GEOLOGY OF THE CENTRAL MORESBY ISLAND REGION,

QUEEN CHARLOTTE ISLANDS, (HAIDA GWAII)

BRITISH COLUMBIA

by

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Abstract

The Queen Charlotte Islands represent the most outboard exposure of Wrangellia in the Canadian Cordillera. This study analyzes the structural and stratigraphic history of the central Moresby Island area, and correlates this history with ongoing and previous studies in the Queen Charlotte Islands. The stratigraphic succession preserved in central Moresby Island comprises marine volcanic and sedimentary rocks of the Triassic Karmutsen Formation and Kunga Group, Middle Jurassic arc volcanic rocks of the Yakoun Group, marine sedimentary rocks of the Longarm Formation and Queen Charlotte Group, and Tertiary volcanic rocks.

The Karmutsen Formation and Kunga Group rocks exposed in central Moresby Island formed during a widespread Triassic volcanic event followed by marine carbonate and clastic sedimentation. Coarse clastic lithologies in the Kunga Group indicate a volcanic provenance as early as the Norian. The Early to Middle Jurassic marine sedimentary rocks of the Maude Group, present elsewhere in the Queen Charlotte Islands, are absent in central Moresby Island. Oldest rocks of the clastic Longarm Formation in central Moresby Island are of Hauterivian age, and the conformably overlying Queen Charlotte Group extends into at least the Turonian. Both field and petrographic evidence suggest two distinct suites of Tertiary volcanic rocks exist in central Moresby Island.

Dominant megascopic structures in central Moresby Island are dominated by north, northeast and northwest-trending fault sets. Folding is common in stratified Kunga Group lithologies, and only of minor importance in younger successions. The deformational history outlines five events: Middle Jurassic shortening, Middle to Late Jurassic extension, post-Cretaceous and pre-Tertiary shortening, post-Cretaceous and pre-(syn ?) Tertiary extension, and a syn (?) to post-Tertiary extension.

The structural history outlined for the central Moresby Island area provides several refinements to pre-existing models. It provides evidence that Middle Jurassic shortening continued into and possibly outlasted Yakoun Group arc volcanism. Cretaceous block faulting, documented on Graham Island and northern Moresby Island, extended into central Moresby Island. Asymmetric south-directed Tertiary extension, documented on southern Moresby Island, also extended into central Moresby Island, and has implications to the offset history of regional faults.

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Acknowledgements

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1 INTRODUCTION

1.1 Location

The Queen Charlotte Islands lie off the northwest coast of British Columbia, Canada, and comprise an archipelago of approximately one hundred and fifty islands. Two main islands represent most of the land mass, Graham Island in the north, and Moresby Island in the south (Figure 1.1). Most of Moresby Island, and the west coast of Graham Island are mountainous and rugged, whereas the eastern part of Graham Island forms a broad lowland. The study area is situated in central Moresby Island, and includes the region surrounding Sewell Inlet, Newcombe Inlet, and Wilson Bay. It occurs between 52°55' N, 132°10' W, and 52°45' N, 131°50' W, and covers approximately 150 square kilometres (Figure 1.1).

The climate of the Pacific coast of British Columbia is temperate, and the flora within the Queen Charlotte Islands is dominated by coastal rain forest. Giant first growth trees are extensively harvested on both Graham and Moresby islands, and logging and fishing form the economic base of the islands. Tourism is becoming increasingly important with the creation of a new national park on southern Moresby Island dedicated to the preservation of the ancient climax forests. Wildlife is abundant, and consists of both endemic and introduced species of mammals, and diverse migratory and resident bird populations.

The central Moresby Island study area coincides largely with the area managed by Western Forest Products in Sewell Inlet. Access is by float plane or helicopter from the village of Sandspit on northern Moresby Island, or by boat from Moresby Camp at the head of Cumshewa Inlet (Figure 1.1). Logging roads are extensive within the study

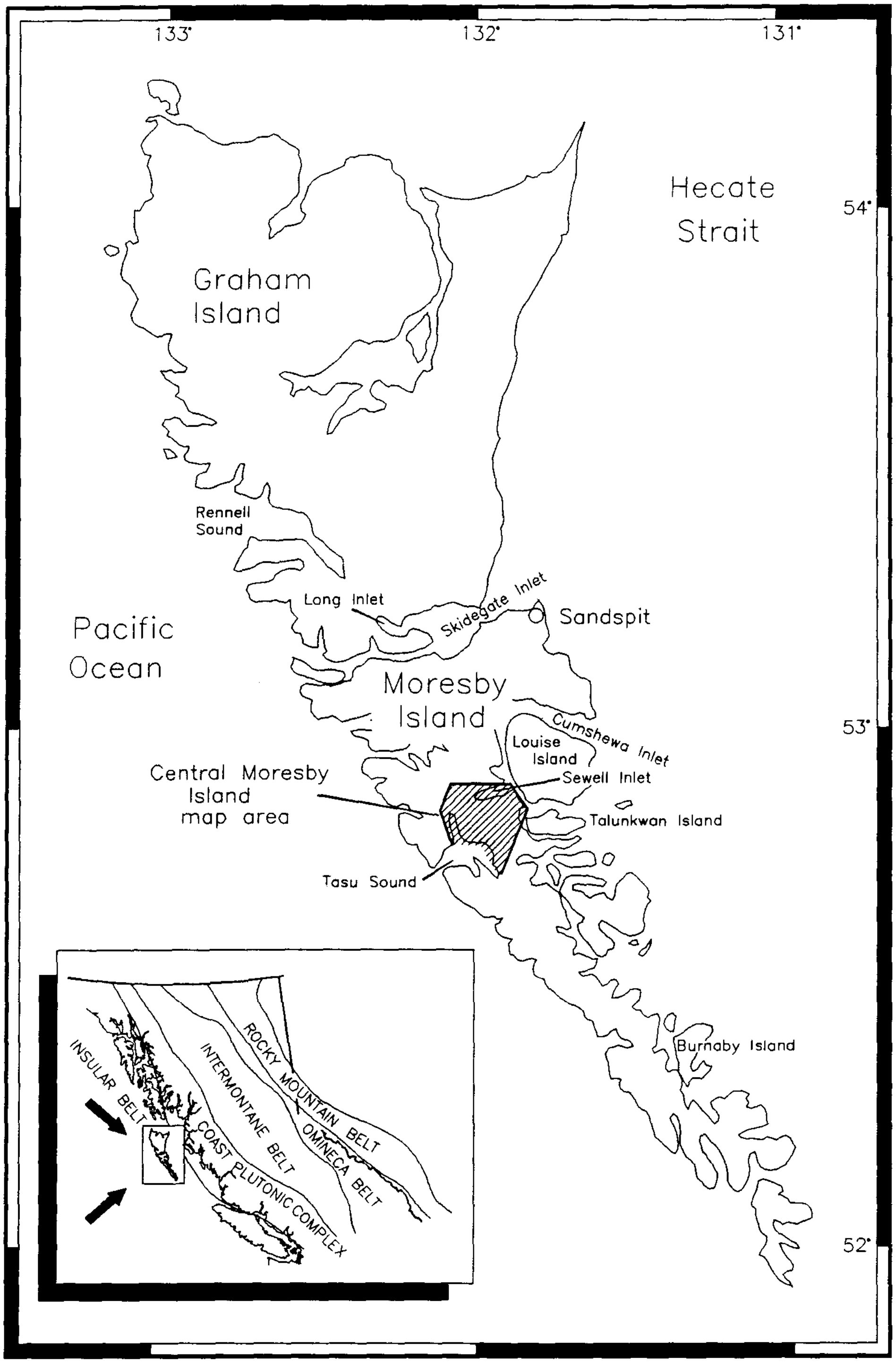

Figure 1.1: *Map showing the major islands of the Queen Charlotte Islands, and the position of the central Moresby Island study area. Inset map shows the position of the islands in British Columbia, and relative to the five tectonic belts of the Canadian Cordillera.*

and the majority of geologic observations are from road cuts and road metal quarries; the rest were made from stream exposures, ridge tops, shore exposures and rare outcrops in forest

1.2 History and previous work

The Queen Charlotte Islands, also known as Haida Gwaii are the ancestral home for the Haida Indians. These seafaring warriors have inhabited the region for thousands of years. The history of European explorers date to the voyages of discovery of Dixon, Juan Perez, Caamano, and others in the Sixteenth and Seventeenth centuries. Scientific investigations initiated with the reconnaissance study of Richardson (1873), and G.M. Dawson's remarkable natural science and anthropology treatise in 1878. Since then, the diverse geology within the islands has attracted the attention of many researchers, both academic and industrial. Their work has been invaluable in deciphering the geologic history of the islands, and relevant parts are reviewed in later sections of this thesis. Notable among these studies is that of Sutherland-Brown (1968). Initiated in 1958 with the goal of cataloging possible iron-ore exploration targets on Moresby Island, it was extended in 1961 to include all of the islands and resulted in the first account of the geology of the entire Queen Charlotte Islands.

In 1987, the federal government of Canada, acting on a mandate to evaluate the hydrocarbon reserves in Canada, charged the Geological Survey of Canada with the task of exploring the frontier basins. The Frontier Geoscience Program was the umbrella organization which united researchers from industry, academia, and government in this task (Thompson, 1988a). Geologic mapping, geophysical surveys, and stratigraphic and biostratigraphic investigations were among the studies engaged in during the first two years of the Frontier Geoscience Program in the Queen Charlotte Islands.

By 1989, 1:50,000 scale geologic map coverage for much of central Graham Island and northern Moresby Island existed (Hickson, 1990a, 1990b; Hickson and Lewis, 1990; Lewis and Hickson, 1990; Lewis et al, 1990; Thompson, 1990; Thompson and Lewis, 1990a, 1990b; Figure 1.3). Several important conclusions regarding the geologic evolution of the region had already been reached. Firstly, Wrangellian strata were found on the east side of Hecate Strait. Thus, the hydrocarbon exploration target (the Queen Charlotte Basin) is underlain by the potentially petroliferous strata exposed onshore within the Queen Charlotte Islands (Woodsworth, 1988; Thompson et al., 1991), and the relevance of onshore studies as an aid to hydrocarbon exploration increased. A second important discovery was that the Queen Charlotte Islands likely were not dominated by strike-slip tectonic styles as proposed in earlier models (Yorath and Chase, 1981; Yorath and Hyndman, 1983); instead, a tectonic history with multiple episodes of shortening and extension was revealed. The tectonic history of the Queen Charlotte Islands was thus more complex than many had heretofore envisioned.

