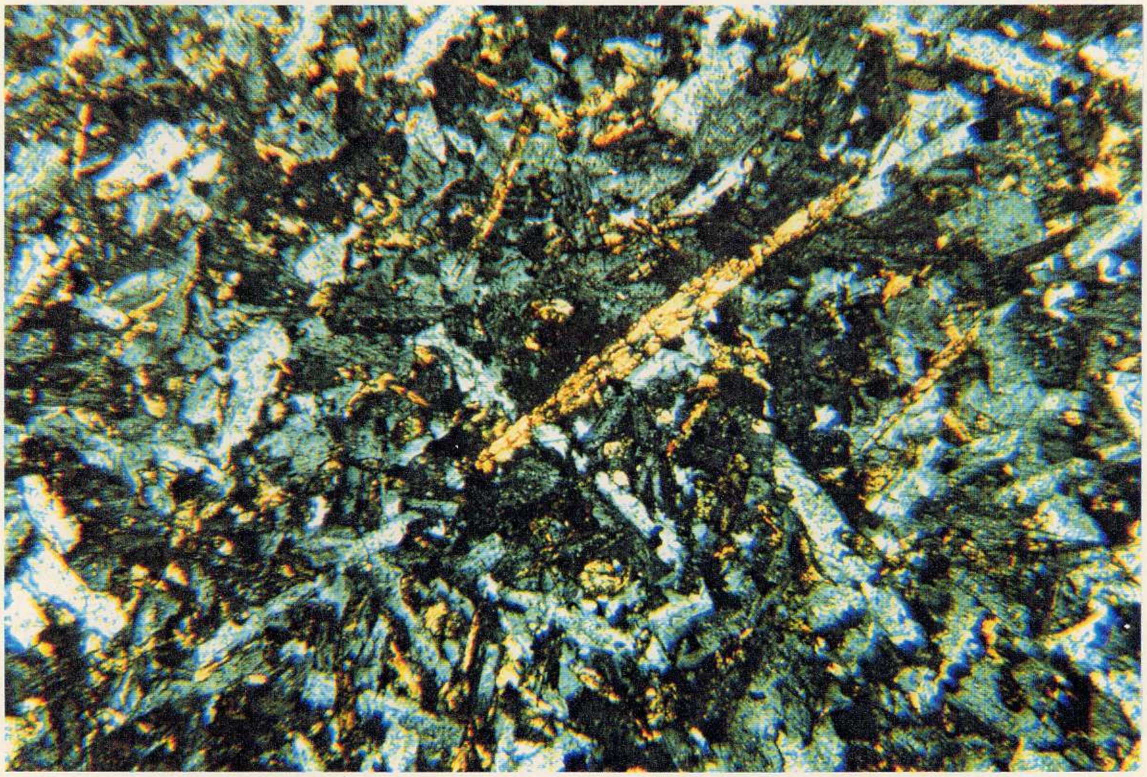
The volcanic rocks that make up the stratigraphically lowest unit in the area are characteristically heterogeneous and range from silicified tuffs to lapilli-crystal-lithic tuffs. The unit is typically highly indurated, resistent, lacks bedding, and crops out over many of the high relief areas to the east, west, and south of Tom Mackay Lake.

The silicified tuffs are extremely fine grained, highly indurated, and amorphous in hand sample. They have very distinct white to light grey weathered surfaces and crop out most prominently on the ridges to the southeast of Tom Mackay Lake. The lapilli-crystal-lithic tuffs are less indurated and slightly more extensive in outcrop than the silicified tuffs, covering almost all of the areas to the south and west of Tom Mackay Lake. They weather to a dark green, and the lithic fragments are often a light grey. The groundmass appears aphanitic in hand sample but in thin section is seen to be composed of greater than 80% euhedral plagioclase laths (An_{50-60}). Silicification of the lapilli groundmass is common. Mineral fragments make up 5% of the rock and include euhedral plagioclase (An_{50-60}) and sub-rounded, polycrystalline quartz grains. Lithic fragments make up 5% of the rock and include dark brown, fine grained, and sub-rounded volcanic fragments and lesser amounts of lighter brown sedimentary rock fragments. Welding is not observed in any of the tuffs and cubic crystals of pyrite are disseminated throughout the tuffs.

A more detailed study of the composition of the volcanic sequences in the Tom Mackay Lake area was completed by D. Donnelly in 1976. In his study, he describes the composition and texture of the 1000 meter thick Hettangian to Bajocian volcanic unit that is located about 5 km southwest of Tom Mackay Lake (Fig. 2.1). The unit ranges in composition from crystal tuffs at the base to greenstones and tuffaceous wackes in the middle and finally to rhyolite breccias and pillow lavas at the top. The volcanic rocks in the Tom Mackay Lake area are correlative with the middle unit of the volcanic sequence in the Kay Claims (Fig. 2.1). The top unit of Donnelly is missing in the thesis area and this may be due to its removal by erosion.



2a)



2b)

FIGURE 2.2 Photomicrographs of the silicified (2a) and hornblende-crystal (2b) tuffs typical of Unit B in the Tom Mackay Lake area.

The age of the volcanic sequence at Tom Mackay Lake is believed to be Hettangian to Late Pliensbachian from the occurrence of Weyla in the volcanics (Donnelly, 1976), and the occurrence of belemnites in the overlying sandstone-conglomerate unit.

The volcanic sequence is unconformably overlain by the sandstone-conglomerate unit. The unconformity is not visible in the field but is inferred from biostratigraphy and the correlation of strata in the Tom Mackay Lake and Storie Creek areas.

UNIT C: Sandstone - Conglomerate

Unit C is composed of interbedded medium grained lithic arenites and coarse polymict conglomerates. Beds range from 5 cm to 10 meters in thickness. The arenites are generally more dominant in the higher part of the section, while the conglomerate is more dominant stratigraphically lower in the unit. The unit is approximately 50 to 75 meters thick and is a distinct ridge former in the area. Cleavage is not developed but jointing is generally well developed with joint spacing ranging from 5 cm to 100 cm. Joints are a pervasive feature throughout the unit and are related to the first phase of deformation in the area. A more detailed discusssion on both the geometry and formation of these joints is given in the structure section of the paper.

Graded bedding is common in the conglomerate beds throughout the area.

The lithic arenites are light grey to brown in color on weathered surfaces, well sorted, medium grained (1-2 mm average grain size), highly indurated, and texturally mature with sub to well-rounded grains and less than 5% dark brown, muddy matrix. They are moderately compositionally mature with rounded chert grains making up 60% of the rock. Monocrystalline, straight-extinction quartz varieties make up 25% of the rock and euhedral, lath shaped plagioclase grains (An_{50}) make up 5%. Very fine grained, intermediate to acid volcanic fragments and dark brown sedimentary rock fragments make up the remaining 5% of the rock and are slightly more angular than the other framework grains.

The polymict conglomerates are very poorly sorted, largely framework supported, and composed of rounded clasts that range from .5 cm to 5 cm in diameter. The matrix is a dark brown mud which makes up 10% of the rock. The compositional heterogeneity of the conglomerate is a distinctive feature.

Chert pebbles may make up to 60% of the rock while polycrystalline (metamorphic) quartz grains make up 5%. Plutonic, straight-extinction quartz grains make up 5% of the conglomerate, and euhedral plagioclase grains (An_{50-60}) also make up 5% of the rock. Fine grained, black, intermediate to acidic volcanic fragments make up the

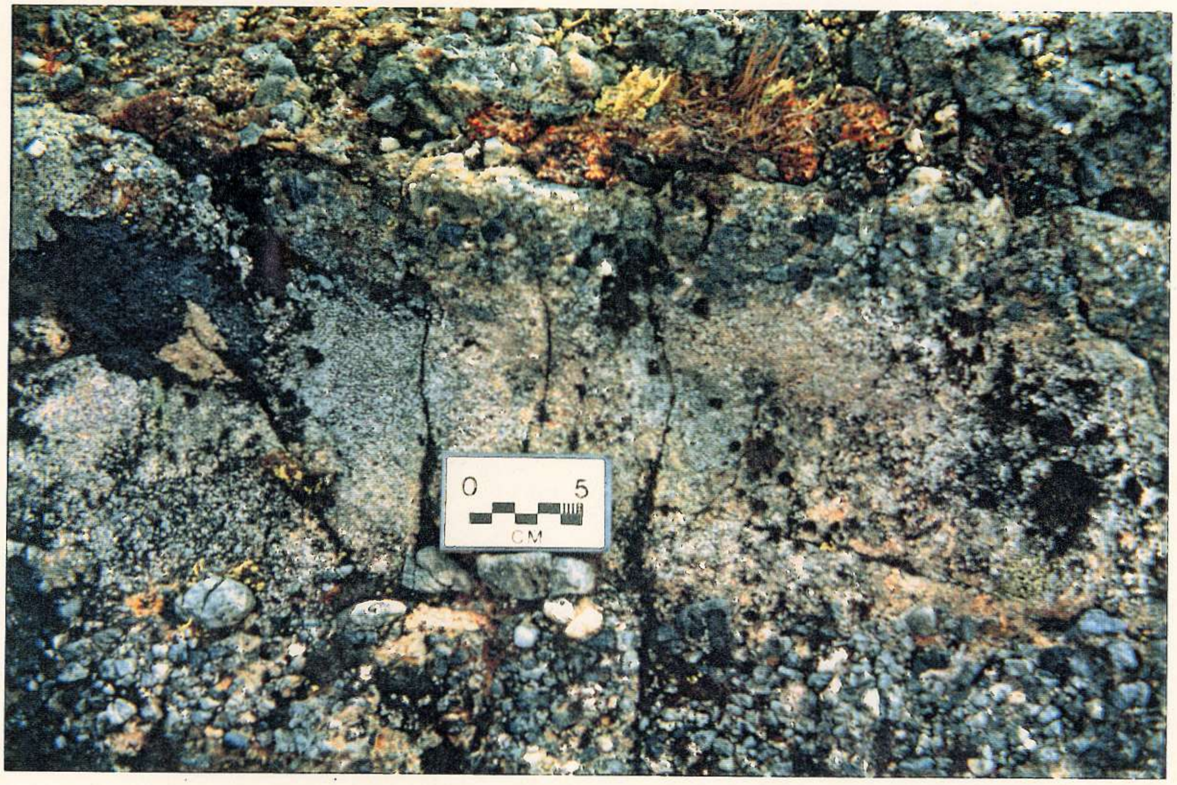


FIGURE 2.3 Photograph of an outcrop (station 105; see inset map for exact location) showing the interbedded nature of the lithic arenites and conglomerates in the Tom Mackay Lake area.

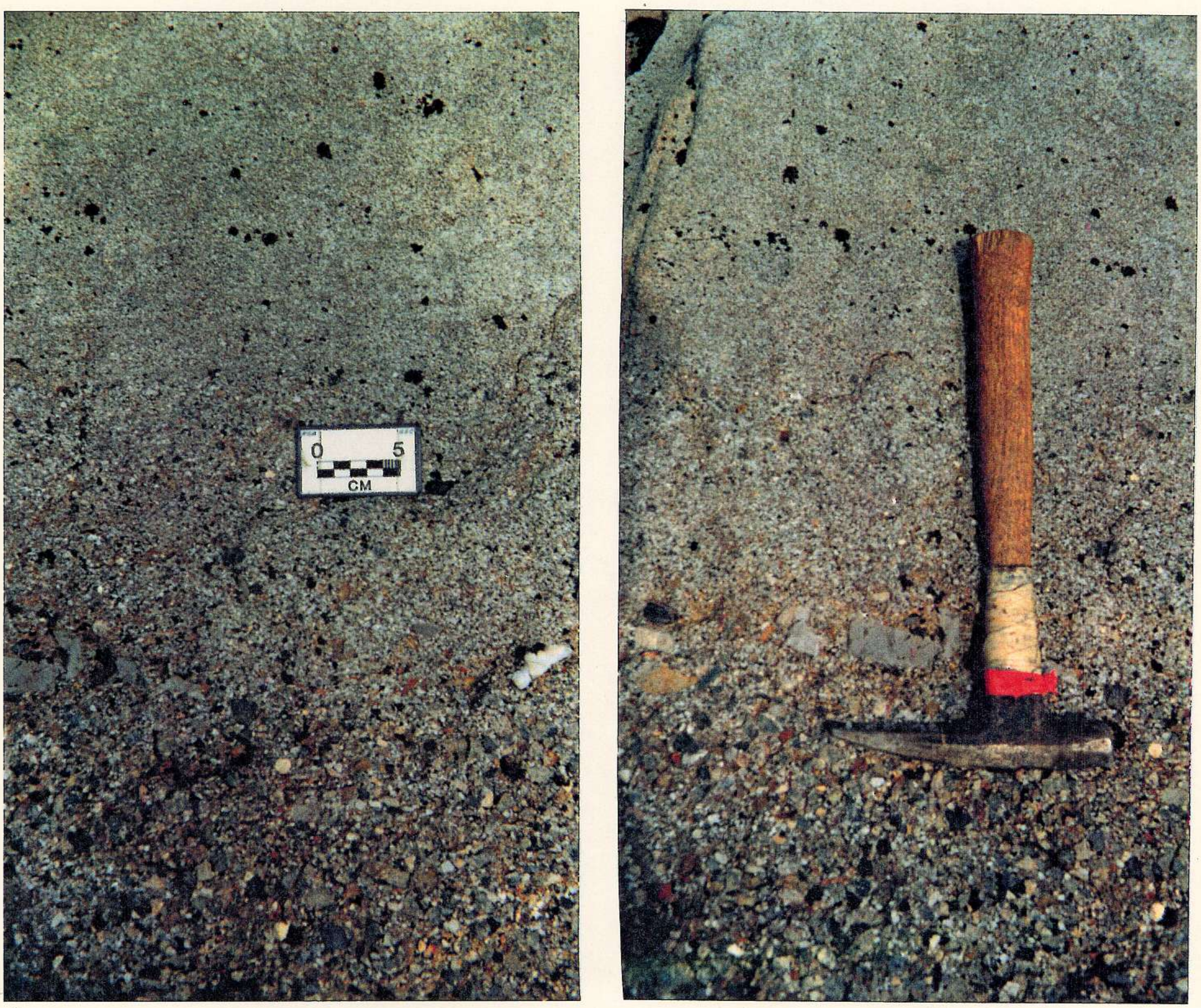


FIGURE 2.4 Photographs of outcrops (station 98; see inset map for exact location) showing graded bedding which is characteristic of the conglomerate in Unit C found in the Tom Mackay Lake area.