1.3 Geologic Setting

The Queen Charlotte Islands lie along the west coast of North America, within the Insular Belt of the Canadian Cordillera (Figure 1.1). These islands are within the known extent of Wrangellia, an allochthonous terrane which has been identified from Oregon (Vallier, 1977) to Alaska (Smith and MacKevett, 1970). The western margin of Wrangellia is defined by the Queen Charlotte Fault, the plate boundary between the North American and Pacific plates (Chase et al., 1975); the eastern margin is now placed somewhere, as yet undefined, east of Hecate Strait (Woodsworth, 1988).

Strata exposed in the Queen Charlotte Islands range in age from Permian and possibly Carboniferous (Hesthammer et al., 1991) to Tertiary. They have been divided by many workers into four tectonostratigraphic sequences (Thompson et al, 1991; Lewis and Ross, 1991). The first comprises Paleozoic strata, Upper Triassic volcanic rocks of the Karmutsen Formation, and Upper Triassic and lower Middle Jurassic rocks of the Kunga and Maude groups. The second comprises arc-related volcanic rocks and derivative sedimentary rocks of the Middle Jurassic Yakoun and Moresby groups. Upper Jurassic to Cretaceous sedimentary rocks of the Longarm Formation and the Queen Charlotte Group represent a diachronous transgressive marine sequence, the third tectonostratigraphic division. Tertiary volcanic rocks and sedimentary rocks, the fourth sequence, cap the stratigraphic column. Three plutonic suites exist in the Queen Charlotte Islands: the Jurassic Burnaby Island plutonic suite, the Jurassic San Christoval plutonic suite, and the Tertiary Kano plutonic suite (Anderson and Greig, 1989); the latter two suites are found within central Moresby Island. Units making up the major stratigraphic divisions are more completely discussed in the stratigraphy section, chapter 2, of this study.

Structural studies based on both regional and detailed mapping, an important part of the Frontier Geoscience Program, defined four major episodes of deformation in the Queen Charlotte Islands. The oldest recognizable structures were formed during Middle Jurassic southwest-directed shortening, and include abundant folds and contractional faults (Lewis and Ross, 1991; Thompson et al., 1991). Late Jurassic through Early Cretaceous time was characterized by block faulting which resulted in differential preservation of Mesozoic strata (Thompson and Thorkelson, 1989; Thompson et al.,1991). In Late Cretaceous to early Tertiary time, a contractional folding event resulted in megascopic folds and faults in the Cretaceous strata (Indrelid, 1990;

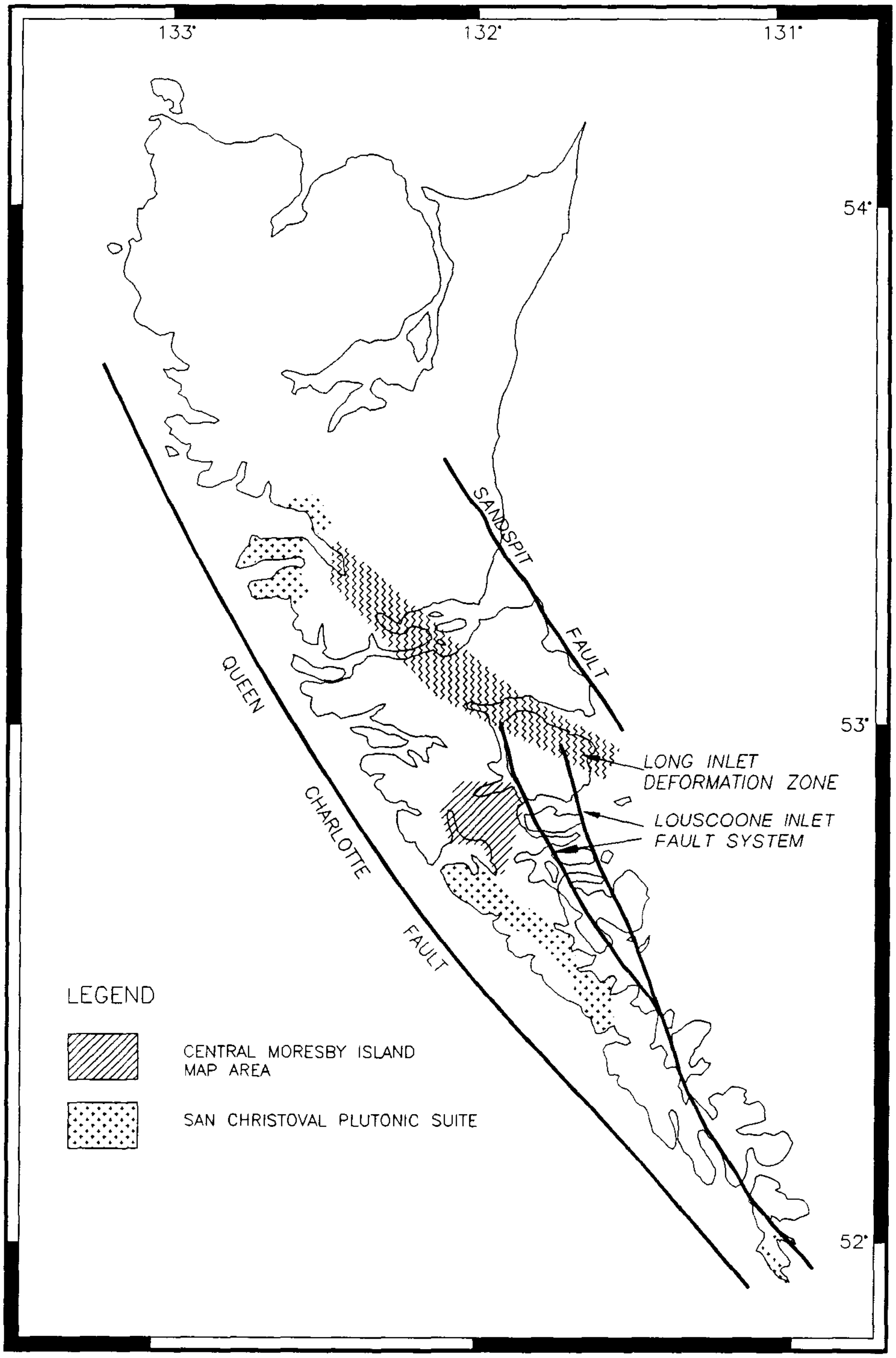

Figure 1.2: *Major tectonic elements of the Queen Charlotte Islands.*

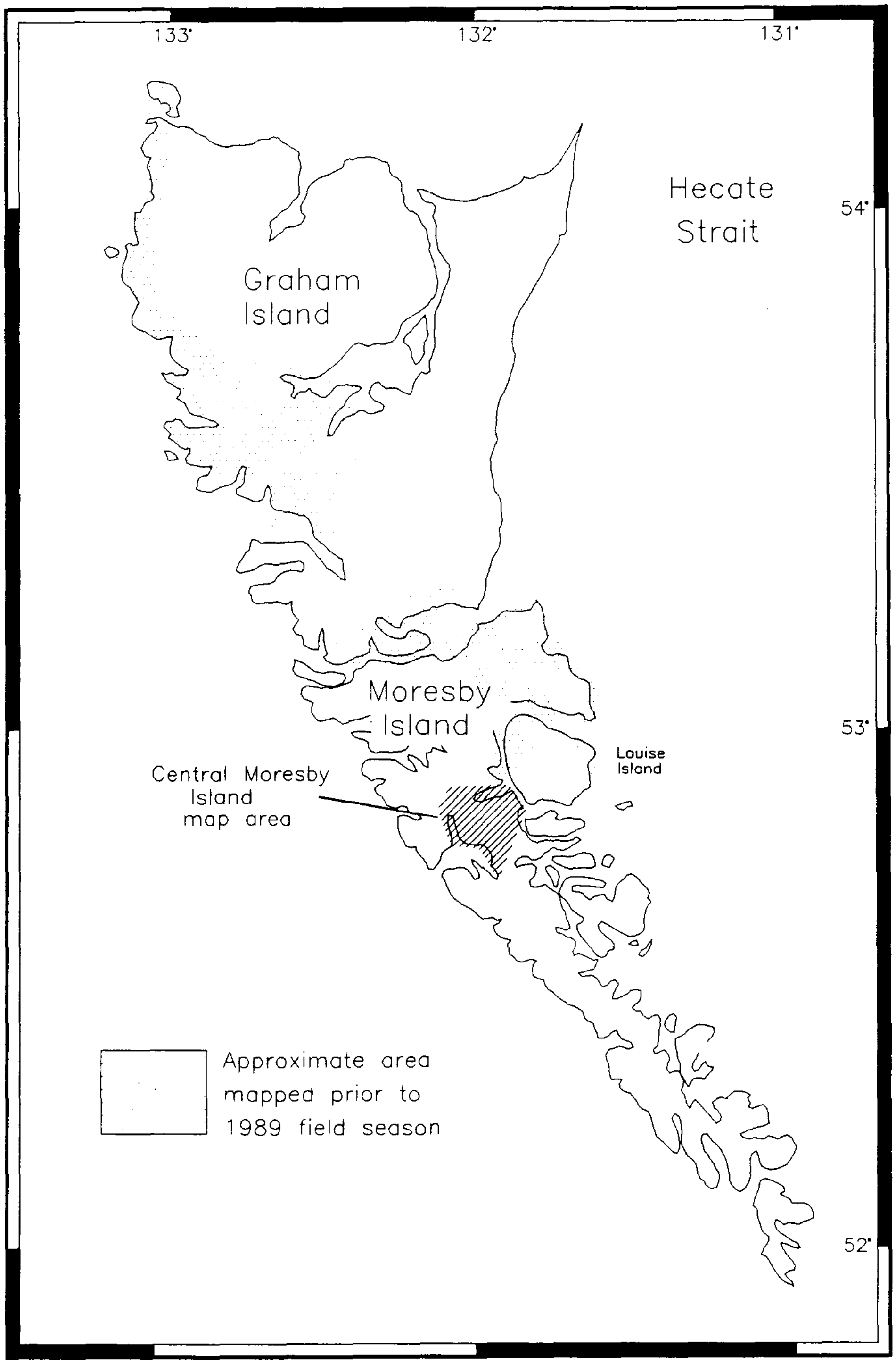

Figure 1.3: *Mapping coverage produced by Frontier Geoscience Program workers prior to the 1989 field season.*

Thompson et al., 1991). In the late Tertiary extensional and strike-slip faulting was the dominant tectonic style, and was synchronous with the formation of the Queen Charlotte Basin, (Lewis, 1991a).

Several major tectonic and geologic elements of the Queen Charlotte Islands have undoubtedly influenced the geologic evolution of the central Moresby Island region (Figure 1.2). The Long Inlet deformation zone is a zone of intense Middle Jurassic through Tertiary deformation which trends north-northwest approximately ten kilometres north of the study area (Lewis, 1991b). The Louscoone Inlet fault system, the subject of recent detailed work by Lewis (1991a), is a complex zone coupling a strike-slip fault system with an area of asymmetric extension, and likely was active synchronously with Tertiary extension in Hecate Strait. Strands of the Louscoone Inlet fault system occur along the eastern boundary of the central Moresby Island study area. The San Christoval plutonic suite is a mountain-forming body of Middle Jurassic plutonic rocks which lies southwest of the study area. The plate bounding Queen Charlotte Fault is presently active as a dextral oblique-slip fault, and is situated ten kilometres offshore Moresby Island, west of the study area. These elements may all have influenced the structural evolution of the central Moresby Island region, and resulted in structural styles in the area unique within the Queen Charlotte Islands. Their influence on the structural evolution of the study area is the subject of the structural synthesis and regional correlation section presented in chapters 4 and 5.

1.4 Objectives and Methods

This study represents the first detailed geologic investigation conducted in the central Moresby Island area, and the initial objectives defined for this study were therefore general. An initial objective was to identify the stratigraphy in central Moresby Island and test the lateral extent of stratigraphic divisions identified on northern Moresby

Island and Graham Island. Another major objective of this study was to further the growing understanding of the structural evolution of the Queen Charlotte Islands, and to test the regional applicability of recent models developed through map studies elsewhere in the islands. To this end, the author spent two field seasons in the area engaged in geological mapping, stratigraphic, and sedimentological studies (Taite, 1990a;1990b; 1991a, 1991b; Gamba et. al, 1990; Haggart et. al, 1991). Thin section analyses were conducted on selected samples, with the aim of describing provenance and lithologies of strata in central Moresby Island, and particular attention was afforded anomalous lithologic occurrences. Specific structural objectives evolved as concurrent studies illuminated different aspects of the tectonic history of the Queen Charlotte Islands, and are discussed in detail in chapter 3.

Preliminary products of this investigation include four Geological Survey of Canada Current Research Papers (Taite, 1990a, 1991a, Gamba et al., 1990; Haggart et al., 1991) which examined different aspects of the geology of central Moresby Island and the Queen Charlotte Islands, and related conference presentations (Taite, 1990c, 1990d). The map produced for this thesis (Plate 1) is a component of the mapping conducted during the Frontier Geoscience Program, and is published as a Geological Survey of Canada Open File Report (Taite, 1991b).

2 STRATIGRAPHY

2.1 Introduction to the Stratigraphic History

Stratigraphic studies within the Queen Charlotte Islands began with Richardson's (1873) examination of the coal-bearing strata in the Skidegate Inlet area. Since then, numerous studies have subsequently refined the understanding of Queen Charlotte Islands stratigraphy. Many geographic names within the Queen Charlotte Islands, such as Dawson, Newcombe, Whiteaves, and Richardson, bear testament to the natural scientists who undertook the initial reconnaissance work.

The stratigraphic nomenclature used in the Queen Charlotte Islands has evolved as successive biostratigraphic and lithostratigraphic studies were completed, and the synthesis of the modern stratigraphic column is largely the result of detailed biostratigraphic control. Evolution of stratigraphic nomenclature up to the inception of the Frontier Geoscience Program is well described by Woodsworth and Tercier (1991). The stratigraphic sequence, as understood at the initiation of this project, is illustrated in figure 2.1. Details of the stratigraphic scheme continue to improve as biostratigraphic studies progress (Jakobs, Palfy, Smith, Tipper, Haggart, personal communications, 1991). Whereas the Triassic – Lower Jurassic nomenclature seems relatively stable (Woodsworth and Tercier, 1991), the nomenclature for both the Middle Jurassic and the Cretaceous strata is in a state of flux (i.e. Haggart et. al., 1991; Hesthammer, 1991, Taite, 1990d). Recent developments in the understanding of these divisions will be discussed in this chapter.

Recent workers in the Queen Charlotte Islands have informally divided the stratigraphic succession into four unconformity bound sequences – a device which facilitates the understanding and description of the sedimentological, igneous, and tectonic history (Thompson et. al, 1991; Lewis and Ross 1991; Taite, 1991a), and which is employed in this study. Strata belonging to these four sequences exposed in the central Moresby Island region range in age from Late Triassic through Tertiary (Figure 2.2). The lowest succession includes Upper Triassic volcanic rocks of the Karmutsen Formation and Upper Triassic to Lower Jurassic sedimentary rocks of the Kunga Group (comprising the Sadler Limestone and Peril and Sandilands formations), and is characteristic of Wrangellian successions (Jones et al., 1977). It is unconformably overlain by volcanic and sedimentary rocks of the Middle Jurassic (Bajocian) Yakoun Group. The Cretaceous clastic rocks of the Longarm Formation and Queen Charlotte Group (including the Haida, Skidegate, and Honna formations) comprise the third succession, and the fourth succession includes volcanic rocks of Tertiary age.

Several units which are present in the Queen Charlotte Islands, and are well exposed on northern Moresby Island and Graham Island, do not occur in the central Moresby Island study area. Late Paleozoic sedimentary rocks, recently identified on northwest Moresby Island (Hesthammer et. al., 1991) do not crop out in the central Moresby Island region, but likely underlie all of the Queen Charlotte Islands. The Lower to Middle Jurassic Maude Group, a sequence of clastic marine sedimentary rocks which conformably overlies the Kunga Group, and the upper Middle Jurassic Moresby Group sedimentary strata are also absent in the study area. In addition, the upper age limit of the Queen Charlotte Group rocks exposed in central Moresby Island has not been determined; newly identified unnamed sedimentary and volcanic strata of Upper Cretaceous age have been recognized on Graham Island (Haggart et al., 1990) but not in central Moresby Island. Finally, Tertiary sedimentary rocks of the Skonun Formation crop out only in central and northeastern Graham Island.

Two suites of intrusive rocks occur in central Moresby Island. The Middle to Late Jurassic plutonic rocks of the San Christoval plutonic suite crop out extensively southeast of the study area (Figure 1.2), where they form the San Christoval Mountain Range. In the study area, small intrusive bodies related to this suite intrude Kunga Group lithologies east of Newcombe Inlet and Wilson Bay. The second suite of intrusive rocks is Tertiary in age and is locally volumetrically significant. In outcrops east of Wilson Bay and south of Sewell Inlet, they form up to 80% of the rock exposed. They comprise an extensive suite of compositionally heterogeneous dykes, sills, and irregular bodies, and were likely feeders for extensive Tertiary volcanism (Souther, 1988, 1989; Souther and Jessop, 1991)

This chapter summarizes the present understanding of the stratigraphic units present in central Moresby Island. It includes both observations made in the central Moresby Island area as part of the present study, and where necessary for completeness, summaries of lithologic descriptions from elsewhere in the Queen Charlotte Islands. Descriptions pertaining directly to the central Moresby Island study area are products of this investigation exclusively, while those of other workers are referenced accordingly. Some of the stratigraphic analyses completed in this study, particularly those involving the Cretaceous succession, have formed components of previously published discussions (Gamba et al., 1990; Haggart et al., 1991; Taite, 1990a; 1991a).

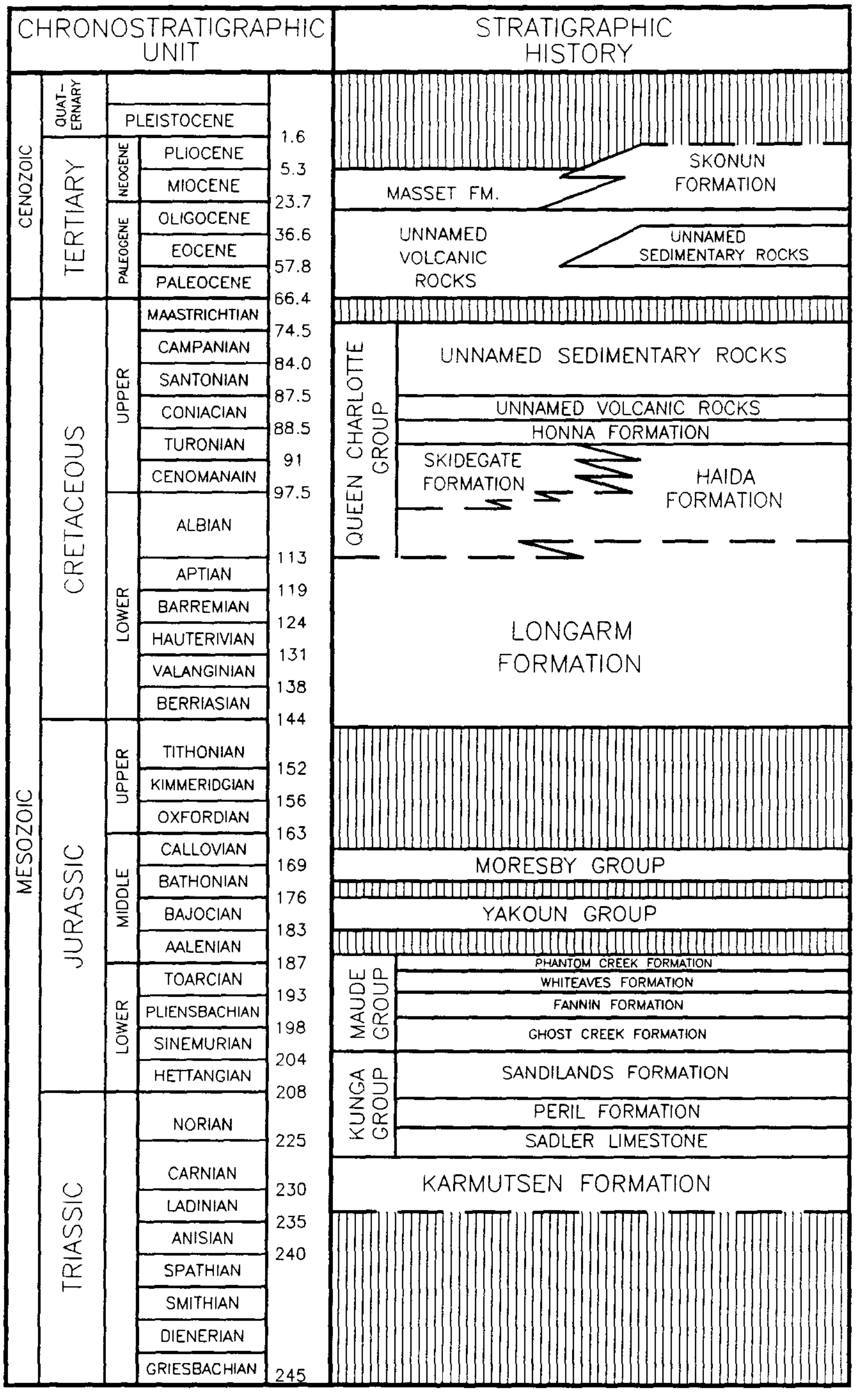

Figure 2.1: *Stratigraphic column outlining ages and contact relationships of the major mappable units of the Queen Charlotte Islands, modified from Lewis and Ross (1991).*