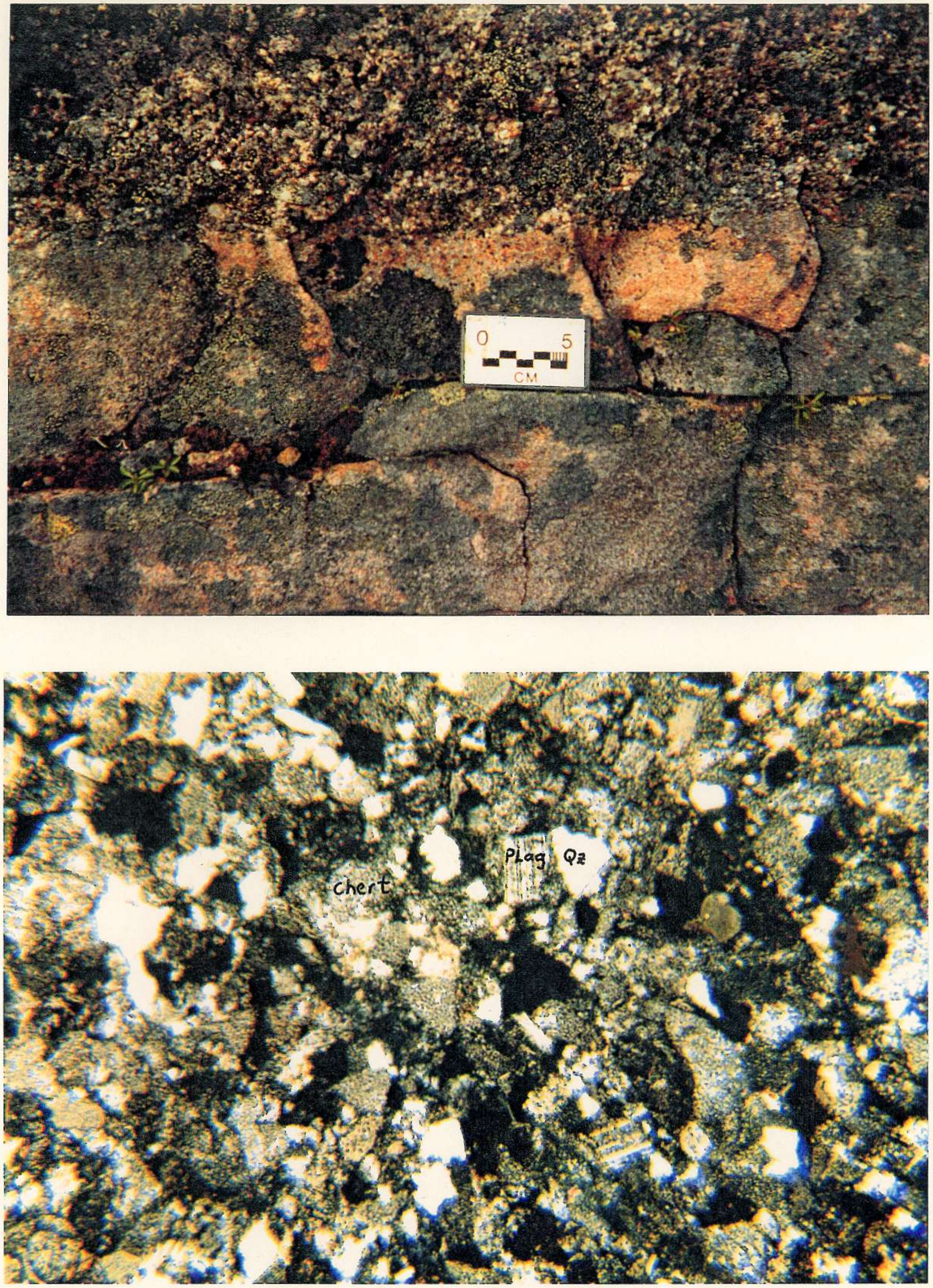


FIGURE 2.5 Photograph of an outcrop showing the lithic arenite in contact with overlying conglomerate (5a), and a photomicrograph of the lithic arenite (5b) showing the abundance of sub-rounded chert grains and lesser amounts of quartz and feldspar.

remaining 15% of the rock. They are generally sub-angular and may be up to 5 cm in diameter.

The sandstone-conglomerate unit unconformably overlies the tuffaceous volcanic sequences in the area. The significance of this unconformity will be discussed in more detail in the correlation sections of this chapter. The age of the unit is Toarcian to Late Bathonian as evidenced by belemnites preserved in the arenites, and ammonites (Iniskinites) preserved in the overlying shales.

UNIT E: Siltstone - Shale

Fine grained black shales and siltstones form the uppermost unit in the stratigraphy of the Tom Mackay Lake area and crop out over an extensive area in the core of the large synclinoria in the region. The shale outcrops are commonly highly cleaved with well developed scree at their base. The shales are commonly laminated (1-5 mm) with layers of light grey siltstone that make up less that 10% of the unit. Load structures and flame structures are characteristic of the unit. Minor folds are common.

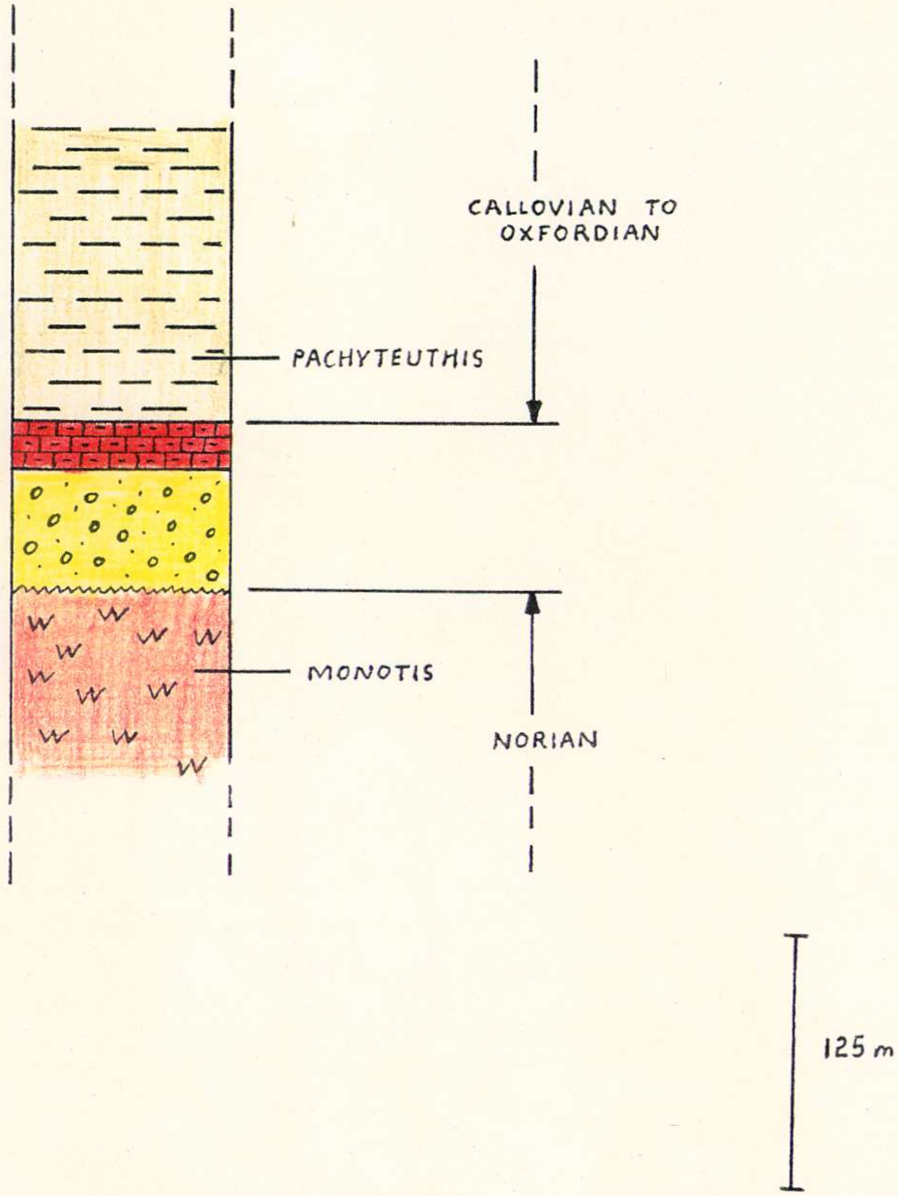
The siltstone-shale unit conformably overlies the coarser sandstone and conglomerate unit. The boundary is a gradational one with the transition from sandstones with 10% shale beds to greater than 90% shale beds occurring over a 10 meter span. The age of the shale unit is Late Bathonian as evidenced by the ammonite Iniskinities.

STORIE CREEK AREA

The stratigraphy of the Storie Creek area is significantly different from that found in the Tom Mackay Lake area. There is a distinct low-grade phyllite bed that is the result of the metamorphism of the black shales. The phyllite is located in the core of the main syncline in the Storie Creek area. In addition, the volcanic sequences in the Storie Creek area are significantly older than the volcanic rocks in the Tom Mackay Lake area.

There are four distinct units that are mappable in the area: a lower unit of porphyritic andesites, volcanic breccia, and lithic tuffs with thin shale and siltstone interbeds (Unit A), a unit of arenites and coarse, polymict conglomerates (Unit C), a thin "transitional" unit of calcareous siltstone (Unit D), and an upper unit of black shales that in many areas has been metamorphosed to low-grade phyllite (Unit E).

The description of these units is given on the following pages. The ages of these units are based on fossil identifications by Dr. H.W. Tipper (March 1985) of the Geological Survey of Canada. Figure 2.6 is a stratigraphic section of the Storie Creek area.



LEGEND

UNIT E : LAMINATED BLACK SHALE, PHYLLITE

UNIT D : CALCAREOUS, NONFOSSILIFEROUS SILTSTONE

UNIT B : LITHIC ARENITE AND COARSE CONGLOMERATE

UNIT A : SILICIFIED AND LITHIC TUFF, VOLCANIC BRECCIA

FIGURE 2.6 Stratigraphic section of the Storie Creek area.

TABLE 2.2 Biostratigraphic summary of the Storie Creek area.

MAP UNIT	FOSSIL IDENTIFICATION	AGE PERIOD	AGE STAGE	LITHOLOGY
E	*Pachyteuthis*, sp.	Late-Middle Jurassic	Callovian to Oxfordian	Laminated shale and phyllite
A	*Monotis*, sp.	Late Triassic	Norian	Shale bed in lithic tuff

UNIT A: Tuffs and Volcanic Breccias

Tuffs and volcanic breccias are very extensive along the high relief ridges to the south and southeast of Storie Creek, and form the stratigraphically lowest unit in the area. The unit is composed of lithic tuffs, porphyritic andesites, and coarse polymict volcanic breccias with minor interbedded shales and siltstones. The shale beds are generally less than 10 m thick and are locally fossiliferous.

The breccias are poorly sorted and framework supported by angular to sub-angular, dark brown to black sedimentary and volcanic rock fragments that are up to 20 cm in diameter. The fragments make up about 80% of the rock and are in a light brown muddy matrix. Weathered surfaces are variable in color. Normal grading is common in the conglomerate. Cleavage is poorly developed and jointing is prominent.

The tuffs are highly indurated and weather to a distinctive dark brown. They are less resistent than the conglomerates. They are compositionally heterogeneous, and the lithic fragment content in the tuffs is variable. The tuffs may be locally silicified and aphanitic, similar to the silicified tuffs observed in the Tom Mackay Lake area. Clinopyroxene porphyritic andesites were observed on the southeast limb of the Storie Creek Syncline, but do not make up a significant component of the unit. This volcanic unit contains no minor fold structures or cleavage. The shaly interbeds are highly cleaved and produce significant scree.

This volcanic sequence is unconformably overlain by the sandstone-conglomerate unit. This unconformity is not visible in the field but is inferred from biostratigraphy and the correlation of strata between the Tom Mackay Lake and Storie Creek areas.

The age of this sequence is thought to be Norian from the occurrence of the pelecypod, Monotis found in the interbedded shales. This volcanic sequence comprises the oldest rocks exposed in the thesis area.

FIGURE 2.7 Photograph of an outcrop (station 88; see inset map for exact location) of the coarse, framework supported polymict volcanic breccia typical of Unit A in the Storie Creek area.

UNIT C: Sandstone - Conglomerate

The sandstone-conglomerate unit is very similar lithologically to Unit C found in the Tom Mackay Lake area, although no fossils were located to make a time correlation.

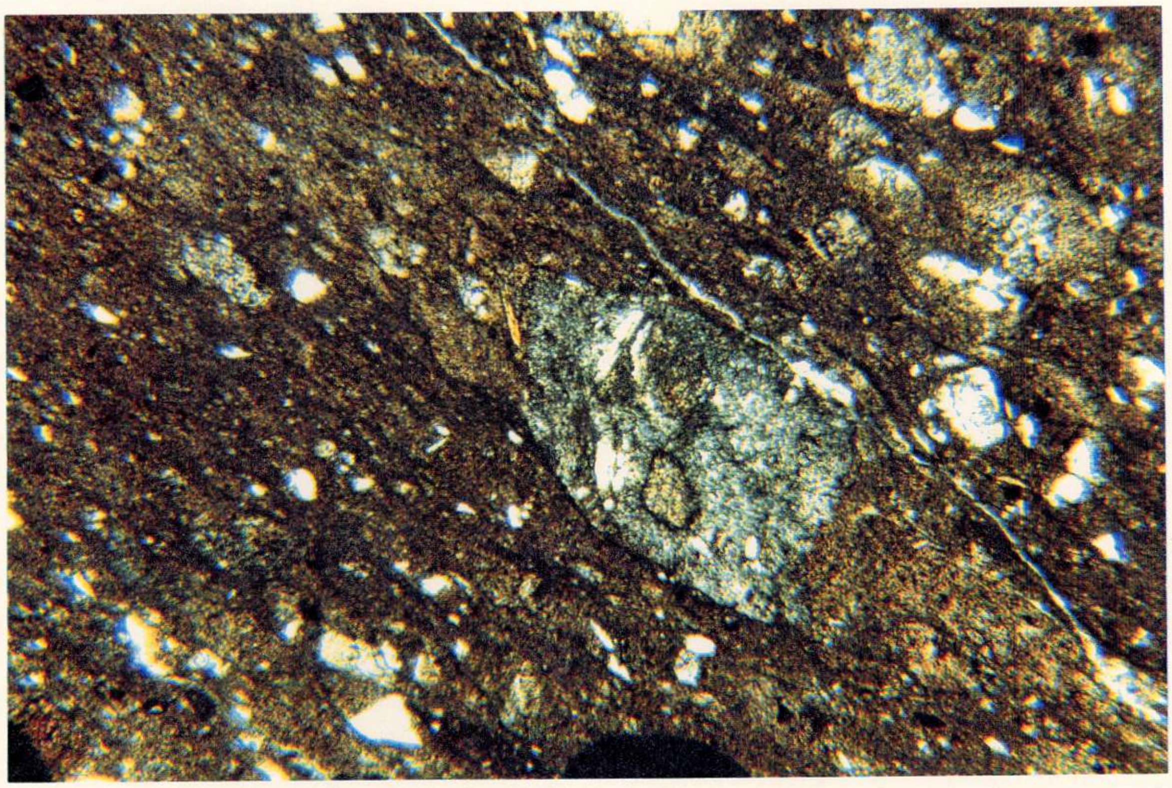
Coarse (2-10 cm cobbles), framework supported polymict conglomerates dominate lower in the unit and dark grey, well sorted, medium grained lithic arenites dominate stratigraphically higher in the unit. Minor limestone clasts were also found in the conglomerate but they formed less than 1% of the rock. Minor tuffs also formed in this unit and one tuff bed located near the Storie Creek fold core on the northwestern fold limb displays a "fiammied" texture with elongated mafic clasts. The groundmass is aphanitic and very resistent.

The entire unit is 50-75 meters thick. As at Tom Mackay Lake, this unit unconformably overlies volcanic sequences.

UNIT D: Calcareous Siltstone

This transitional calcareous siltstone bed lies between the overlying shales and phyllites and underlying arenites and conglomerates. It is found only in the southeast limb of the Storie Creek syncline and is characterized by a very distinct orange weathered surface. The unit is only about 10 m thick and is nonfossiliferous. This unit conformably overlies the sandstone-conglomerate unit. It is not found in the Tom Mackay Lake area.

8a)



8b)

FIGURE 2.8 Photograph of an outcrop (station 83; see inset map for exact location) of "fiammied" tuff near the core of the Storie Creek Syncline (8a), and a photomicrograph of the same tuff showing the flattened or fiammied texture of the lithic fragments in the groundmass of the lithic tuff (8b)

UNIT E: Shale-Phyllite

Black shales and siltstones form the stratigraphically highest unit in the Storie Creek area, and like at Tom Mackay Lake, they are exposed in the major fold cores. The shales are laminated (1-5 mm) with layers of light grey siltstone that make up less than 10% of the unit. They are highly cleaved and contain minor fold structures.

The black shales are metamorphosed to a phyllite in the fold core at Storie Creek. These phyllites are light green, well folliated, and very weak. The phyllite in the fold core also commonly contains minor fold structures.

This unit conformably overlies the "transitional" calcareous siltstone unit.

The age of the shaly sequences in the Storie Creek area is Callovian to Oxfordian from the occurrence of the belemnite, *Pachyteuthis*.

LOCAL CORRELATION

Correlation of the stratigraphy between the Storie Creek and Tom Mackay Lake areas is shown in figure 2.8. The correlation of units is based on lithologic similarities and biostratigraphy, and reveals several important aspects of the depositional history of the area.

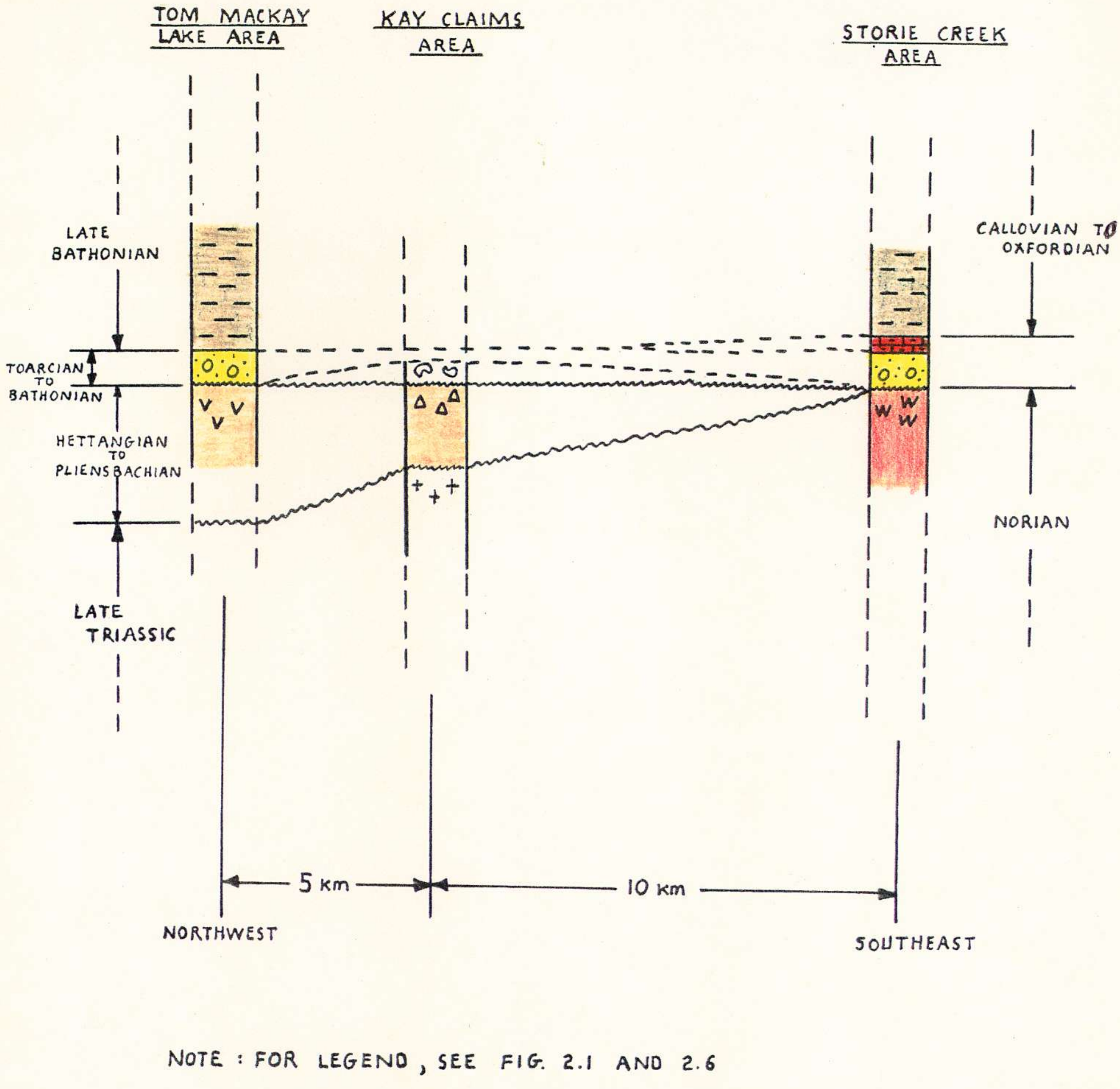


FIGURE 2.9 Correlation of the stratigraphy of the Tom Mackay Lake and Storie Creek areas.

The silicified-lithic tuffs containing Weyla in the Tom Mackay Lake area are Hettangian to Late Pliensbachian, while Monotis preserved in the volcanic sequences in the Storie Creek area indicate their age to be Norian. Both of these volcanic sequences underlie Toarcian to Bathonian sandstone and conglomerate lithologies (i.e. Unit C). Thus, the tops of these volcanic sequences in the thesis area are erosional surfaces upon which clastic sediments were unconformably deposited. A similar unconformable relationship was described by Donnelly (1976) for the upper surface of the Early to Middle Jurassic volcanic rocks of the Kay Claims.

The volcanic sequence in the Tom Mackay Lake area correlates with the middle volcanic unit of the Kay Claims (Fig. 2.1) located 5 km east of Tom Mackay Lake. The Norian volcanic sequences in the Storie Creek area are time correlative with the lowest volanic strata in the Kay Claims (Fig. 2.9). Erosion of Early Jurassic volcanic strata in the Storie Creek area removed the rocks that were correlative with the Early Jurassic volcanic strata in the Tom Mackay Lake (Kay Claims) area.

The sandstone-conglomerate unit conformably underlies the black shales in the Tom Mackay Lake area, and the limey siltstone and black shales in the Storie Creek area. Belemnites preserved in the lithic arenites suggest that the unit is Toarcian to Bathonian in age. Although no fossils were found in this unit in the Storie Creek Area, its lithologic and stratigraphic similarities with the conglomerate and sandstones in the Tom Mackay Lake area suggest a correlation of the two units.

In the Tom Mackay Lake area, the ammonite-bearing black shales and siltstones are correlative with the belemnite-bearing shales and phyllites in the Storie Creek area. The age of this pelitic unit is Bathonian to Oxfordian.

In the Storie Creek area, the shale unit is underlain by the calcareous siltstone unit that is not found in the Tom Mackay Lake area. This suggests that there is a local facies change between the two areas prior to the deposition of the black shales. Temporarily, shallow water may have existed in the Storie Creek area prior to Bathonian time to allow for the accumulation of calcareous material.

In conclusion, volcanic strata were deposited in the thesis area from Norian to Late Pliensbachian time. At the end of Pliensbachian time, a significant erosional surface was formed on the top of these volcanic sequences and in the Storie Creek area, all Early Jurassic volcanic rocks were removed by erosion. Commencing in Toarcian time, deposition of coarse clastic conglomerates and sandstones, with local calcareous facies in the Storie Creek area, occurred. This continued until Late Bajocian time when sub-aqueous environments deepened and ammonite-bearing black shales were conformably deposited on top of the clastic lithologies.

REGIONAL CORRELATION

Triassic and Jurassic volcanic and sedimentary strata cover extensive areas of north-central British Columbia and have received a significant amount of study over the past 20 years. Correlation of these deposits throughout the Bowser Basin and surrounding areas is becoming increasingly clear and the depositional history of the region better understood.

Triassic volcanism in northern British Columbia formed the Late Triassic Takla Group (Tipper and Richards, 1976) found extensively in the southern Bowser Basin, and the correlative Late Triassic Stuhini Group (Monger, 1980) found in the northern areas of the Bowser Basin. These volcanic sequences are characterized by basal pyroclastic flows that are overlain by tuffs and argillites, and finally by coarse volcanic breccia and conglomerate with interbedded tuffs, greywackes, and siltstones. The Takla and Stuhini Groups are Late Carnian to Late Norian in age (Tipper and Richards, 1976; Monger, 1980). The volcanic sequence in the Storie Creek area contains *Monotis*-bearing shale beds, is Norian in age, and is correlative with the Stuhini Group.

The silicified and lapilli-crystal-lithic tuffs that form the volcanic sequences in the Tom Mackay Lake area are Hettangian to Late Pliensbachian in age and represent Early Jurassic volcanic activity in the northern Bowser Basin.

The Hazelton Group is a thick sequence of primarily marine volcanic flows and tuffs with lesser sedimentary assemblages that is very extensive in the southern Bowser Basin. The age of the Hazelton Group is Sinemurian to Late Bajocian (Tipper and Richards, 1976). The Middle Toarcian to Late Bajocian Smithers Formation makes up the uppermost strata in this group.

The Toodoggone volcanics is an informally named group that is Sinemurian to Late Bajocian in age and comprises volcanic flows, tuffs, and breccias (Smith et al, 1984). These rocks are correlative with the upper sequences of the Hazelton Group (i.e. the Smithers Formation) and occur throughout the northern Bowser Basin. The Hettangian to Late Pliensbachian volcanic rocks of the Tom Mackay Lake area are correlative with the Toodoggone volcanics and contain similar lithologies and fossils. These volcanic rocks are not completely correlative with the upper formations of the Hazelton Group because the Hazelton Group volcanic rocks are defined as being formed from source material derived from the uplifted Skeena Arch. By contrast, volcanic srata of the Toodoggone volcanics formed from material derived from the uplifted Stikine Arch to the north so that the two volcanic groups are only correlative by age.

The Toodoggone volcanics are time correlative with the Spatsizi sediments (Smith et al, 1984) which formed during periods of low volcanic activity. These deposits are also

Early to Middle Jurassic (ie. Sinemurian to Late Bajocian), and are characterized by siltstone, sandstone, rare calcareous siltstones, cobble-conglomerates, and tuffaceous siltstone. Like the Toodoggone volcanics, they cover extensive areas in the northern Bowser Basin with type localities described by Smith et al (1984) in the Spatsizi map area. The sandstone-conglomerate units found in both the Tom Mackay Lake and Storie Creek areas are Toarcian to Bathonian in age and are correlative in time and lithology with the Spatsizi sediments. They are also time correlative with the Smithers Formation of the Hazelton Group.

Both the Spatsizi sediments and the Smithers Formation of the Hazelton Group contain calcareous siltstone beds similar to the "transitional" calcareous siltstone unit described in the Storie Creek area. Thus, the calcareous siltstone unit may be time and lithology correlative with the upper strata (Early Bajocian) of the Spatsizi sediments and time correlative with the upper strata of the Smithers Formation of the Hazelton Group.

The absence of this unit in the Tom Mackay Lake area is due to a local environment change in the Storie Creek area that produced a facies change between the two areas during Toarcian to Bajocian time. Smith et al (1984) also describes abrupt facies changes in the Spatsizi sediments found in the Spatsizi map area. These abrubt facies changes may be the result of the dynamic nature of the depositional environment during Early Jurassic time in the northern Bowser Basin (i.e. rapid and spasmodic periods of uplift and subsidence).

Recognition of the calcareous siltstone unit in the field may be valuable as it forms a key marker bed that immediately underlies the deep water, ammonite-bearing black shale deposits of the Ashman Formation that form the base of the Bowser Lake Group.

The Middle Jurassic sandstone-conglomerate unit is underlain by Early Jurassic Toodoggone volcanic rocks in the Tom Mackay Lake area, and by Late Triassic Stuhini Group volcanic rocks in the Storie Creek area. This suggests the presence of a major unconformity above the volcanic sequences. The occurrence of this erosional surface, below which units of various ages are foumed, is also described by Tipper and Richards (1976) to occur below the time correlative sandstones, conglomerates, and tuffs of the Smithers Formation.

Deposition of the Bowser Lake Group sediments occurred from Late Bajocian to Kimmeridgian time (Tipper and Richards,1976) when volcanic activity in north-central British Columbia was minimal and deltaic to pro-deltaic depositional environments prevailed. The resulting deposits were primarily marine shales, siltstones, sandstones and interbedded conglomerates which are now called the Ashman Formation (Late Bajocian to Early Oxfordian; Tipper and Richards, 1976). This formation typically forms a prograding, coarsening upwards sequence of sedimentary strata. The ammonite-bearing black shales (and their metamorphosed equivalents in the Storie Creek area) are Late Bathonian to Callovian in age and are correlative with the Ashman Formation which forms the lower sections of the Bowser Lake Group.

In 1984, L. Currie completed a study on the three distinctive chert-pebble conglomerate beds that are characteristic of the Ashman Formation in the Spatsizi area. The three beds are distributed in the lower, middle, and upper sections of the formation and are generally less than 100 meters thick. The entire formation thickness is approximately 400 meters with shaly sequences separating the conglomerate beds.

The black shale and siltstone sequences in the thesis area are in excess of 500 meters thick with no interbedded sequences of chert-pebble conglomerate. Tipper and Richards (1976) report that the Ashman Formation can attain great thicknesses in the southern Bowser Basin but that this thickness can be extremely variable. Thus, the excessive thickness of the Bowser Lake Group sediments that formed in the thesis area is common elsewhere in the Bowser Basin. However, the lack of interbedded conglomerate sequences is a significant feature.

The lack of coarser clastic sequences in the Bowser Lake Group shales in the thesis area may suggest that the deposits formed in a deeper water, more off shore environment relative to the Bowser Lake Group sediments found to the north in the Spatsizi map area which formed in a shallower water, higher energy environment. Thus, a significant facies change may occur as one moves south from the northern margin of the Bowser Basin. This interpretation would have a large implication in the correlation of strata in the northern Bowser Basin and will be discussed in more detail in the provenance and depositional environment sections of the study.

There is no evidence that suggests that the relation between the Bowser Lake Group black shales and the underlying coarse clastic sediments and volcanics is an unconformable one in the thesis area. A similar conclusion was drawn for the black shales of the lower Ashman Formation in the southern Bowser Basin by Tipper and Richards (1976). However, L. Currie (1984) proposed an unconformable relationship between the Ashman Formation and the underlying volcanic sequences in the northern Spatsizi map area, as did Smith et al (1984) for the Spatsizi plateau area in the central section of the Spatsizi map sheet. Thus, it appears that the relationship between Bowser Lake Group and underlying strata could be an inconsistent one. This may reflect a variation in the time at which Middle Jurassic volcanism and arch upheaval stopped in the Bowser Basin region, and molasse sedimentation started.

SEDIMENTOLOGY

SANDSTONE COMPOSITION AND PROVENANCE

The fringes of the northwestern region of the Bowser Basin are characteristically composed of coarse clastic sediments informally called the Spatsizi sediments which unconformably overlie volcanic sequences of both the Toodoggone volcanics and the older Stuhini Group (correlative with the more extensive Takla Group to the south). The modal proportions of the sandstones constituent grain types indicate their provenance and give some insight into the formation and sedimentation of the northwestern region of the Bowser Basin.

The composition of a sandstone is influenced by factors such as the intensity of weathering and erosion of the source rock, the composition of the source rock, the tectonic setting of the source region, and the depositional environment of the basin. Of these factors, the most influencial on the composition of the resulting sandstone are the tectonic setting and the composition of the source rock (Yagishita, 1985).

W.R. Dickinson and others (1979; 1983) have described in detail many studies which suggest that the provenance terrane for sandstone suites may be determined through the application of ternary QFL (Q_mFL_t) diagrams. These diagrams can classify the provenance terrane for a sandstone into three broad tectonic settings: a Magmatic Arc provenance, a Continental Block provenance, and a Recycled Orogen provenance. The modal amounts of key framework grain types of quartz, feldspar, and lithic fragments are determined for such a classification.

The two types of ternary diagrams used are differentiated by the constituent grain types which mark their respective apicies and are shown in figure 3.1. These two types are:

1. QFL DIAGRAMS - The poles are designated by; total quartzose grains (Q), including both monocrystalline and polycrystalline grain types such as chert; monocrystalline feldspar grains (F); and unstable lithic fragments (L), of either metamorphic, sedimentary, or igneous orogin.

2. Q_mFL_t DIAGRAMS - The poles are designated by: exclusively monocrystalline quartz grains (Q_m); monocrystalline feldspar grains (F); and total unstable, polycrystalline lithic fragments (L_t), including chert.