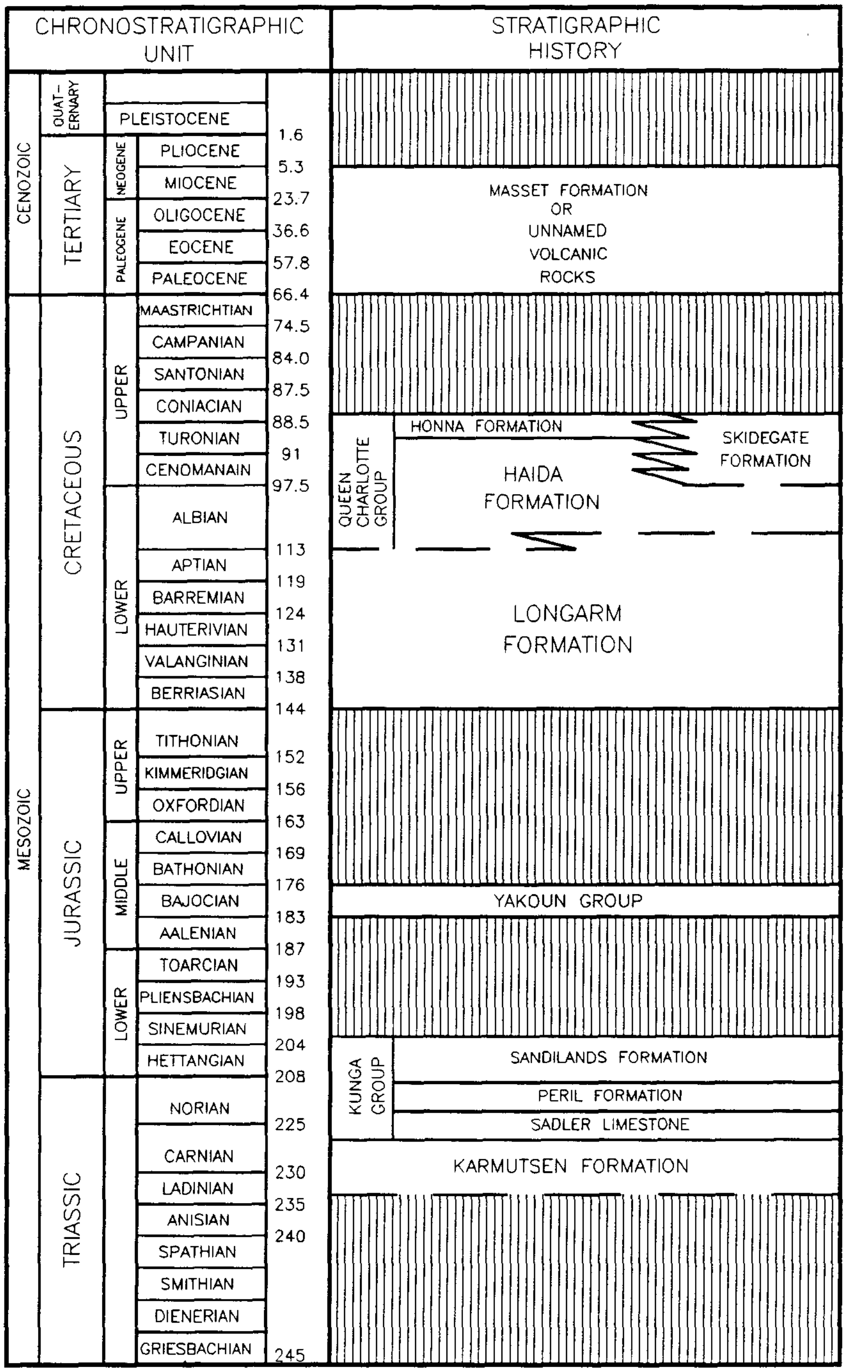

Figure 2.2: *Stratigraphic chart outlining ages and contact relationships of the mappable units occurring in the central Moresby Island area, adapted from Lewis and Ross (1991).*

2.2 The Wrangellian succession: the Upper Triassic to lower Middle Jurassic Karmutsen Formation and Kunga Group

Dawson (1880) recognized the regional correlation between the Triassic and Lower Jurassic volcanic and sedimentary rocks (now known as the Karmutsen Formation and the Kunga Group) of the Queen Charlotte Islands and coeval Vancouver series strata on Vancouver Island. These rocks are now all included within the Wrangellian succession (Coney et al., 1980), and indeed, this succession is characteristic of Wrangellia throughout the Cordillera: Jones et al. (1977) define the unifying Wrangellian characteristics as Upper Triassic basalts overlain by calcareous sedimentary rocks whose deposition commenced during late Carnian to Norian time. Both the Karmutsen Formation and the Kunga Group, along with the Maude Group and the Yakoun Group, were previously included in the Vancouver Group (Sutherland Brown, 1968), a term now fallen from common usage (Cameron and Tipper, 1985).

2.3.1 The Karmutsen Formation

The lowest unit exposed in the central Moresby Island region is the Upper Triassic Karmutsen Formation. Named by Gunning (1932) for its type location in the Karmutsen Range of northern Vancouver Island, this distinctive volcanic unit is widespread throughout the Insular Belt. The Karmutsen Formation is best exposed in central Moresby Island to the north and west of Newcombe Inlet, and to the northeast of Barrier Bay. The lack of continuous outcrop in the study area, due to irregular exposure and structural complication, precludes the construction of a stratigraphic column for the Karmutsen Formation. The aggregate thickness of this unit is estimated by Sutherland Brown (1968) to exceed 4,200 metres.

The Karmutsen Formation comprises a suite of basaltic rocks of Late Triassic age that accumulated in a subaqueous environment (Sutherland Brown, 1968). This unit is commonly green to black in outcrop, often with a brown to rusty weathering rind. Sutherland Brown (1968, page 41) described several different lithologic types in this unit, three of which have been identified in central Moresby Island: a massive flow lithology, pillow lavas and breccias, and a glomeroporphyry lithology. Figure 2.3 shows the distribution of these lithologies in the map area; the lithotype shown on this diagram represents the dominant lithology in outcrop, but other lithotypes may be interlayered.

The most common lithotype of the Karmutsen Formation exposed in central Moresby Island is the massive flow lithology (Figure 2.4). Amygdule-rich layers often define primary layering in outcrop, otherwise this unit is featureless. Pillow basalt and pillow breccia lithotypes occur northeast of Newcombe Inlet. Pillows range in size from tens of centimetres to several metres; average pillows are approximately one metre in length, and ellipsoidal. Pillow breccias consist of resistant pillow fragments in a monolithic matrix. The glomeroporphyry (colloquially the "star porphyry" of Sutherland Brown, 1968; p. 68) is the least common lithology in outcrop, and is defined by the presence of radial clusters of plagioclase feldspar laths greater than one centimetre in length. Sutherland Brown (1968) notes that this lithology occurs approximately 60 − 150 metres below the top of the Karmutsen Formation elsewhere in the islands. A pervasive foliation is locally developed in outcrop where the Karmutsen Formation occurs in fault zones, and is defined by the parallel preferred orientation of platy minerals (chlorite).

All Karmutsen Formation samples show pervasive alteration in thin section. The glomeroporphyry lithotype exhibits chlorite pseudomorphs partially replacing 0.5 centimetre pyroxene phenocrysts (pigeonite). Two populations of feldspars exist −