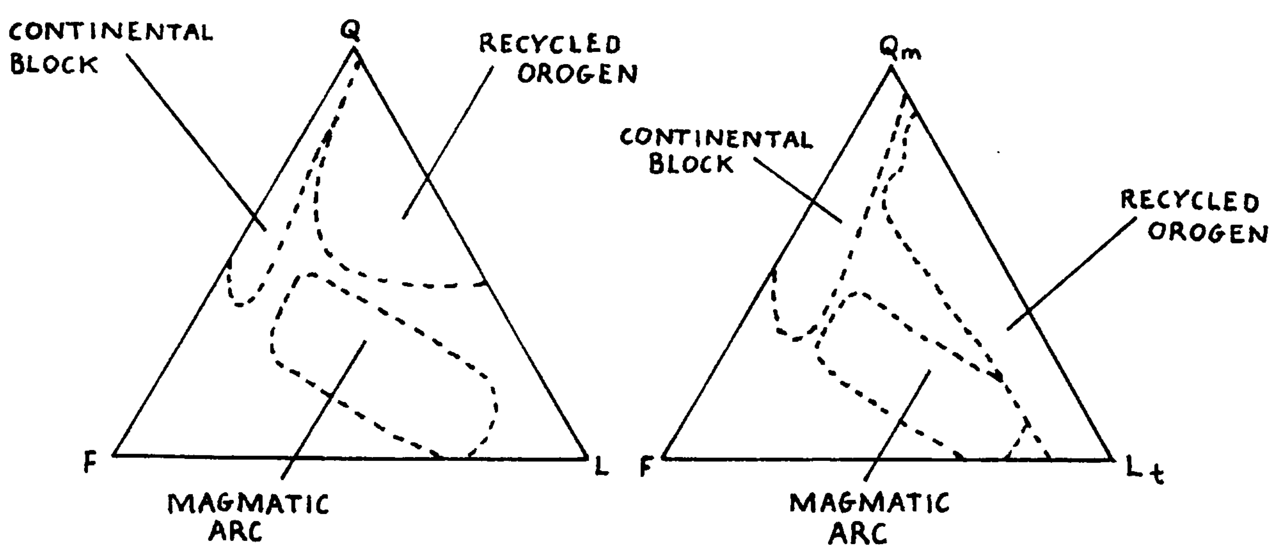


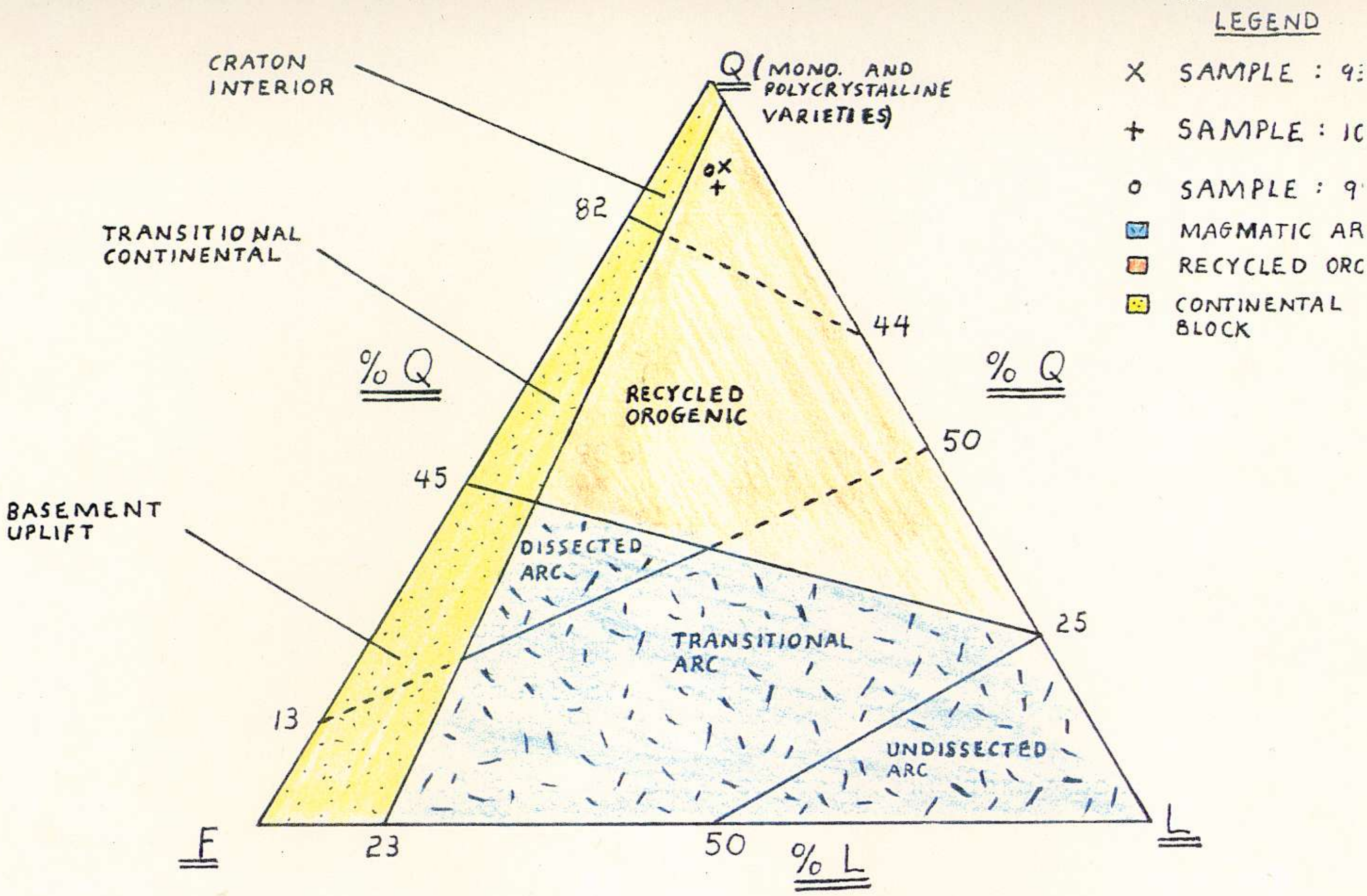
FIGURE 3.1 The two types of ternary diagrams and their respective provenance terrane boundaries as originally proposed by Dickinson (from Dickinson et al, 1979).

The main difference between the two diagrams is in their respective treatment of quartzose lithic fragments. The QFL diagrams assign all quartz varieties to the quartz group (Q), and thus reflect the relative maturity of the sandstone. By contrast, by assigning polycrystlline quartz varieties such as chert to the lithic fragment group (L_t), the Q_mFL_t diagram places more emphasis on the provenance of the sandstone (Yagishita, 1985).

A detailed description of the medium grained lithic arenites used for this study are given in the stratigraphy portion of the paper. Pointcounts of three arenite samples from the Tom Mackay Lake area (see inset map for exact sample location) were done and the results of these pointcounts are shown in table 3.1 below. Approximately 1500 grains were counted for each sample.

TABLE 3.1 Percentages of key framework grains in the lithic arenite samples from the Tom Mackay Lake area.

SAMPLE #	QUARTZ (MONO.)	QUARTZ (POLY.)	FELDSPAR	LITHIC FRAGMENTS
93-3	41.6	48.2	3.11	7.09
99-1	40.0	47.8	5.00	7.20
105-2	39.7	50.6	2.13	7.57



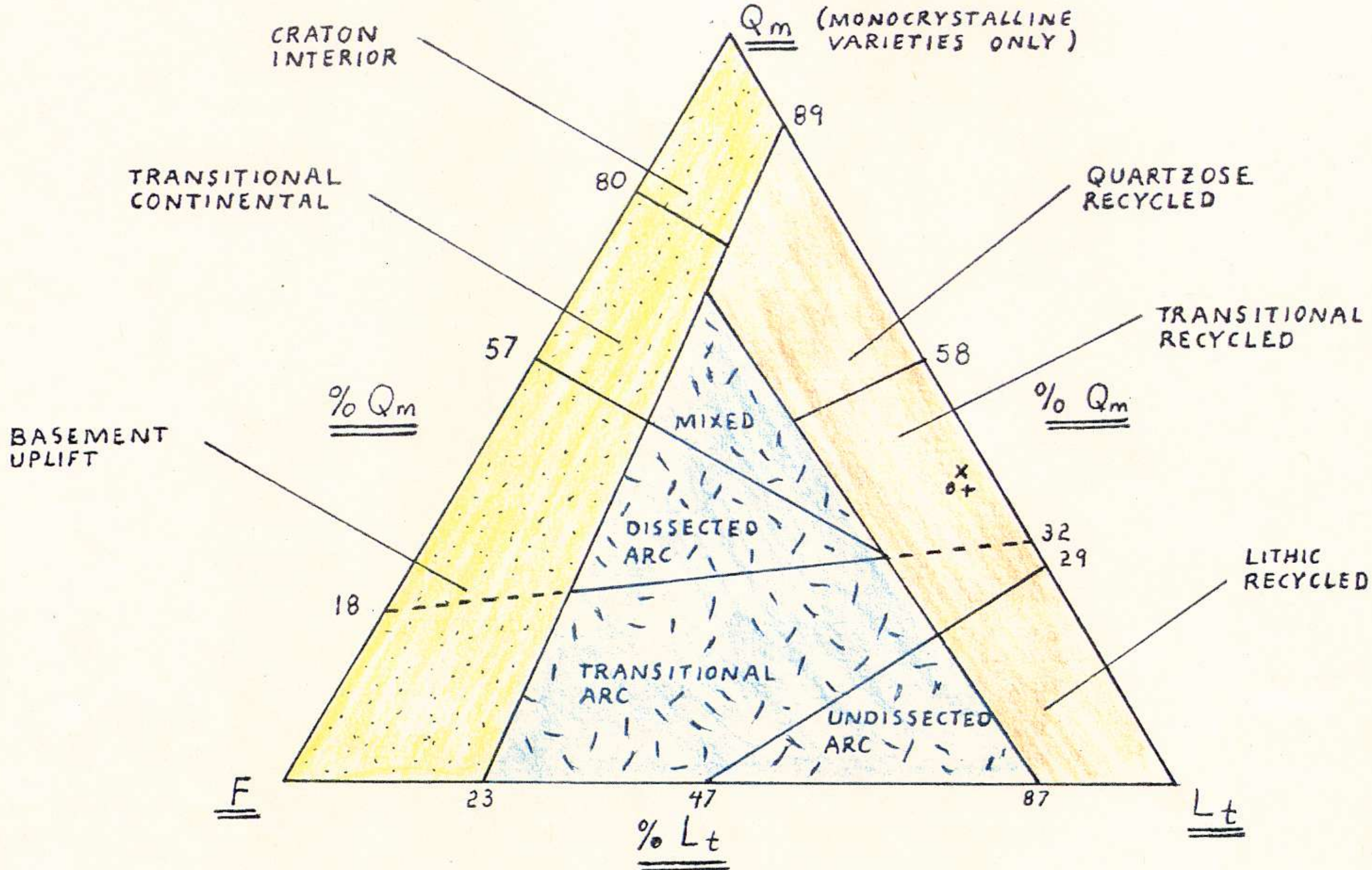


FIGURE 3.2 Ternary diagram presentation of the provenance terrane proposed from point counts of three arenite samples from the Tom Mackay Lake area.(modified from Dickinson et al, 1983).

The samples were then plotted on both QFL and Q_mFL_t diagrams according to their framework grain proportions shown in table 3.1 (Fig. 3.3). Both diagrams suggest the same provenance terrane for the medium grained lithic arenites: that of a Recycled Orogen. As described by W.R. Dickinson et al (1979; 1983), this provenance terrane is characterized by uplifted folded and faulted sedimentary and volcanic strata. Sediments derived from these regions are typically high in quartz, low in feldspar, and can have up to a 10% lithic fragment component.

Thus, the lithic arenites from the Tom Mackay Lake area can be clasified as "second cycle" sandstones derived from pre-existing sediments. Their anomolously low feldspar content probably reflects the feldspars mechanical instability and inability to survive erosion and transport, although it may also reflect a low feldspar content in the source region. The high proportion of polycrystalline to monocrystalline quartz reflects the mechanical instability of monocrystalline quartz during processes of erosion and transport. The high lithic fragment content suggests that detritus derived from previously indurated lithologies provided the source material. The high percentage of volcanic fragments in the lithic component suggest that the provenance terrane was at least in part composed of indurated volcanic layers.

PROVENANCE DISCUSSIONS AND DEPOSITIONAL ENVIRONMENT

The source region for the lithic arenites of the thesis area must have been quartz-rich with an abundance of chert. The Cache Creek Group, located in the uplifted Atlin Terrane (Horst) to the north of the Bowser Basin (Fig. 3.3), is the only chert-rich sequence in the region and is therefore the most likely sediment source. Paleocurrent indicators cited by G.H. Eisbacher (1976,1981; Fig. 3.3, 3.4) suggest that the sediment supply for the northern Bowser Basin was located to the north which supports the idea that the Cache Creek Group in the Atlin terrane was as a possible source region for the sediments. Radiolaria studies of the chert would confirm this proposal as was done by L. Currie (1984) for the Ashman Formation conglomerates in the Spatsizi Map area.

The minor limestone clasts found in the conglomerates (see unit descriptions in the stratigraphy section) have two possible source areas: the Cache Creek Group, or the Sinwa Limestone of the King Salmon Assemblage (Currie, 1984; Fig. 3.3). Although the latter may be a more likely source due to the shorter transport distances involved, the Cache Creek Group supplies the chert to the Spatsizi sediments and therefore would most likely supply the limestone cobbles as well. The minor amount of these limestone clasts in the conglomerates may be due to their mechanical inablity to survive the erosion and transport that was involved during the formation of the Spatsizi sediments.

The lack of modally significant amounts of volcanic fragments in the lithic arenites (Table 3.1) and conglomerates is surprising if the volcano-granitic Stikine Arch region located to the north of the basin was the source area. One explanation is that very early Bowser Basin sedimenation in the north covered over , or "blanketed" the Stikine Arch with a layer of sediments (Eisbacher, 1974). Thus, the influence of tha volcanic sequences on the eroded detritus was minimized by the overlying sediments.

The Cache Creek Group in the Atlin terrane is fault bounded against the northeastern border of the Stikine Arch (Fig. 3.3). It is possible that during Middle to Late Jurassic time, it had not yet been faulted to its present position and subsequently formed a "sedimentary cap" over the Stikine Arch during this time. In this manner, erosion of the Stikine Arch region would supply eroded Cache Creek Group detritus to the northern parts of the Bowser Basin. This would explain the high chert content and low volcanic fragment content in the lithic arenites of the thesis area as the Caohe Creek Group is chert-rich and relatively low in volcanic lithologies. However, the volcanic sequences of the Cache Creek Group are generally basic whereas the volcanic fragments found in the lithic arenites are more intermediate to acidic in composition. Thus, it is likely that there was still a small input of acidic volcanic rock fragments from particularly high relief areas of the Stikine Arch that were exposed by differential erosion of the stratigraphically higher Cache Creek Group.

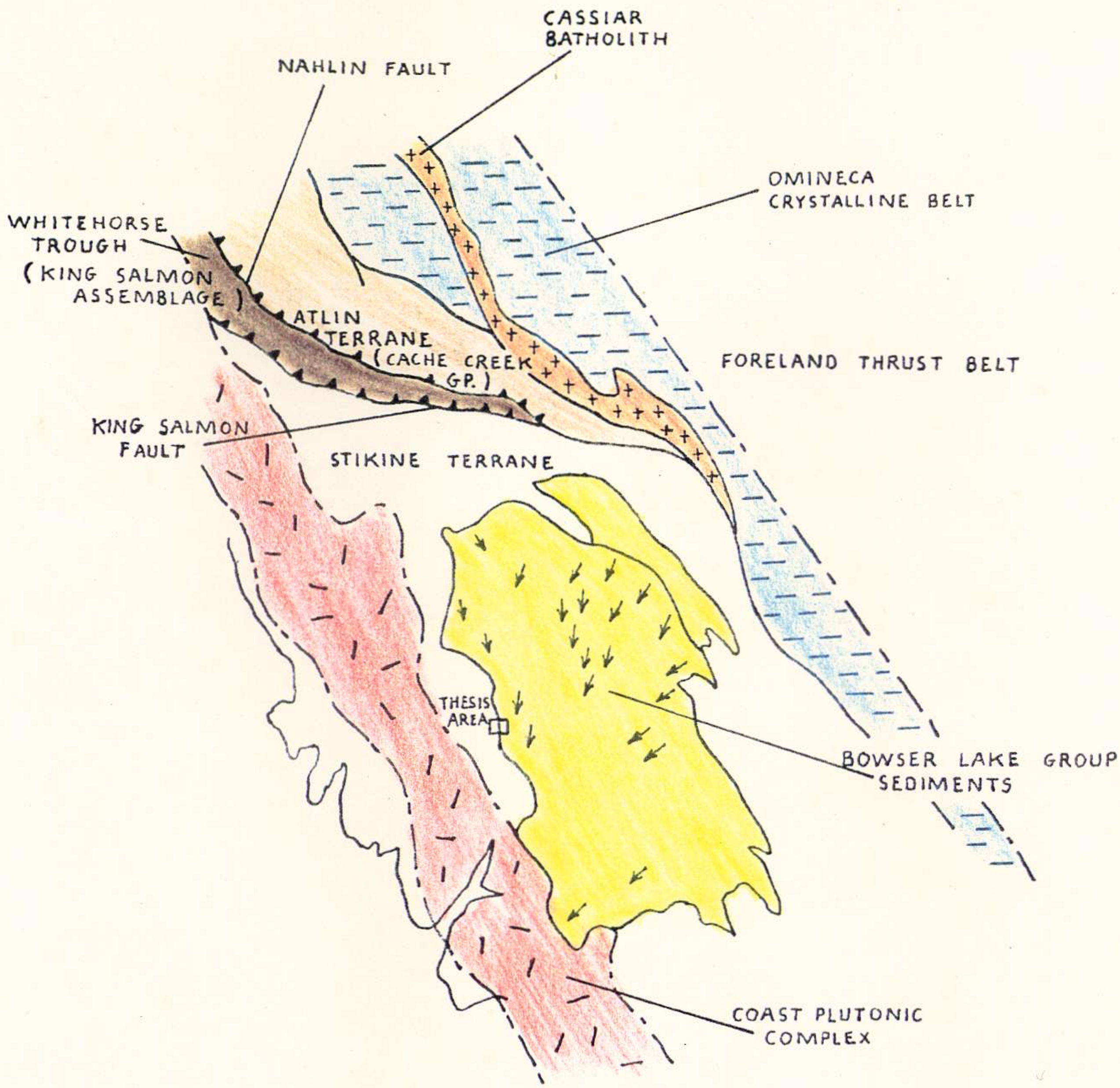


FIGURE 3.3 Sediment transport directions of detritus that infilled the Bowser Basin and the location of the source terranes that supplied the material (modified from Eisbacher, 1981).