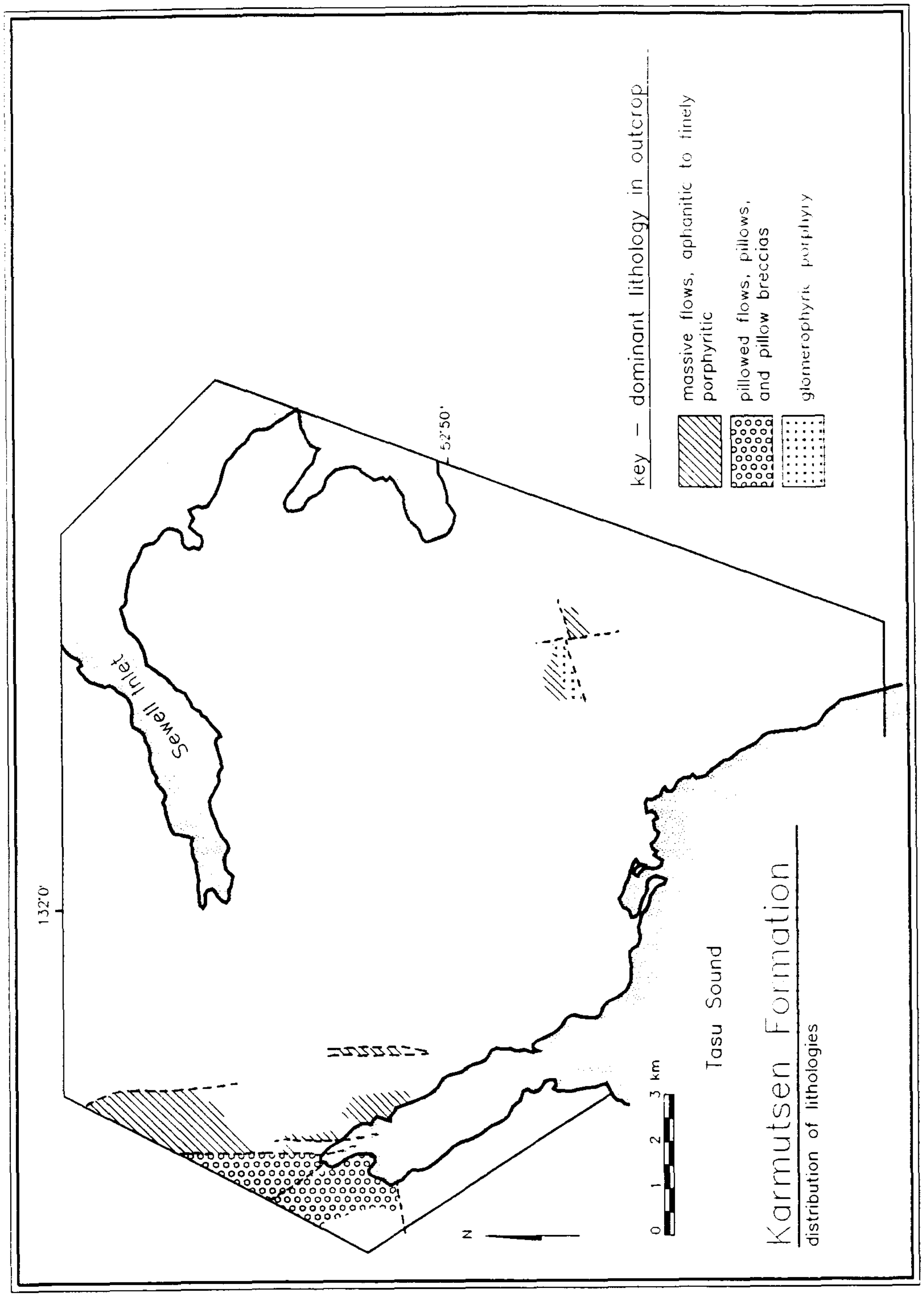

Figure 2.3: *Map of central Moresby Island area illustrating the distribution of Karmutsen Formation lithologies in outcrop. Major faults affecting outcrop distribution are indicated by dashed lines.*

larger (1-2 centimetre) laths of oligoclase in radiating clusters, and a second generation of microphenocrysts (<0.5 millimetre), that along with chloritized pyroxene, form the matrix. Both plagioclase types have been altered to clays or sericite (Figure 2.5). The massive, pillow flow, and breccia lithologies exhibit similar petrographic characteristics, with a single population of feldspar and chloritized pyroxene microphenocrysts forming sub-ophitic to intersertal texture.

2.3.2 The Kunga Group

The Kunga Group comprises three formations, the Upper Carnian to Norian Sadler Limestone, the Norian Peril Formation, and the Norian to Pliensbachian Sandilands Formation. Estimates of stratigraphic thickness for the Kunga Group units have been attempted by Desrochers and Orchard (1991) with their disclaimer that complete sections have been constructed from dismembered and fault-bound exposures using biostratigraphic markers for correlation. In addition, these units may vary widely in thickness throughout their regional extent; the Sadler Formation ranges from 42 to 200 metres in several different sections examined by Desrochers and Orchard (1991). The Peril Formation is approximately 350 metres thick, and the Sandilands Formation has an estimated aggregate thickness of approximately 500 metres (Desrochers and Orchard, 1991). Structural disruption and lack of biostratigraphic control thwarted attempts to estimate original stratigraphic thicknesses in the central Moresby Island area.

Sadler Limestone

The Sadler Limestone is a massive to thickly-bedded grey limestone of Late Carnian age, which conformably overlies the Karmutsen Formation. At its basal contact, thin grey limestone beds and lenses are interstratified with the top volcanic layers of the

Figure 2.4: *Massive volcanic flows of the Karmutsen Formation, northwest of Newcombe Inlet. This lithology is the dominant rock type in outcrop, and is distinguished by its lack of stratification, pervasive alteration to chlorite, and its irregular fracturing in outcrop.*

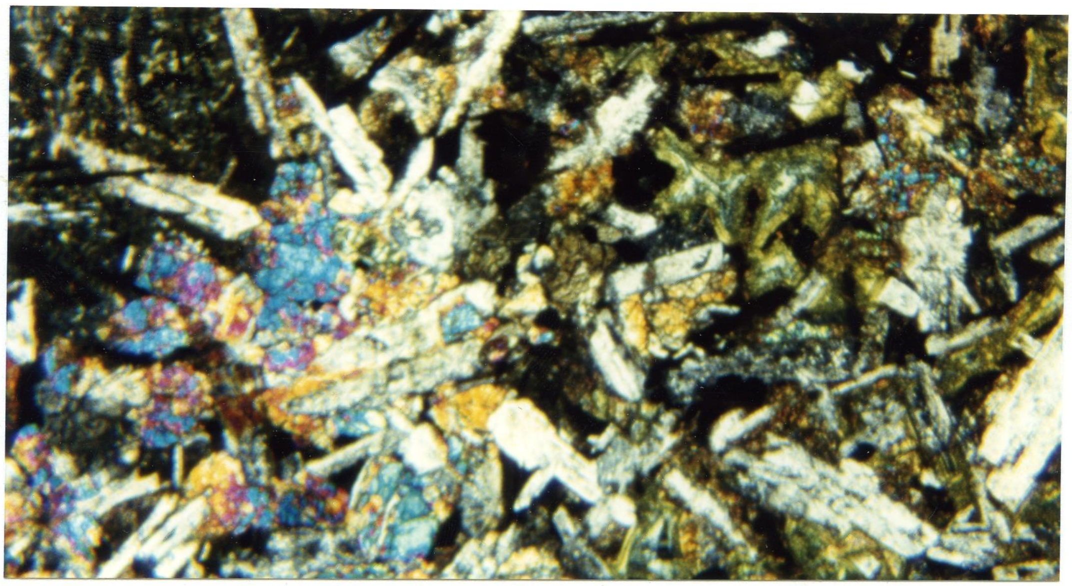

Figure 2.5: *Photomicrograph of the glomeroporphyry lithology of the Karmutsen Formation illustrating subophitic intergrowth of plagioclase and pyroxene. Pyroxene is partially altered to chlorite, and plagioclase is altered to clay minerals. Field of view is approximately 4 mm left to right.*

Karmutsen Formation, representing the last pulses of Karmutsen volcanism and the onset of carbonate sedimentation. Conodonts derived from these interbeds are also Late Carnian (Desrochers and Orchard, 1991). The Sadler Limestone comprises three distinct lithotypes: 1) lime mudstone to peloidal wackestone; 2) bioclastic wackestone to packstone; and 3) oolitic calcarenite (Desrochers and Orchard, 1991). The first lithotype is common in the central Moresby Island region, the second occurs rarely, and the third lithotype was not observed.

The lime mudstone is distinctive in outcrop; on hill slopes it exhibits aesthetic karst formation (Figure 2.6), whereas in shoreline exposures it weathers to sharp irregular peaks (dog-tooth weathering) several centimetres high. It is generally light grey on both fresh and weathered surfaces, except for rare rust coloured staining, or thick black algal coatings which are ubiquitous on intertidal exposures. Bioclastic fragments include corals and crinoid fragments, which weather resistantly relative to the matrix, and are readily observable in outcrop. Thin sections reveal echinoderm, chert and crinoid fragments, and abundant sparry calcite cement. This unit has abundant stylolitic surfaces, usually parallel to bedding planes, with "teeth" reaching five centimetres (Figure 2.8). Pervasively developed veins are randomly oriented in outcrop, and are filled with both fibrous and blocky calcite. This lithology often appears recrystallized in handsample and thin section. Outcrops containing wollastonite are found southwest of Pacofi Bay (Figure 2.9).

Peril Formation

The Peril Formation is characterized by thinly-bedded (3-15 centimetres thick) calcareous argillite layers (Figure 2.10). The age of this unit is Upper Carnian to Upper Norian on the basis of abundant *Monotis* coquinas and rare ammonites (*Discotropites*;

Figure 2.6: *Sadler Limestone shows typical karst weathering. Light grey weathering, rounded outcrops, extensive veining and massive character are all diagnostic of this unit. Field assistant is approximately 0.5 m tall.*

Figure 2.7: *Bedding parallel stylolites in Sadler Limestone. Planar calcite veins are perpendicular to stylolites in this and other outcrops.*

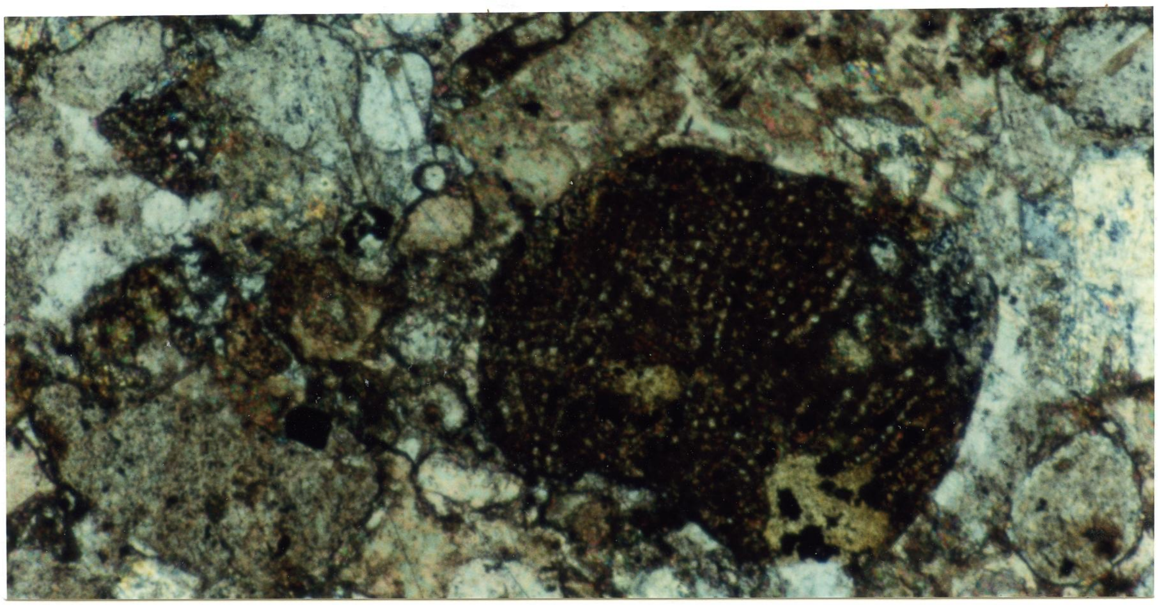

Figure 2.8: *Photomicrograph of the Sadler Limestone illustrating bioclastic echinoderm fragments . Note the rounding of the carbonate clasts. Field of view is 4 mm left to right.*

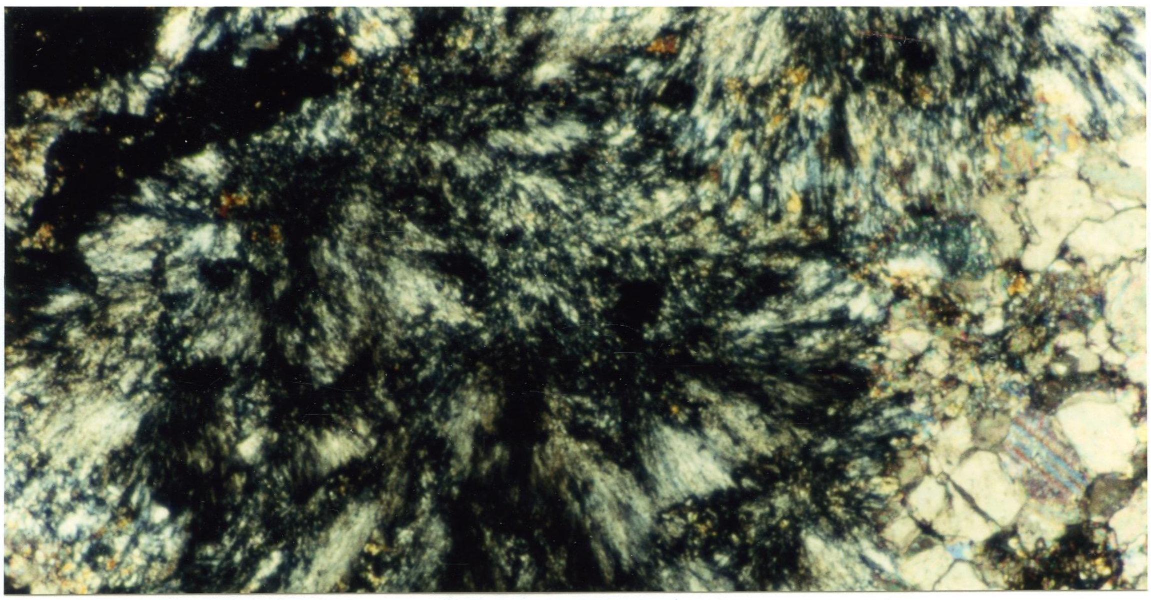

Figure 2.9: *Photomicrograph of Sadler Limestone illustrating radiating wollastonite (?) crystals. Wollastonite is uncommon and occurs in altered rocks adjacent to intrusions. Field of view is 4 mm left to right .*

Dr. E. T. Tozer, personal communication, 1991). The Sadler Limestone – Peril Formation contact is conformable and grades over several metres from thickly-bedded (<1 metre) grey limestones through successively thinner and more argillaceous beds (Figure 2.11). In outcrop, this unit is black, very fine grained, and thinly bedded, with rare white weathering silty to sandy layers. On wave cut benches, it occasionally weathers recessively along bedding planes, leaving free standing 'plates' exposed.

Desrochers and Orchard (1991) describe five lithofacies within the Peril formation: 1) radiolarian rich calcilutite – periplatform ooze; 2) laminated calcarenites – calciturbidites; 3) pelecypod coquinas (*Monotis* and *Halobia*) – pelagic limestone; 4) intraformational conglomerates; and 5) pelmatozoan calcarenites. Within the central Moresby Island region, the most common lithofacies is the calcilutite interbedded with ubiquitous pelecypod coquinas – these coquinas are commonly diagnostic of the Peril Formation. Graded beds of the laminated calcarenites (calciturbidites) are rarely observed – the coarse clastic component in rare Bouma Ta-e and Ta-c sequences consists of silt-sized particles which weather as thin white bands in outcrop. Intraformational conglomerates were not observed in the central Moresby Island area. The pelmatozoan calcarenite occurs sparsely west of Newcombe Inlet, where it generally forms 5 to 15 centimetre thick beds interbedded with calcilutites and pelecypod coquinas. In one outcrop, bedding in this unit is considerably thicker (>1 metre thick), and contain 10 to 20 centimetre concretions (Figure 2.12). Thin section examination of this lithology reveals calcareous bioclastic echinoid plate fragments, pelecypod valve fragments, monocrystalline quartz grains, and abundant plagioclase feldspar. The plagioclase occurs as both angular single crystals, and as phenocrysts in rounded trachytic clasts (Figure 2.13).

***Figure 2.10:** Typical thinly-bedded calcareous argillite of the Peril Formation, northeast of Newcombe Inlet. .*

***Figure 2.11:** Gradational contact between Sadler Limestone (left) and Peril Formation, east side of Newcombe Inlet. Contact typically grades over two to five metres from thickly-bedded grey limestone to thinly-bedded calcareous argillite.*

Figure 2.12: *Pelmetazoan calcarenite lithology of the Peril Formation, Newcombe Inlet. This lithology is common in the study area as thin beds within the calcareous argillite, but only rarely is thickly bedded.*

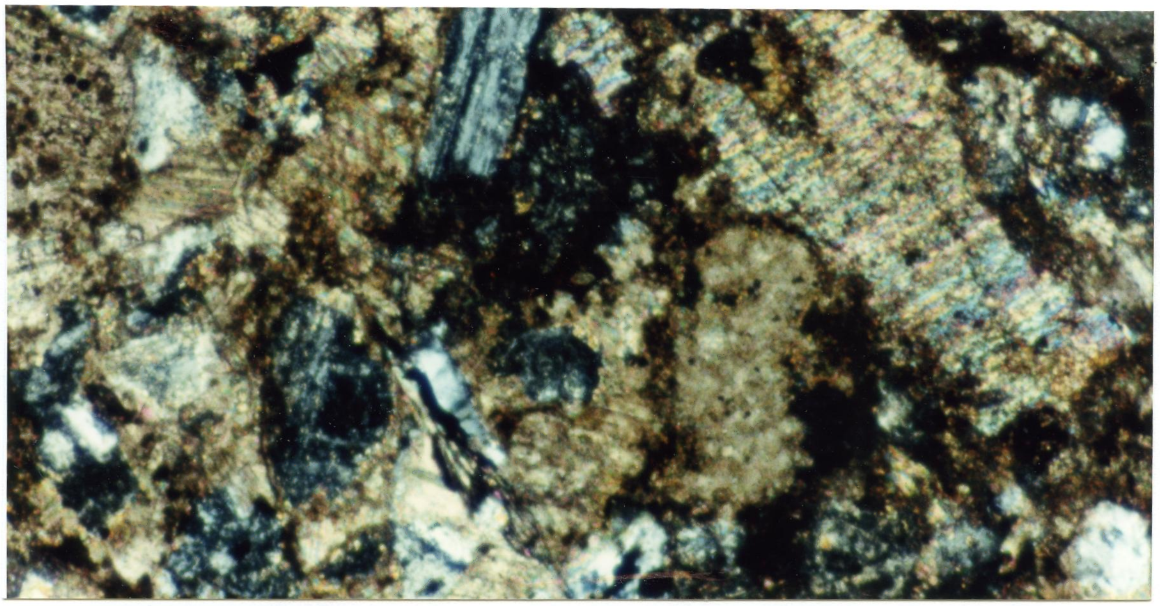

Figure 2.13: *Photomicrograph of Peril Formation showing bioclastic carbonate fragments and plagioclase crystals. Field of view is 4 mm left to right.*

Sandilands Formation

The Sandilands Formation is the Norian to Sinemurian black argillite member of the Kunga Group which conformably overlies the Peril Formation. The contact is gradational and is arbitrarily drawn by Desrochers and Orchard (1991) at the highest *Monotis*-bearing horizon. This level also corresponds to the first appearances of colourful green, white, buff, and grey tuffaceous layers. The dominant lithology in the Sandilands Formation is thinly-bedded siliceous siltstone and tuffaceous shale. This unit has not been subdivided into other lithologic members, but several distinctive lithotypes occur in central Moresby Island. Massive sandstones are noted at the base of the formation on Graham Island (Hesthammer, 1991) and occur west of Newcombe Inlet in central Moresby Island, where massive greywacke layers greater than ten metres thick crop out (Taite, 1990a). The most common lithology in central Moresby Island, and in the Queen Charlotte Islands in general, is the thinly-bedded black argillite and interbedded tuff (Figure 2.14).

The Sandilands Formation is commonly intensely folded and faulted in outcrop. It has a distinctive banded appearance, which is accentuated in intertidal exposures. This unit is well indurated, but has good bedding plane fissility. It fractures into angular blocks on joint sets oriented perpendicular to bedding. In the sandy to silty layers, fining upwards sequences are often present. Euhedral pyrite cubes and clusters of framboidal pyrite are distributed throughout the unit. Near fault zones, and zones of abundant intrusions, the Sandilands Formation appears as bleached green and white bands, seen in thin section as pervasive silicification, or less commonly as carbonate replacing quartz. In these hydrothermally altered exposures, all bedding plane fissility is lost.

Figure 2.14: *Typical thinly-bedded argillites and tuffs of the Sandilands Formation west of Newcombe Inlet. Blocky fracturing and alternating light and dark banding is diagnostic.*

Figure 2.15: *Greywacke lithofacies of the Sandilands Formation, beds are one-half metre thick, east of Two Mountain Bay.*

The Sandilands Formation is highly fossiliferous, with abundant and diverse ammonite faunas appearing throughout the section as bedding plane molds or casts. These faunas have been the subject of detailed examination (Palfy, 1991). Palfy identified different species of *Arnioceras, Paltechioceras*, and *Juraphyllites*; the presence of *Paltechioceras* indicates the uppermost Sinemurian stage is represented (Palfy, 1991).