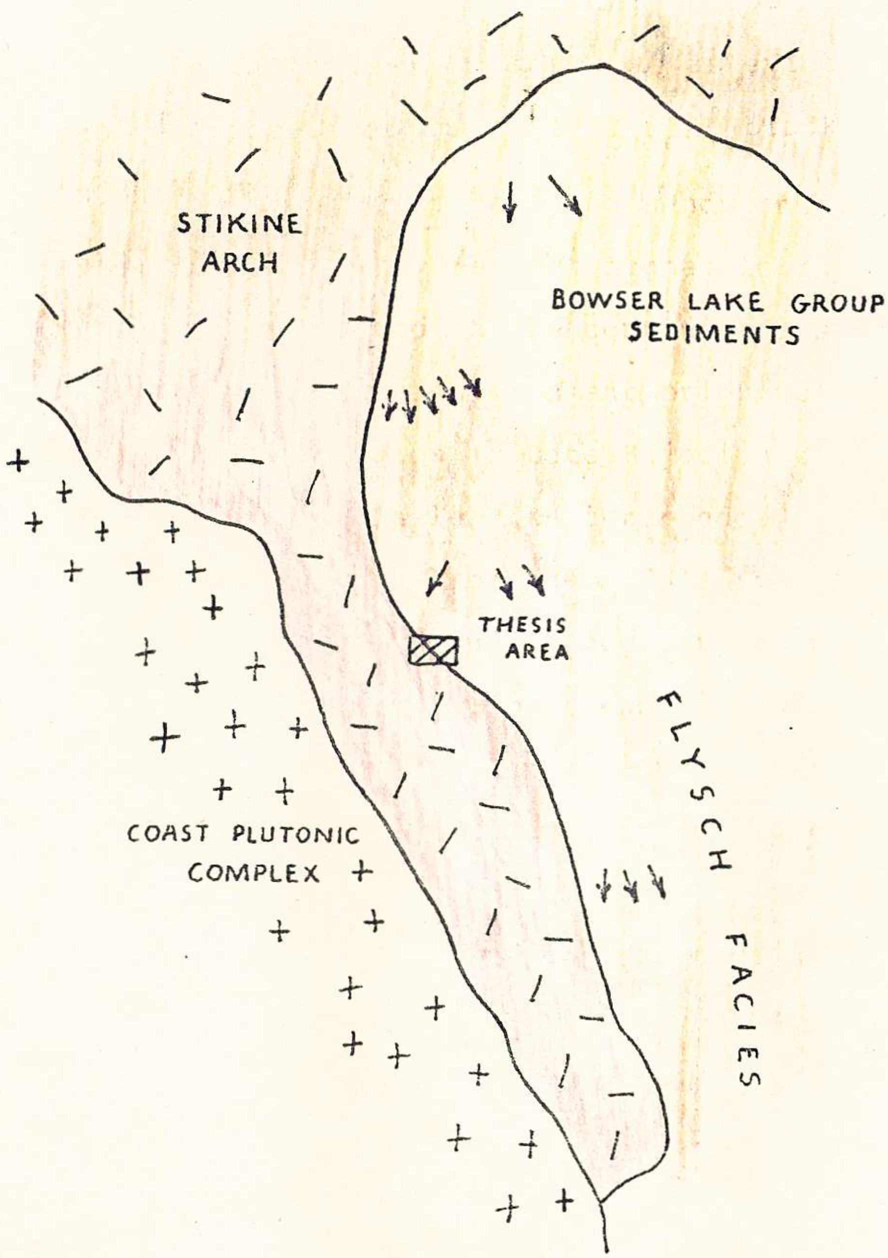


FIGURE 3.4 Sediment transport directions for the northwestern region of the Bowser Basin determined from sedimentary structures in the Bowser Lake Group sediments (modified from Eisbacher, 1976).

The Bowser Lake Group sediments in the thesis area were deposited in the deeper water, basin floor area of the pro-deltaic environment (Fig. 3.5), as evidenced by the extensive deposits of ammonite-bearing black shales and siltstones. The conglomerate and sandstone beds of the Spatsizi sediments may reflect higher energy avalanche deposits that occurred on the continental slope in a submarine fan type of environment prior to the deposition of the deeper water shales in Late Bajocian time. Thick sequences of black shale with interbedded siltstone layers ("flysche") are typical of the Middle to Late Jurassic sedimentary deposits found throughout the northern Bowser Basin (Eisbacher, 1974; Tipper and Richards, 1976; Smith et al, 1984). Most of these shaly sequences however, (particularly those in the Spatsizi map area), have interbedded conglomerate that is not present in the thesis area. Thus, it is proposed that the thesis area formed in the basin floor area distal to the deltaic and submarine fan type environment found to the north.

The Spatsizi map area is located close to the uplifted source region for the northern Bowser Basin (i.e. the Stikine Arch), and subsequently received abundant coarse clastic detritus eroded from the arch. This material then formed the conglomerate beds of the Ashman Formation in that area. This coarse clastic materal however, did not reach the distal, basin floor areas of the submarine environment (Fig. 3.5), so that these areas accumulated large, "uninterrupted" sequences of deep water black shales and siltstones. Thus, a significant facies gradation may occur as one moves south from the northern margin of the Bowser Basin (i.e. the Spatsizi map area) as the input of coarse clastic detritus decreases and deeper water environments prevail. This transition would have a significant effect on the correlation of strata in the region.

In 1984, L. Currie suggested a deltaic to submarine fan type of depositional environment for the Bowser Lake Group sediments (in particular the lowermost conglomerates of the Ashman Formation) located in the Spatsizi Map area, as did Eisbacher (1974) for the northeastern Bowser Basin. These studies support the idea that shallow water, higher energy environments dominated in the north where the supply of coarse clastic material was high. This supply then "dwindled" in the distal, basin floor areas which formed to the south where only deep water shales and siltstones are found.

Uplift in the arch regions was spasmodic during Middle to Late Jurassic time (Eisbacher, 1981) so that time correlative sequences can vary significantly in thickness throughout the northern parts of the basin. These episodic uplift rates may explain the formation of the coarse sandstone and conglomerate beds as the result of unusually high energy environments produced during particularly high rates of arch uplift.

As the Bowser Basin was being filled with clastic detritus, sea level fell (Eisbacher, 1974) as the result of continual uplift of regions such as the Stikine Arch, and the rapid rates of deposition that exceeded the rates of basin subsidence. Subsequently, the Bowser Basin sediments form a coarsening upwards, prograding sedimentary sequence from basal shales grading upwards to coarser deltaic facies with less shale and more sandstone and conglomerate. The uppermost layers of the Bowser Lake Group are sub-aerial (Tipper and Richards, 1976), and formed from Late Jurassic to Early Tertiary time when the Bowser Basin had been completely cut-off from open ocean. The non-marine deposits of the Groundhog Coalfield in the northeastern Bowser Basin formed in such depositional environments.

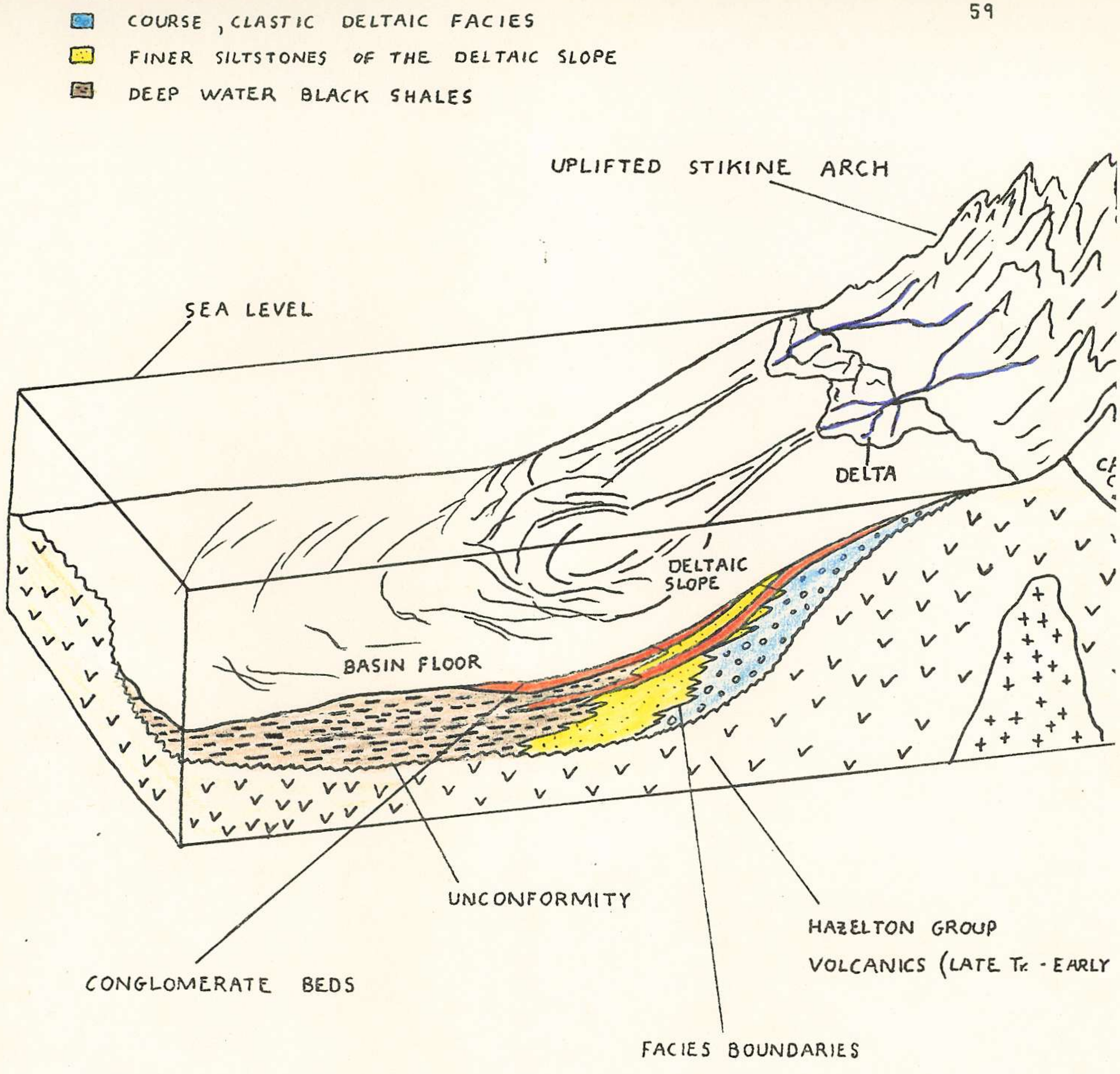


FIGURE 3.5 Sketch of the depositional environment of the northwestern Bowser Basin during Middle to Late Jurassic time. Possible facies relationships are shown. The conglomerate beds may form from sub-marine avalanches on the deltaic slope.

STRUCTURAL GEOLOGY

INTRODUCTION

Structure in the Tom Mackay Lake region is characterized by a large, tight synclinoria that trends northeast-southwest (Fig. 4.1). Polyphase deformation is suggested by minor fold attitudes on the limbs of the major folds. A distinctive planar cleavage is well developed in the pelitic lithologies, but jointing is characteristic of the more competent conglomerate and sandstone. Faults are not a dominant feature in the area although an important reverse fault occures near the core of the main syncline at Storie Creek (Fig. 4.2).

The structure imparts a significant geomorphologic grain to the thesis area. Tom Mackay Lake, approximately 3 km long and 1/2 km wide, occupies the core of the large, tight northwest-trending synclinoria in the area. Many of the ridges and rivers in the area, including Storie Creek, also trend in a northeast-southwest direction as a direct result of the structures formed in the region.

Data collected in the field for sructural analysis included bedding, planar cleavage and joint attitudes, and minor folds orientations in the less competent shales.

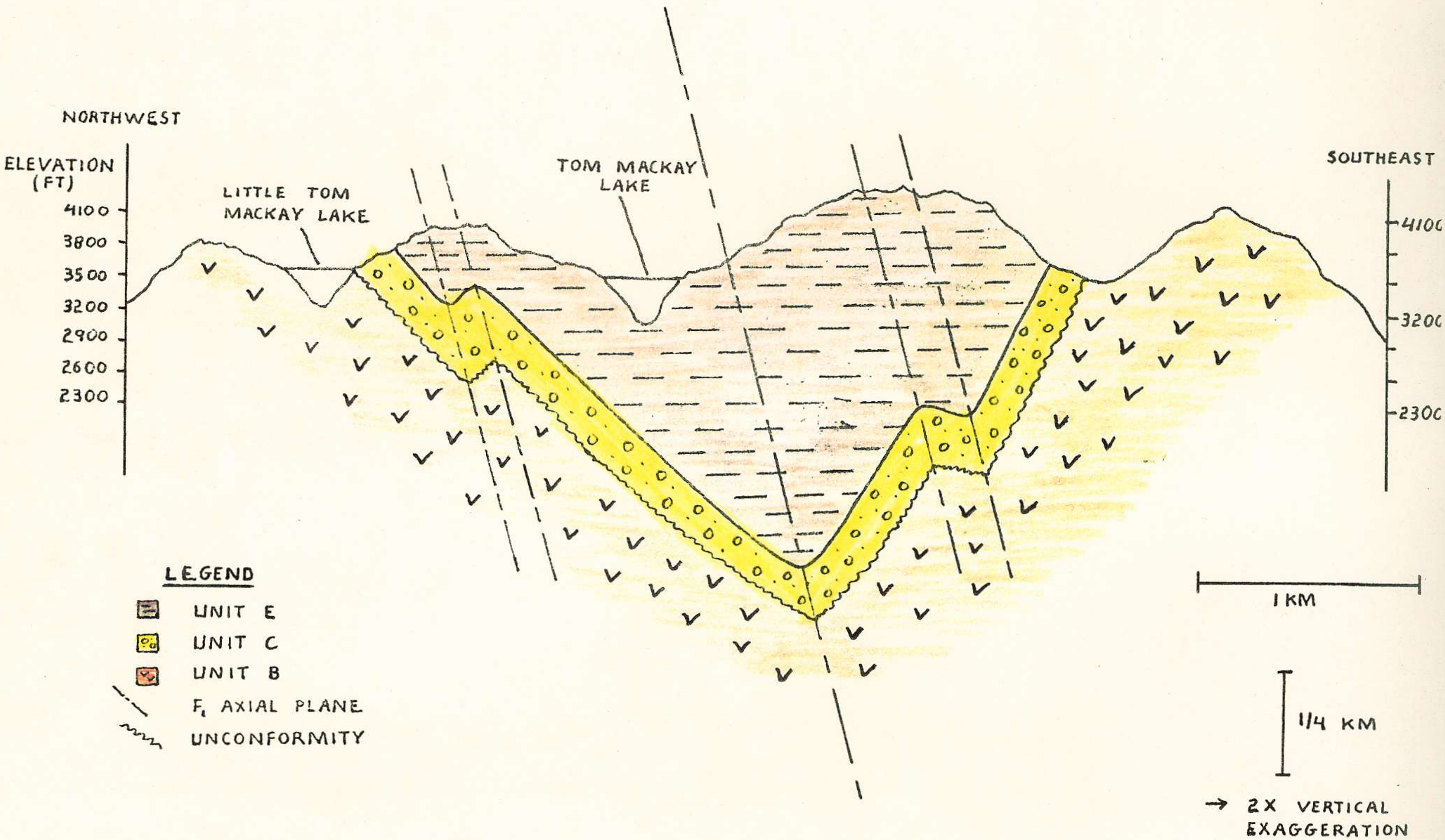
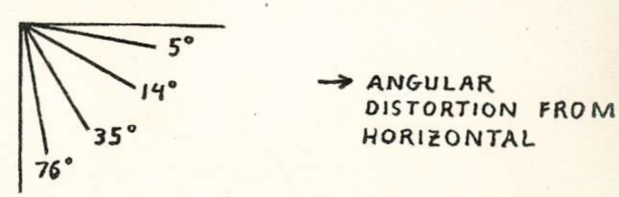


FIGURE 4.1 A down-plunge projection of the Tom Mackay Lake area showing the geometries of the F_1 megascopic fold structures.



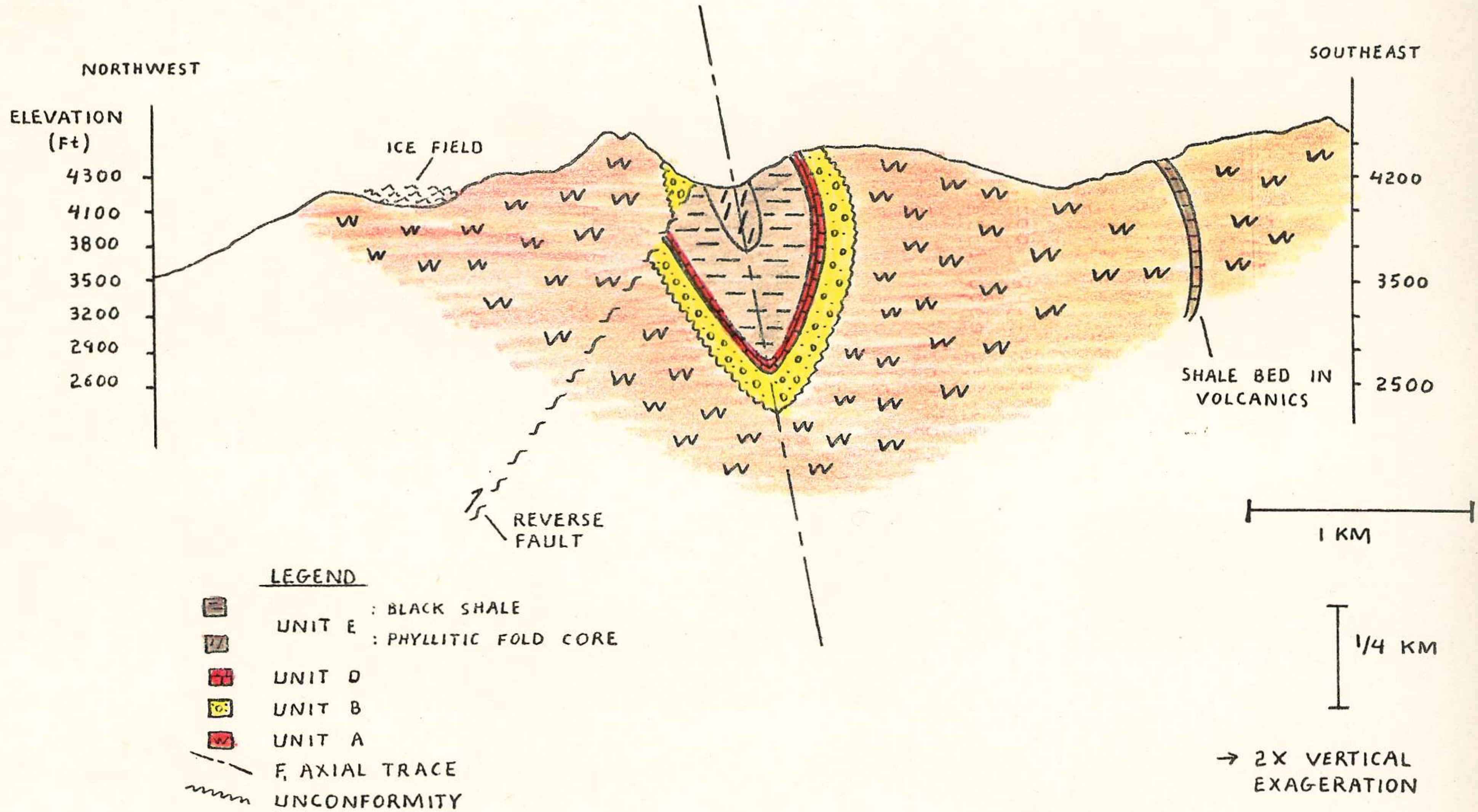
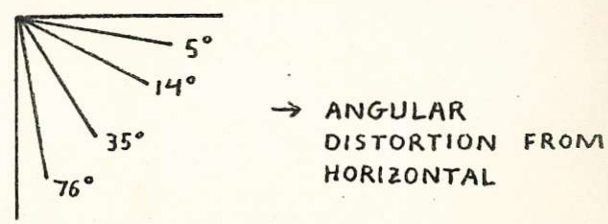


FIGURE 4.2 A down-plunge projection of the Storie Creek area showing the megascopic F_1 fold structure geometries.



FOLDS

TOM MACKAY LAKE AREA

Structure in the Tom Mackay Lake area is dominated by large, tight northeast-trending folds that are characteristic of the F_1 event.

A contoured equal area stereonet plot of the poles to bedding (123 attitudes plotted) indicates that the F_1 event is characterized by cylindrical fold surfaces with axial planes striking 43° and dipping 76° to the southeast (F_1 axial plane determined by passing a plane through both the calculated fold axis and the axial trace taken from the inset map). The F_1 fold axis plunges 25° towards 049°. The large-scale F_1 synclinoria of the Tom Mackay Lake area displays closure to the southwest as do the parallel to sub-parallel minor folds located on the limbs of the larger structures.

Diagram 4.1 reveals the geometries of these folds and allows us to speculate as to the mechanism of folding as well. The folds can be classified as tight folds with an interlimb angle of approximately 70° (Fig. 4.3b). The hinge zone is rounded as displayed by the diffuse nature of the limb clusters shown on the contoured stereonet plot(Fig. 4.3a). The folds are essentially symmetric about their axial plane.

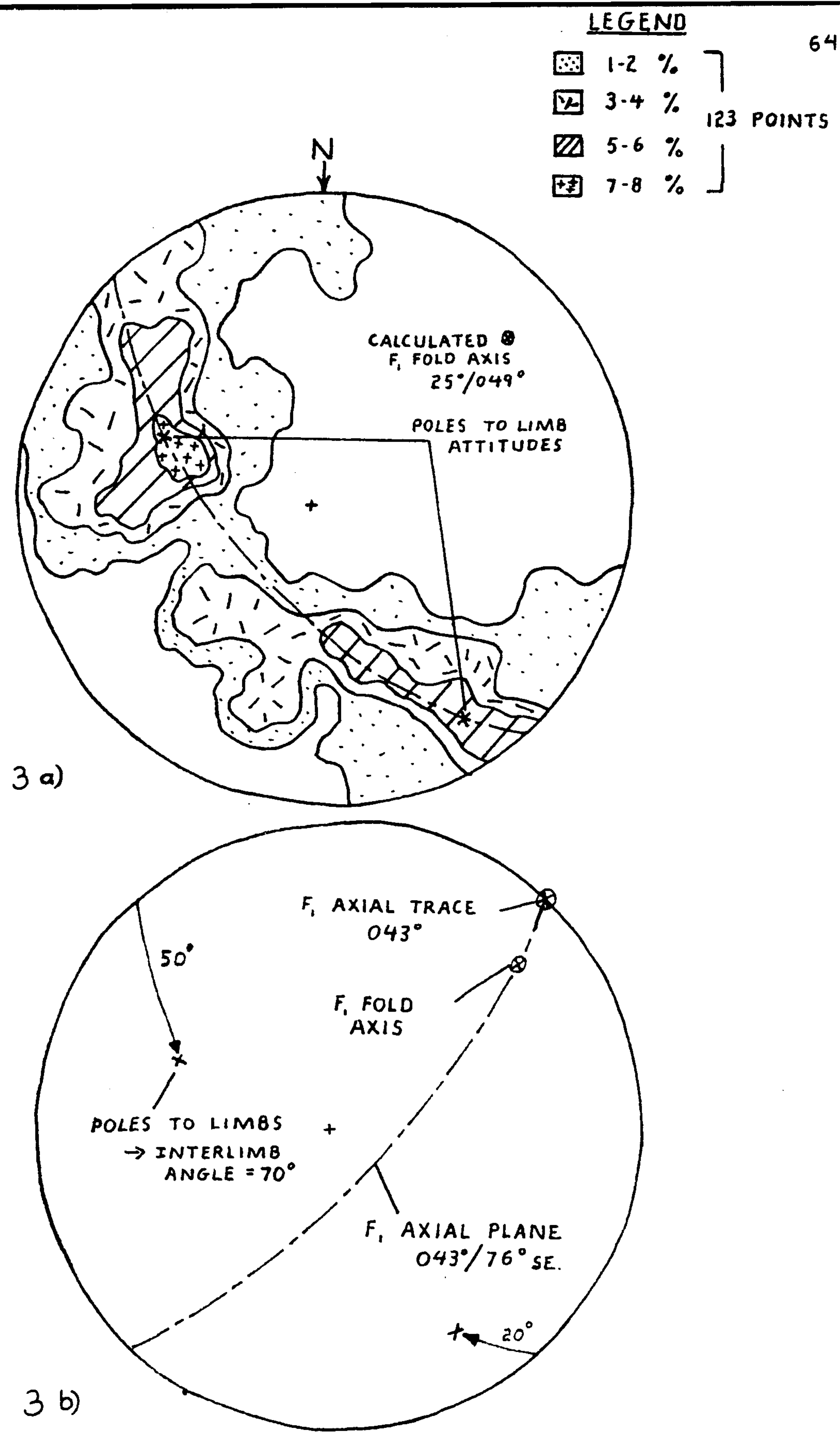


FIGURE 4.3 Equal area stereonet plots of poles to bedding. Figure 3a is a contoured stereonet plot showing the calculated F_1 fold axis and limb orientations. Figure 3b shows the F_1 axial plane orientation and the interlimb angle (i.e. the fold "tightness").

The mechanism of folding during the F_1 event is dominated by flexural-slip processes whereby shear movement is accommodated along,or parallel to, and not across layer boundaries. The maximum compressive forces of the F_1 event are orientated at 133° in an southeast-northwest direction. The amount of shortening achieved by this phase of folding is only about 20%. This is largely due to the relatively small amount of "shearing" that would allow for greater amounts of shortening to occur. Small meter scale shear zones are present in the area however (Anderson, per. comm.), so that shearing was not totally absent during deformation.

A very distinctive feature of the area is the development of a pervasive planar cleavage that is pronounced in the cores of minor folds. The poles to this cleavage were plotted (Fig. 4.4a), and from this diagram we can see that the cleavage originated as an axial planar cleavage associated with the first phase of deformation (i.e. the poles to cleavage cluster about the pole to the F_1 axial plane). However, since its formation it has been deformed by a second phase of deformation which has produced a "fanning" of the cleavage about its original orientation parallel to the F_1 axial plane.

Parasitic minor folds (those minor folds which "mimic" the orientation of the megascopic fold structures formed duing the same folding event) are a distinctive structural feature in the area and are found exclusively in the pelitic layers. The wavelength of these folds is less than 10cm (Fig. 4.5b). The distribution of the fold axes and axial plane orientations of the minor folds is presented by equal area stereonet plots (Fig. 4.4a). The orientation of the folds suggest that the minor folds originated as F_1 "parasitic" folds that have since been deformed by the F_2 event in a similar fashion as the cleavage (i.e. the minor fold axial planes and fold axes have been "fanned" from their original orientations about the pole to the F_1 axial plane and fold axis respectively). There are however, two localities where the minor fold orientations are significantly different from the others (Fig. 4.4b). It is possible that these are also F_1 parasitic minor folds that have been heavily reorientated by F_2 to produce axial orientations 90° to their original position. Their extreme departure from the regular fanning of the other minor folds however, suggest that they are in fact parasitic folds that represent minor fold structures formed during the second deformational event. Therefore, one can use these F_2 parasitic folds to determine the axial orientations of F_2 struuotures (i.e. fold axes of F_2 minor folds cluster about the F_2 fold axis, and axial plane poles of F_2 minor folds cluster about the pole to the F_2 axial plane). Therefore, the F_2 axial plane orientation is 118° / 86° NE and the F_2 fold axis plunges 81° towards 076°. The second phase folds are orientated at 90° to the first phase structures and are not

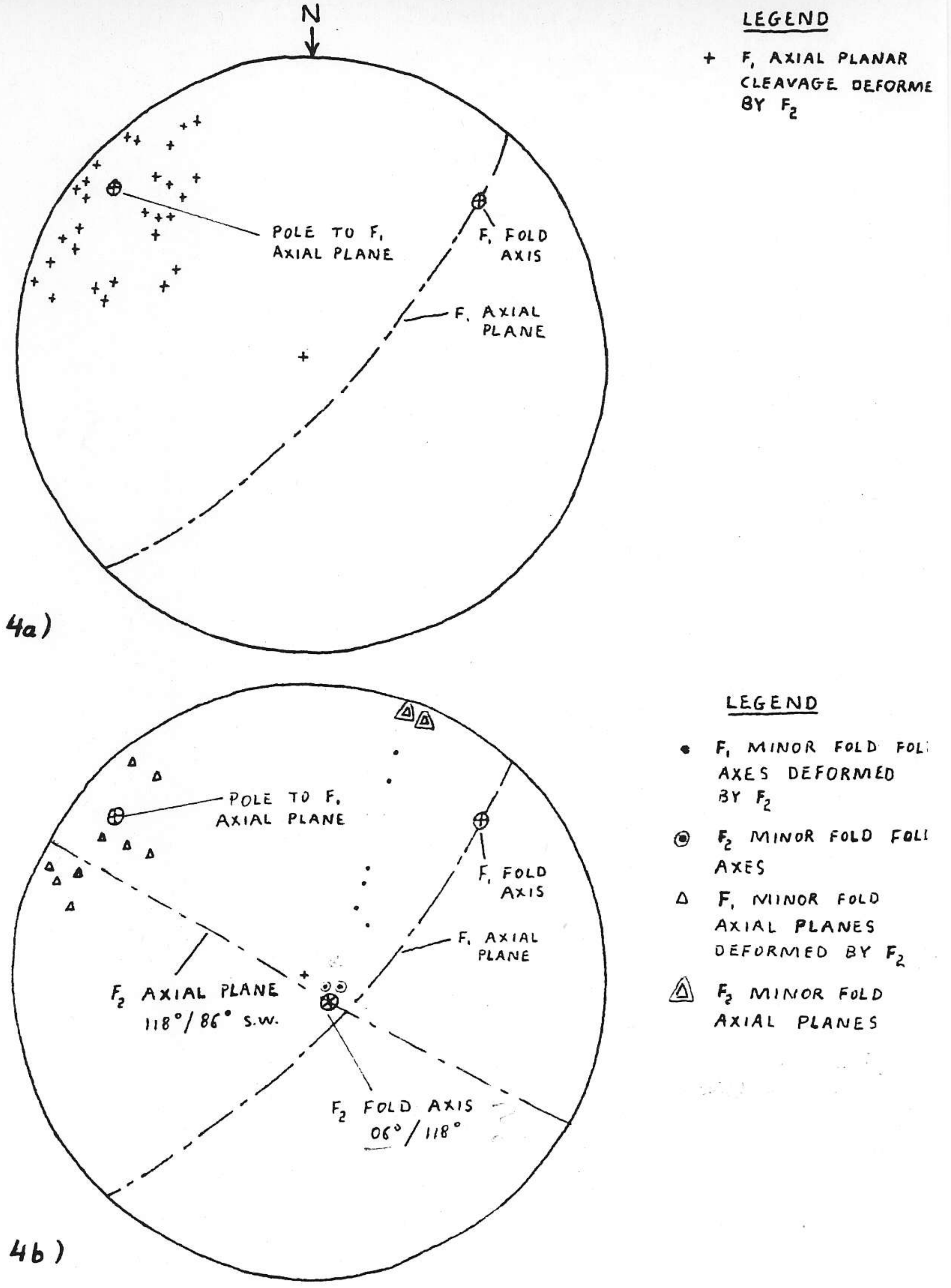


FIGURE 4.4 Equal area stereonet plots of cleavage (4a) and minor fold (4b) data. The F_2 axial plane is defined by the cluster of F_2 parasitic minor fold axial planes which forms the pole to the F_2 axial plane.

associated with the development of an axial planar cleavage.