In thin section, the silty layers contain abundant trachytic volcanic rock fragments, which appear as altered plagioclase laths in a chloritic groundmass. Euhedral plagioclase laths are present and they have been partially to completely altered to clay. Rare chert fragments, and recrystallized quartz or calcified radiolarian spheres, and mono- and polycrystalline quartz grains are also present. The matrix is composed of clays with variable birefringence, and authigenic chlorite, formed through the diagenesis of clays.

Anomalous outcrops of bedded greywackes and lithic arenites have been identified in central Moresby Island. These rocks do not resemble the typical Sandilands Formation lithologies, but their age and stratigraphic position place them within the middle part of that formation. They appear as thickly-bedded (on the metre scale), blocky, and conchoidally fractured siltstones and sandstones (Figure 2.15). Abundant fossils are found in this lithology, including ornamented gastropods, corals, belemnites, and rare three-dimensionally preserved ammonite casts. Fossils are all preserved randomly throughout the rock volume, represent both shallow and deeper water forms, and do not occur as bedding plane 'prints', suggesting deposition was the result of mass sediment movement.

Thin sections of this facies show moderate to good sorting, with angular to subangular clasts. Plagioclase (oligoclase) occurs in volcanic rock fragments, and as euhedral laths. Mono- and polycrystalline quartz fragments are present, as are bioclastic carbonate fragments. K-feldspar occurs as rare angular crystals. Matrix, and pore lining and filling authigenic chlorite is abundant. Iron carbonates, opaque minerals, and organic matter are a minor constituent; organic matter is preserved along 'microstyllolitic' surfaces. There is a small detrital clay component to this unit, relative to typical Sandilands Formation units. Echinoderm fragments and shell fragments are found commonly in impersistent, discrete layers. The rocks in this lithofacies are classified as lithic wackes to lithic and bioclastic lithic arenites (Figure 2.16).

2.3.3 Depositional Environments

Rocks of the Triassic to Middle Jurassic Karmutsen Formation accumulated in a variety of depositional environments. Geochemical data presented by Andrews and Godwin (1989) suggest the Karmutsen Formation basalts of Vancouver Island originated in a back arc rift environment, and an analogous origin for the correlative units in the Queen Charlotte Islands is likely. Carbonate sedimentation of the Sadler Limestone commenced in Late Carnian time (Desrochers and Orchard, 1991) on a widespread volcanic platform. During this time, open marine conditions prevailed, and shallow water depth is consistent the lithologic characteristics and with supporting coral and crinoid fauna. Desrochers and Orchard (1991) indicate depositional environments included sand shoals, which resulted in the oolitic calcarenite facies; this lithotype was not observed in central Moresby Island, and was likely local in extent. During the Late Carnian, the rapidly rising sea level resulted in the deposition of deeper water slope to basin carbonates. The presence of plagioclase crystals and trachytic volcanic rock fragments in the Peril Formation is indicative of a distal volcanic source during Carnian to Norian time.

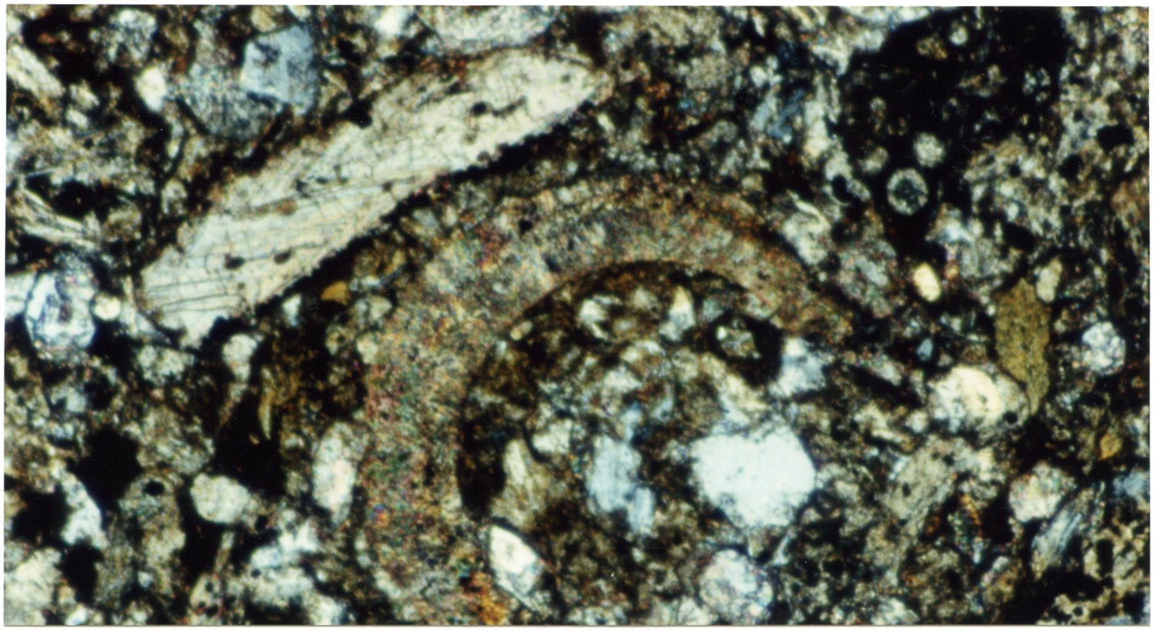

Figure 2.16: *Photomicrograph of Sandilands Formation greywacke lithofacies, with curved gastropod shell fragment . Field of view is 4 mm left to right.*

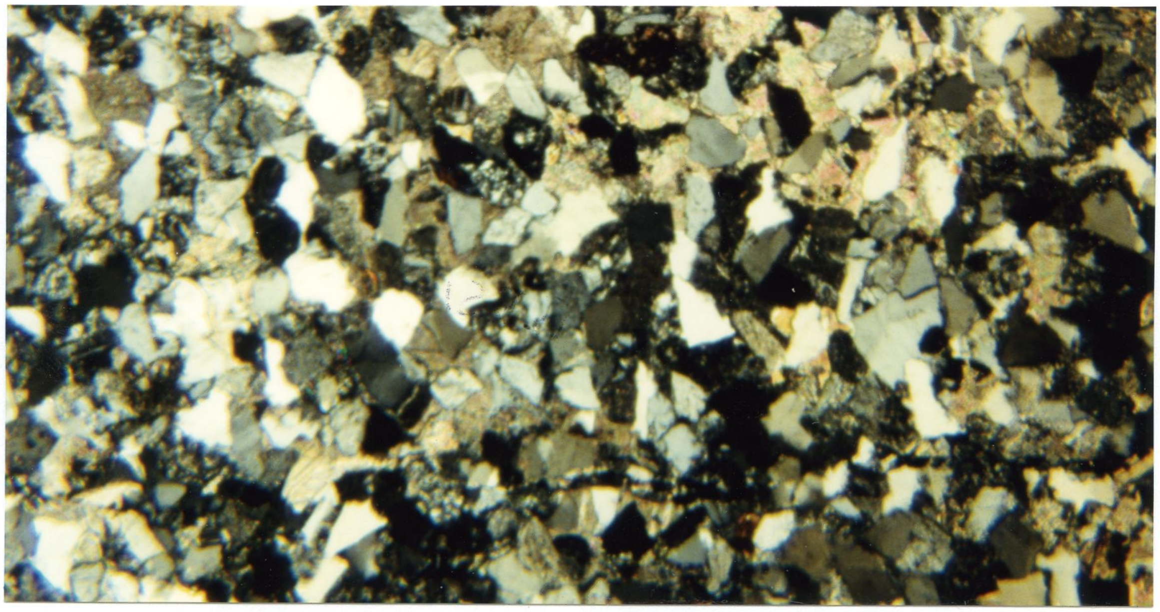

Figure 2.16b: *Photomicrograph of a quartz-rich layer within the Sandilands Formation. This lithology is only documented in the central Moresby Island area. Field of view is 4 mm left to right.*

Carbonate sedimentation ended with the drowning of the carbonate platforms in the Late Triassic to Early Jurassic, and terrigenous Sandilands Formation deposition commenced. The distal turbidites were deposited in a largely euxinic basin; brief periods of oxygenation are evidenced by rare *Chondrites* feeding traces (Palfy, 1991). The presence of the greywacke and lithic arenite facies in the central Moresby Island are indicative of a more proximal terrigenous influence; the faunal assemblage preserved, and the sorting and provenance of the clasts are independent lines of evidence supporting transport in a fluid gravity flow. These sediments may have been deposited at the base of a submarine canyon, where massive influxes of volcanic detritus would result in an unstable sediment source. Subsequent mass movement by fluid gravity flow would transport both volcanogenic sediments and the shallower marine fauna into the basin. A source for the volcanic detritus has not been demonstrated, but the coarser sands are indicative of deposition in a shallow marine near shore environment.

Sandilands Formation deposition ended in Sinemurian to Pliensbachian time, and deposition of the conformable units of the Maude Group commenced (Tipper et al., 1991). The Sandilands Formation - Maude Group contact is diachronous and spans Sinemurian to Pliensbachian time (Palfy, 1991). The Maude Group is thought to represent two successive transgressive-regressive episodes of deposition with a greater terrigenous influence (Palfy 1991). The Maude Group has not been identified in central Moresby Island, and the closest known occurrence is on the east coast of Louise Island (Jakobs, 1989). Whether this is the result of a depositional hiatus or of subsequent erosion of this unit is unclear; however, Jacobs (1990) notes the presence of local depositional breaks at the Louise Island location, and hypothesizes a paleotopographic high may have existed in the southern Queen Charlotte Islands at the time of Maude Group deposition (Tipper et al. 1991).

2.4 Arc Volcanism: the Middle Jurassic (Bajocian) Yakoun Group

The Yakoun Group is composed of predominantly pyroclastic andesitic rocks and derivative epiclastic sedimentary rocks. First described by Dawson (1880), this unit has a complex history of stratigraphic and nomenclatural revision, which is outlined by Woodsworth and Tercier (1991). The latest work before the advent of the Frontier Geoscience Program mapping was that of Cameron and Tipper (1985), where the unit was elevated to group status. The age of the unit is constrained by molluscan fauna to Early Bajocian by Cameron and Tipper (1985), who treated the group as comprising two distinct formations; the predominantly volcanic Richardson Bay Formation, and the clastic Graham Island Formation, based on stratigraphic sections within the central Graham Island area.