The isolated F_2 minor folds restricted to the least competent units indicate the orientations of the F_2 folds. In the absence of well developed F_2 megascopic folds and cleavage,the F_2 event is interpreted as being a simple buckling phase. The compressive forces associated with the second deformational event were relatively weak and unable to produce any large scale megascopic fold structures.

In summary, this second phase of deformation is characterized by the deformation of previously formed F_1 minor fold structures and slaty cleavage. The small circle distribution of the F_1 minor fold fold axes (Fig. 4.4b) indicates that this phase of deformation was also dominated by flexural-slip fold mechanisms. The F_2 event itsef was only able to produce isolated minor fold structures in the weak pelitic lithologies.

STORIE CREEK AREA

Phase one folding in the Storie Creek area comprises a northwest-trending, tight syncline overturned to the northwest (Fig. 4.5a). The recumbent style is determined from bedding attitudes and tops criteria from sedimentary sructures (i.e. load structures and flame structures) in the core of the fold. The syncline displays closure to the southwest. There is a northwestward change in grade and deformation from the southeast limb to the fold core which is characterized by a phyllitic texture in the metasediments. The phyllite continues to a northeast-trending reverse fault which cuts out a mimimum of 100 meters of strata on the northwest limb of the syncline. The reason for this contrast in style to the F_1 folds observed in the Tom Mackay Lake area just 10 kilometers to the west is not clear. Detailed structural and stratigraphic studies across the Unuk River would provide much better constraints for the correlation of the structural styles observed in the two areas.

One important geological aspect of the Storie Creek area as discussed in the stratigraphy section of the study is the presence of an unconformity between the Late Triassic Stuhini Group volcanic rocks and the Early Jurassic sandstone-conglomerate, and limey siltstone units which overlie the Bowser Lake Group black shale sequences. The presence of this unconformity produces a possible structural detachment surface whereby deformation is readily transmitted. The appearance of thin zones of fault gouge around the transitional unit also suggest that dispalcement possibly in the form of thrust faulting may have occurred along this horizon between the Triassic and Jurassic lithologies.

The phyllitic core is also a significant feature in the area which suggests that elevated temperatures were associated with the F_1 event. Both the metamorphic grade and

5a)

5b)

FIGURE 4.5 Photographs of the two fold styles found in the thesis area. Figure 5a shows the southwesterly closure of the overturned syncline at Storie Creek and 5b shows the small scale minor folds formed in the pelitic layers in the Tom Mackay Lake area.

the intensity of deformation are greater in the Storie Creek area. These elevated temperatures may have also produced the fiammied tuffs found near the fold core by allowing for the flattening of the weakened lithic grains due to the increased temperatures.

JOINT AND FAULT PATTERNS

A distinctive feature of the Tom Mackay Lake area is the development of A-C, or cross joints related to the F_1 folding event. They are widespread, typically developed in the more competent sandstone and conglomerate, and are closely spaced from 5 cm to 100 cm. Diagram 4.6 is a stereonet plot of the poles to the joint surfaces and displays the relationship of these joints to the F_1 folds.

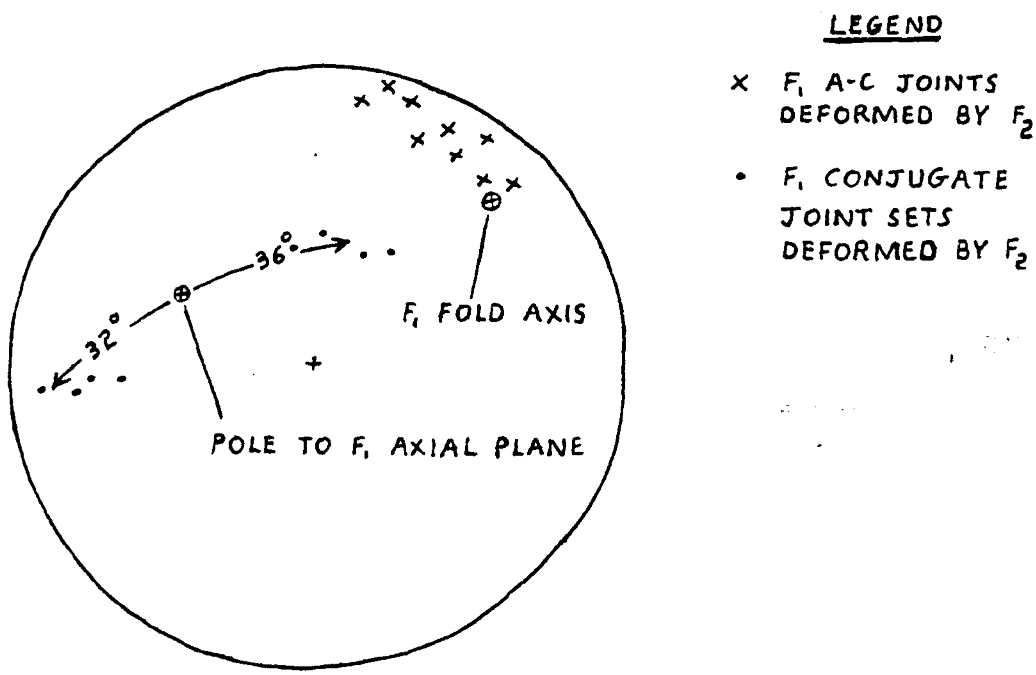


FIGURE 4.6 Equal area stereonet plot of poles to joint surfaces formed in the sandstone-conglomerate unit in the Tom Mackay Lake area. Both the A-C joints and the conjugate joint sets formed during the F_1 event and were later deformed by the F_2 event.

The A-C joints dip steeply to the northeast by 60° to 80° and generally strike at angles between 70° and 100° to the trend of the F_1 fold axis. The fanning of the A-C joints from their original cluster about the F_1 fold axis is attributed to their reorientation by the F_2 event. Conjugate joint sets were not pervasive in the area and were also reorientated by the F_2 event.

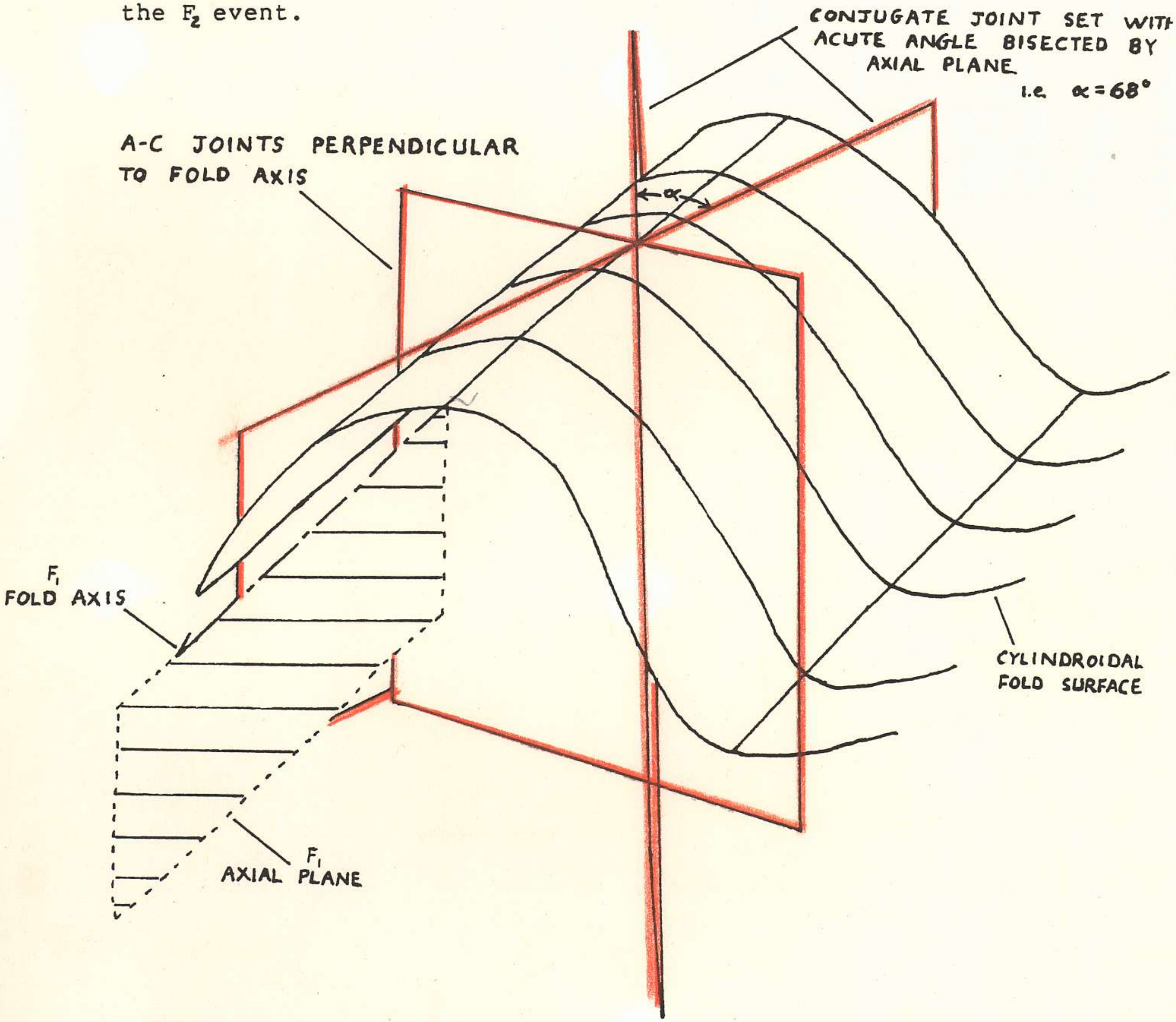


FIGURE 4.7 A sketch of the various joint surfaces formed during the F_1 event before their reorientation by the F_2 event.

Faulting was restricted to a prominent northwesterly dipping reverse fault striking 40° and dipping steeply to the northwest and located on the northwest limb of the overturned syncline at Storie Creek. The reverse fault has displaced the upthrown northwesterly block in a southeasterly direction and accounts for a loss of approximately 100 meters of strata. The phyllitic fabric of the metasediments in the fold core, as well as the fiammied tuffs, may be closely associated with the reverse fault.

The reverse fault may have formed during intense F_1 deformation when shortening was increasing and a "room" problem was developing in the fold core. To alleviate this problem, the thrust fault was formed to remove material from the fold core and allow further deformation and shortening to occur. Temperatures likely rose during this intense deformation and the phyllitic metasediments were formed in the fold core, possibly as a result of hydrothermal fluids migrating along the fault zone. The thrust fault has since been rotated to its present orientation of a steeply dipping reverse fault (Fig. 4.2). Thus shearing and elevated temperatures both associated with thrusting in the fold core may have been characteristic features of the F_1 event in the Storie Creek area.

Threefold evidence exists for the presence of the reverse fault. Firstly, there is a considerable loss of stratigraphic section of up to 100 meters in the northeast fold limb. Notably, the transitional limey siltstone unit that is orange on weathered surfaces only appears on the southeast limb of the syncline. Thus, its absence on the northwest limb is attributed to its truncation by the reverse fault. Secondly, there is a prominent mafic and extremely fine grained volcanic dyke exposed in the volcanic rocks on the northwesterly fold limb that does not appear on the southeast limb. Again, it appears that this dyke has been displaced by the reverse fault. Finally, the phylittic fabric and low grade metasediments in the fold core are likely the result of intense deformation and elevated temperatures related to thrusting which occurred during the F_1 event.

The reverse fault in the Storie Creek syncline is a structural feature that is closely related to the F_1 event. The recognition of this structural style is potentially valuable in the correlation of structural styles found in other areas of the northern Bowser Basin.

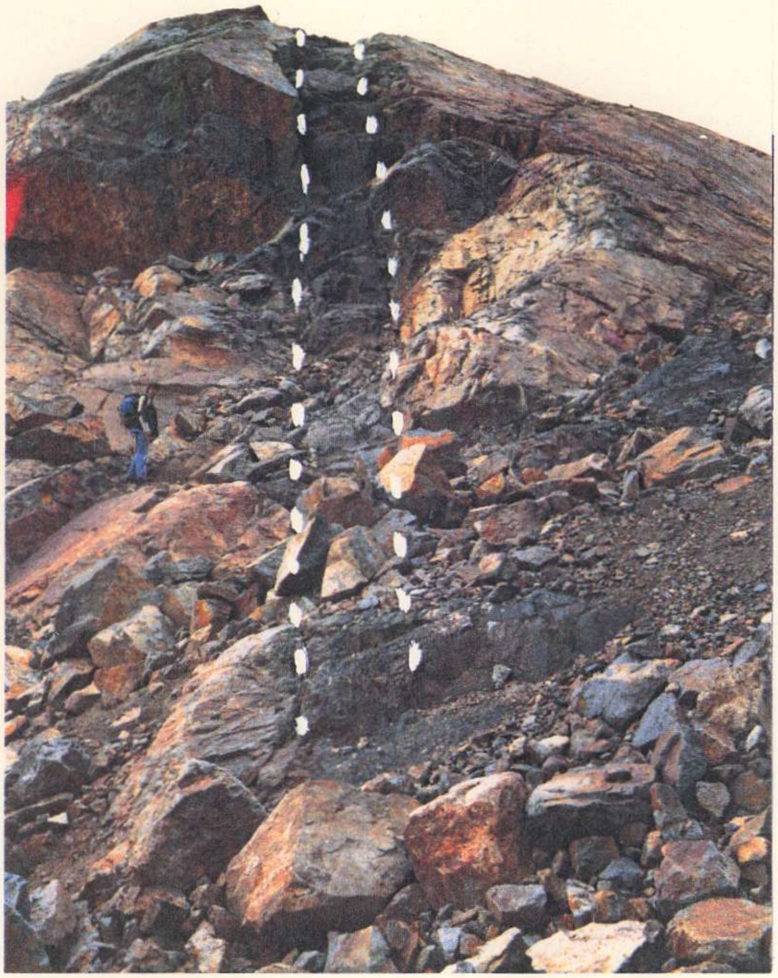


FIGURE 4.8 A view of the northwest limb of the overturned syncline at Storie Creek in which the fine grained, mafic dyke crosscuts the layered volcanics. Its absence in the southeast limb is evidence supporting the emplacement of a thrust fault near the fold core.

SUMMARY AND CORRELATION TO OTHER AREAS

The thesis area is a deformed region in which two non-coaxial phases of deformation have occurred orientated at 90° to each other. First phase axial planar cleavage is distinctive of the pelitic rocks and is commonly deformed by the F_1 event. First phase A-C, or cross joints formed in the more competent sandstone and conglomerate, and were also deformed by the F_2 event. Minor folds are primarily parasitic F_1 minor folds reorientated by F_2, although some parasitic F_2 minor folds did form in the Tom Mackay Lake area. Both folding events are dominated by flexural-slip processes with the first phase producing megascopic structures trending northeast, and the weaker second phase limited to the formation of only minor fold structures. Reverse faults, shearing, and phyllitic metasediments in the fold core characterize the F_1 event in the Storie Creek area.

The most important structural features in the area include the less competent pelitic rocks having been pervasively deformed relative to the more competent sandstone, conglomerate, and tuff. First phase structures are largely deformed by the F_2 event which has no megascopic fold structures associated with it. The contrasting structural style between the Tom Mackay Lake area and the Storie Creek area is significant and could be better understood by further detailed geologic mapping across the Unuk River located between the two areas.

The correlation of the structure observed in the thesis area with that observed in other areas of the Bowser Basin is uncertain. Many detailed structural studies of the Groundhog Coalfield area in the northeastern Bowser Basin describe northwest trending megascopic fold structures that pre-date, and are deformed by, a second phase of northeast trending structures (Koo, 1986; Moffat, 1986; Moffat and Bustin, 1984; Bustin and Moffat, 1983; Richards and Gilcrest, 1979). Thus, the structural synthesis of that area is opposite to that of the Tom Mackay Lake region. Moffat and Bustin (1984) have bracketed the age of the deformation in that area to Late Cretaceous to Early Eocene. The structural contrast between the two areas may be due to the fact that the folding in the Grounhog Coalfield represents much younger deformational events than those events which effected the Late Triassic to Middle Jurassic rocks in the thesis area. In 1985, B. Thomson described the structure of the Spatsizi Plateau area (Spatsizi Map Sheet; Fig. 1.2) to be similar to that described for the Groundhog Coalfield area.

In 1981, G.H. Eisbacher described the structure of the Sustut Basin northeast of the Groundhog Coalfield to be similar to that of this thesis area. As well, G.J. Souther (1972) has described a similar structural style for the Telegraph Map Sheet (Fig. 1.2) located directly to north of the thesis area. Thus, the Groundhog Coalfield appears to be structurally anomolous between two more similar structural styles. This makes any structural correlations or "trends" across the northern Bowser Basin difficult.

A detailed structural analysis of northern and central British Columbia by Monger et al (1978) has proposed that three distinct phases of deformation have produced the major structural grain on the Intermontane Belt of central British Columbia. The first phase was in the Late Triassic and produced folding and metamorphism which was possibly related to the amalgamation of the allocthonous terranes which formed superterrane I. The second phase is Early Cretaceous, and produced fold structures that may have been the result of the accretion of superterrane II with the western edge of North America. The final episode of deformation occurred in Early Tertiary time and was characterized by strike-slip movements which transported the accreted terranes in a northwest direction and placed them into their present positions in the Canadian Cordillera.

The geometries of the structures in the thesis area correspond closely with the structures described by Monger et al (1978) for the Early Cretaceous structural episode that imparted much of the structural grain on central British Columbia. These multiple episodes of active deformation may be the cause of the difficulty in correlating the structural styles found throughout the northern Bowser Basin.

CONCLUSION

During Late Triassic time, the Stikine and Cache Creek Terranes were amalgamated, and uplift of regions such as the Stikine Arch occurred. The Hazelton Trough was formed and subsequently filled with volcanic rocks during Sinemurian to Callovian time to form volcanic sequences now referred to as the Hazelton Group. In Late Bajocian time, the Skeena Arch was uplifted and divided the Hazelton Trough into two successor basins. The Bowser Basin formed to the north of the Skeena Arch and the Nechako Basin formed to the south of the arch. The Bowser Basin was then filled with marine and non-marine deposits from Late Bajocian to Kimmeridgian time. These sedimentary sequences are now referred to as the Bowser Lake Group.

The formation of the Bowser Basin occurred as superterrane I was being accreted to the margin of continental North America from Middle to Late Jurassic time. The dynamic history of terrane amalgamation and accretion that occurred throughout the formation of the Central Cordillera is in a large part responsible for the formation, and subsequent deformation of the Bowser Basin.

The thesis area lies in the northwestern portion of the Bowser Basin and is underlain by sedimentary and volcanic strata that range from Norian to Oxfordian in age. In the Storie Creek area, Norian volcanic sequences, correlative with the Stuhini Group, are composed largely of tuffs and volcanic breccias. These rocks are unconformably overlain by coarse, clastic sediments and minor calcareous beds that are correlative with the Spatsizi sediments. The calcareous beds are not found in the Tom Mackay Lake area and suggest a local facies change between the two areas in Early Bajocian time. Black shales and phyllites conformably overlie the clastic sedimentary sequences, are Callovian to Oxfordian in age, and are correlative with the Ashman Formation of the Bowser lake Group.

In the Tom Mackay Lake area, Hettangian to Pliensbachian volcanic tuffs form the lowermost unit in the area, and are correlative with the Toodoggone volcanics. These volcanic sequences, like in the Storie Creek area, are unconformably overlain by coarse conglomerates and arenites that are Toarician to Bajocian in age. This unit is correlative with the Spatsizi sediments. Black shales form the stratigraphically highest unit in the Tom Mackay Lake area, are Late Bajocian and younger in age, and are correlative with the Ashman Formation.

The source area for the clastic sequences described in the thesis area was the chert-rich Cache Creek Group located in the uplifted Stikine Arch region directly to the north of the basin. The sandstones and conglomerates are chert-rich, texturally mature, and compositionally moderately mature. The lack of a more significant volcanic component in these rocks is due to the lack of volcanic rocks in the Cache

Creek Group. The lack of limestone clasts reflects their mechanical instability and inability to survive erosion and long transport distances.

The thick sequences of ammonite-bearing black shales in the thesis area suggest that the depositional environment was one of deep water, distal to the influence of coarse clastic material from deltaic and pro-deltaic environments. A significant facies transition occurs from primarily deep water to primarily shallow water lithologies as one moves north from the thesis area towards the northern margin of the Bowser Basin. The Ashman Formation is an example of this facies change as it has an increasingly large chert-pebble conglomerate content as it is traced northward from the thesis area where it is composed entirely of shale.

In the thesis araa, there are two non co-axial, passive phases of deformation that have occurred at 90° to each other. Megascopic, large-scale fold structures trend northeast-southwest in the area, and were formed during the first phase of deformation. The second phase of deformation was weak, restricted only to the formation of minor fold structures, and pervasively deformed first phase structures.

Correlation of the structural synthesis of the thesis area to that of other areas in the northern Bowser Basin is unclear. The Groundhog Coalfield area is an example of an area where the structural synthesis is opposite to that of the thesis area (i.e. northeast-southwest trending structures post-date an earlier phase of northwest-southeast trending structures). The uncertainty in correlation may be due to the multiple periods of deformation that have effected much of north-central British Columbia in relation to terrane accretion and amalgamation events in the Canadian Cordillera.

Further study in the area would be best utilized in the Unuk River area where further correlation of the stratigraphy and stucture between the Tom Mackay Lake and Storie Creek areas might be possible. In addition, an attempt to map, and better understand the relationship between the abundant conglomerate and breccia outcrops in the thesis area might lead to a more precise correlation of these lithologies with other strata in the Bowser Basin. This might result in a better understanding of both the depositional history of the area, and of the facies transition that occurs between the Spatsizi map area and the thesis area.

BIBLIOGRAPHY

Alldrick, D.J., 1984. Geologic setting of precious metal deposits in the Stewart area. British Columbia Ministry of Energy, Mines, and Petroleum Resources, Geological Fieldwork, 1985, p. 149-163.

Bustin, R.M., Moffatt, I., 1983. Groundhog Coalfield, central British Columbia: Reconnaissance stratigraphy and structure. Bulletin of Canadian Petroleum Geology, v. 31, p. 231-245.

Currie, L., 1984. The provenance of chert clasts in the Ashman Conglomerates of the northeastern Bowser Basin. B.Sc. Thesis, Queens Universiy, Ontario, 55p.

Donnelly, D., 1976. A study of the volcanic stratigraphy and volcanogenic mineralization on the Kay Claim Group, northwestern British Columbia. B.Sc. Thesis, The University of British Columbia, 34p.

Dickinson, W.R., et al, 1983. Provenance of North American Phanerozoic sandstones in relation to tectonic setting. Geologial Society of America Bulletin, v. 94, p. 222-235.

Dickinson, W.R., Suczek, A., 1983. Plate tectonics and sandstone compositions. The American Society of Petroleum Geologists Bulletin, v. 63, p. 2164-2182.

Eisbacher, G.H., 1974a. Deltaic sedimentation in the northeastern Bowser Basin, British Columbia. Geological Survey of Canada, Paper 73-33, 13p.

Eisbacher, G.H., 1974b. Sedimentary history and tectonic evolution of the Sustut and Sifton Basins, north-central British Columbia. Geological Survey of Canada, Paper 33-31, 57p.

Eisbacher, G.H., 1981. Late Mesozoic-Paleogene Bowser Basin Molasse and Cordilleran tectonics, western Canada. Geological Association of Canada, Special Paper 23, p. 125-146.

Frebold, H., Tipper, H. W., 1970. Status of the Jurassic in the Canadian Cordllera of British Columbia, Alberta, and Southern Yukon. Canadian Journal of Earth Scinces, v. 7, p. 1-21.

Grove, W., 1971. Geology and mineral deposits of the Stewart area, northwestern British Columbia. British Columbia Department of Energy, Mines , and Petroleum Resources Bulletin, no. 58, 209p.

Koo, J., 1986. Geology of the Klappan Coalfield in northeastern British Columbia. British Columbia Department of Energy, Mines, and Petroleum Resources, Geological Fieldwork, p. 343-350

Moffatt, I., Bustin, R.M., 1984. Superposed folding in the northern Groundhog Coalfield; evidence for polyphase deformation in the northeastern corner of the Bowser Basin. Geological Survey of Canada, Paper 84-1b, p. 255-261.

Monger, J.H., Richards, T.A., Patterson, I.A., 1978. The Hinterland Belt of the Canadian Cordillera: new data from northern and central British Columbia. Canadian Journal of Earth Sciences, v. 15, p. 823-830.

Monger, J.H., Irving, E., 1980. Northward displacement of north-central British Columbia. Nature, v. 285, p. 289-294.

Monger, J.H., Price, R.A., Templeman-Kluit, D.J., 1982. Tectonic accretion and the origin of the two major metamorphic and plutonic welts in the Canadian Cordillera. Geology, v. 10, p. 70-75.

Monger, J.H., 1984. Cordilleran tectonics: A Canadian perspective. Bulletin du Societe Geologiquede la France, v. 26, p. 225-278.

Richards, T.A., Gilcrest, R. D., 1979. Groundhog coal area, British Columbia. Geological Survey of Canada, Paper 79-1b, p. 411-414.

Smith, P.L., Thomson, R.C., Tipper, H.W., 1984. Lower and Middle Jurassic sediments and volcanics of the Spatsizi map area, British Columbia. Geological Survey of Canada, Paper 84-1a, p. 117-120.

Souther, J.G., 1972. Telegraph Creek map area, British Columbia. Geological Survey of Canada, Paper 71-44, 38p.

Souther, J.G., 1977. Volcanism and tectonic environments in the Canadian Cordillera - a second look. Geological Association of Canada, Special Paper 16, p. 3-24.

Souther, J.G., Armstrong J.E., 1966. North-central belt of the Cordileran of British Columbia. Canadian Institute of Mining and Metalurgy, Special v. 8, p. 121-138.

Taylor, D.G., et al, 1984. Jurassic ammonite biogeography of western North America: the teconic implications. Geological Association of Canada, Special Paper 27, p. 121-138.

Tipper, H.W., 1976. Biostratigraphic study of the Mesozoic rocks in the Intermontane and Insular belts of the Canadian Cordillera, British Columbia. Geological Survey of Canada, Paper 76-1a, p. 59-61.

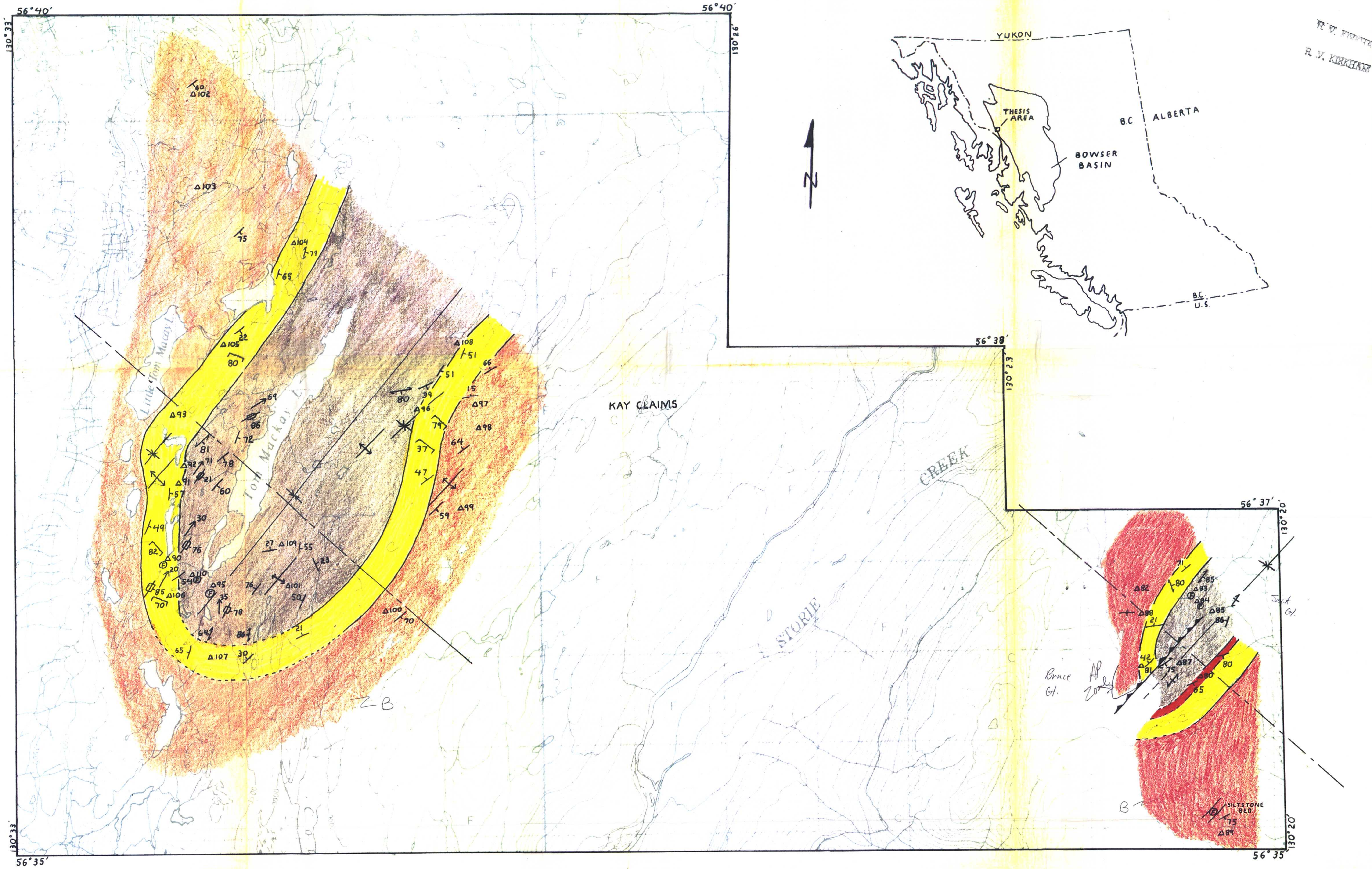
Tipper, H.W., 1984. The allocthonous Jurassic - Lower Cretaceous terranes of the Canadian Cordillera and their relation to correlative strata of the North American craton. Geological Association of Canada, Special Paper 27, p. 113-120.

Tipper, H.W., Richards, T.A., 1976. Jurassic stratigraphy and history of north-central British Columbia. Geological Survey of Canada, Bulletin 270, 73p.

Thomson, R.C., 1985. Lower to Middle Jurassic (Pliensbachian to Bajocian) stratigraphy and Pliensbachian ammonite fauna of the northern Spatsizi map area, north-central British Columbia. M.Sc. Thesis, University of British Columbia, 146p.

Wheeler, J.O., Gabriesle, H., 1972. The Cordilleran structural province. Geological Association of Canada, Special Paper 11, p. 1-81.

Yagishita, K., 1985. Evolution of a provenance as revealed by petrographic analysis of Cretaceous formations in the Queen Charlotts Islands, British Columbia, Canada. Sedimentology, v. 32, p. 671-684.



INSET MAP GEOLOGICAL MAP OF THE THE THESIS AREA

LEGEND

GEOLOGIC BOUNDARY :
DEFINED
INFERRED
THRUST FAULT
STATION LOCALITY
FOSSIL LOCALITY
BEDDING ORIENTATION (NUMBER INDICATES DIP VALUE)
CROSS-SECTION LINE
CLEAVAGE ORIENTATION (NUMBER INDICATES DIP VALUE)
AXIAL PLANE ORIENTATION OF MINOR FOLDS (NUMBER INDICATES DIP VALUE)
FOLD AXIS ORIENTATION OF MINOR FOLDS (NUMBER INDICATES PLUNGE VALUE)
JOINT ORIENTATION (NUMBER INDICATES DIP VALUE)
AXIAL TRACE OF MEGASCOPIC SYNCLINE
AXIAL TRACE OF MEGASCOPIC ANTICLINE

MAP UNIT

E : LAMINATED BLACK SHALE, PHYLLITE. LATE BATHONIAN TO CALLOVIAN.

D : CALCAREOUS, NON-FOSSILIFEROUS. SILTSTONE.

C : LITHIC ARENITE, COARSE POLYMICT CONGLOMERATE. TOARCIAN TO LATE BATHONIAN.

B : LAPILLI-CRYSTAL-LITHIC TUFF, SILICIFIED TUFF. HETTANGIAN TO PLIENSBACHIAN.

A : SILICIFIED TUFF, VOLCANIC BRECCIA, PORPHYRITIC ANDESITE. NORIAN

0 1 2 3
KM

SCALE - 1:25,000

inches
0 1 2
0 1 2 3 4 5
centimetres

BRITISH COLUMBIA GEOLOGICAL SURVEY

This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.