Initial Frontier Geoscience Program mapping brought into question the stratigraphic and regional significance of these formational divisions. As a result, mappers of the Frontier Geoscience Program individually devised their own stratigraphic schemes, based on the lithostratigaphy within their respective study areas (Haggart, 1991b, Hesthammer, 1991a, 1991b). The thickness of the Yakoun Group varies widely, due to variations in both initial depositional thickness, and subsequent preservation.

2.4.1 Yakoun Group rocks in central Moresby Island

Within central Moresby Island, four lithostratigraphic divisions occur within the Yakoun Group: 1) lapilli tuff and interstratified tuff and epiclastic sedimentary rocks, 2) debris flow and lahar deposits, 3) conglomerate and sandstone, and 4) shale and siltstone. No stratigraphic sequence for these divisions has been determined. Slight differences exist between these arbitrarily assigned divisions, and those proposed in the new stratigraphic scheme by Hesthammer (1991) for central Graham Island. The shale and tuff lithologies are interstratified in the central Graham Island area, and were assigned to a single unit, whereas in the central Moresby Island, they are seldom associated. Conglomerates within central Moresby Island are not volumetrically significant, and are always interbedded with sandstones; on central Graham Island these lithologies form a significant facies on their own. In addition, the volcanic lithofacies of Hesthammer (1991) includes volcanic flows, which are not documented on central Moresby Island. Figure 2.17 illustrates the distribution of Yakoun Group lithotypes in central Moresby Island; the lithology shown is the one dominant in outcrop, but other lithologies may occur as minor components.

Thin section analyses of Yakoun Group rocks reveal several characteristics common to all lithofacies. Trachytic volcanic rock fragments contain common plagioclase phenocrysts altered to clay, and minor highly-altered mafic phenocrysts. Alteration products include abundant chlorite replacing mafic crystals, and chlorite in the matrix as a replacement product and a pore filling phase. Carbonate cement is common to all lithofacies. Secondary pyrite and associated sulfide minerals with both framboidal and cubic habits are found in all lithofacies. In epiclastic sedimentary rocks, clasts are almost exclusively volcanic rock fragments, with chlorite and other clays forming the matrix.

Lapilli tuffs and interstratified sedimentary rocks

This lithofacies occurs in all outcrops of Yakoun Group rocks in the study area, and forms significant deposits northeast of Wilson Bay. There are two major subdivisions within this unit, an unstratified lapilli tuff, and interstratified tuff and sedimentary

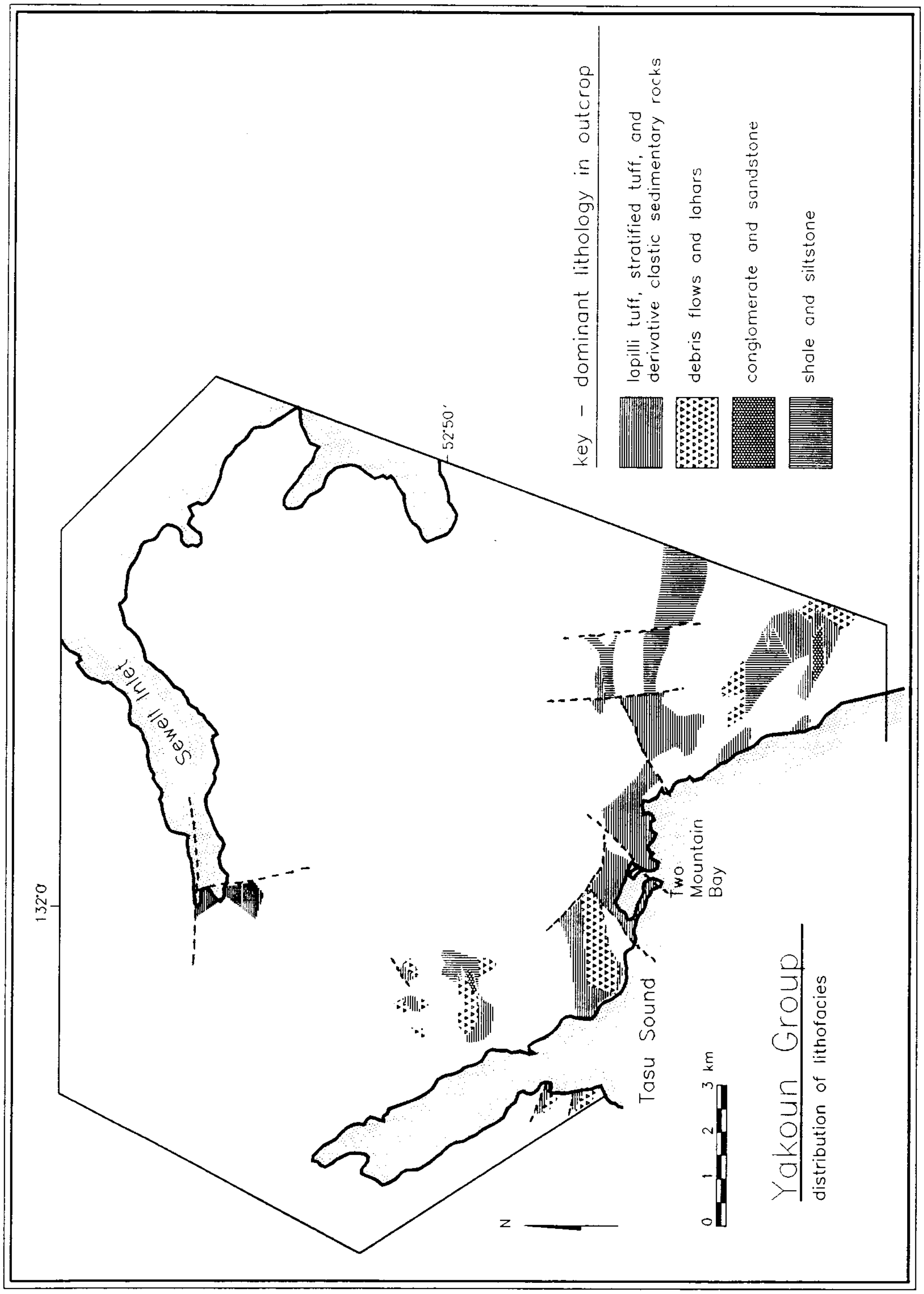

Figure 2.17: *Map illustrating the distribution of the Yakoun Group lithotypes. Major faults affecting lithotype distribution are illustrated by dashed lines.*

rock layers. Lapilli and tuffaceous ash range in size from less than one millimetre to several millimetres, discrete clasts are composed of accretionary lapilli formed of agglutinated ash particles. Vesicular blocks up to ten centimetres across occur rarely (Figure 2.18). This unit exhibits a characteristic green colour on weathered surfaces with whits calcite or zeolite (rare) interstitial cement. Interstratified lapilli tuff - sedimentary rocks grade upwards through repeated sections of accretionary lapilli, sandstones, siltstones, and shales. All of the clasts in the sedimentary strata are derived from subjacent reworked tuffs. Sedimentary structures observed in this unit include cross bedding, planar laminated bedding, and ripples. Small (less than two centimetre), and rare ammonite casts are preserved in the shale interbeds, indicating marine conditions.

Debris flows and lahars

The debris flow lithofacies is the most common facies preserved in north and northwest of Two Mountain Bay (Figure 2.19). It is characterized by either compositionally intermediate angular volcanic clasts within a monolithologic matrix, or by volcanic clasts and rare angular accidental clasts derived from the subjacent Sandilands Formation in a muddy matrix. Clasts range from granule to boulder size. Most clasts are derived from the unstratified lapilli tuff facies, and lend the outcrops their characteristic green weathering colour. This facies is generally matrix supported, unstratified, and ungraded. Scour surfaces occur where this facies unconformably overlies the Sandilands Formation.

Figure 2.18a: *Poorly sorted, weakly-stratified lapilli tuff lithology of the Yakoun Group, northeast of Two Mountain Bay. Yakoun Group lithology is olive green in fresh exposures, rusty orange on weathered surfaces.*

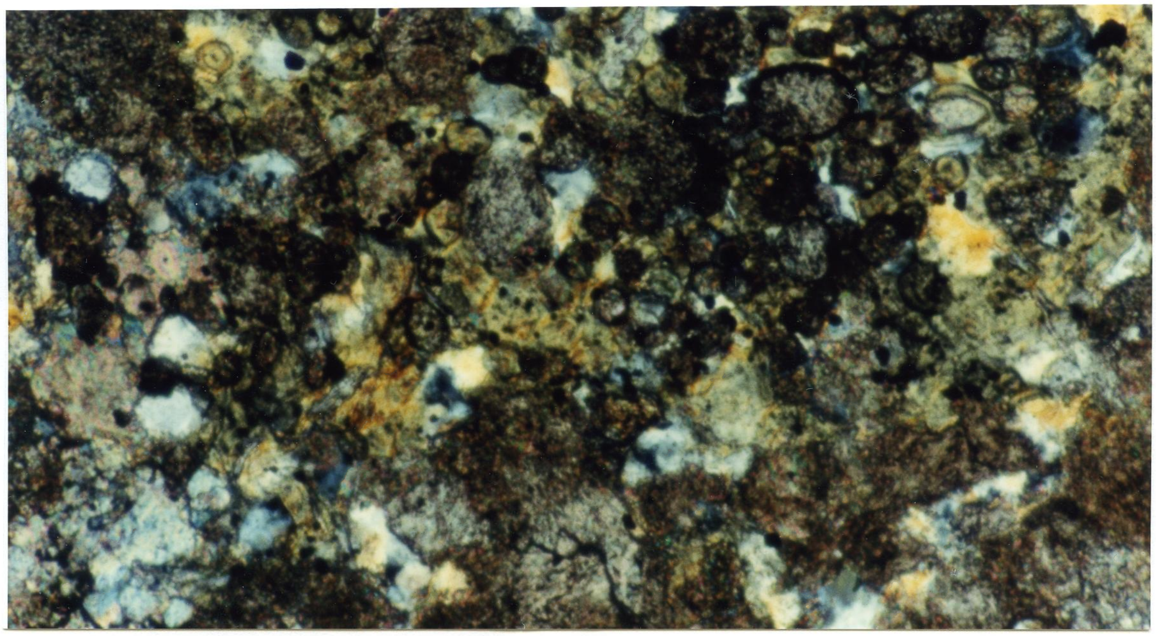

Figure 2.18b: *Photomicrograph of the lapilli tuff lithology of the Yakoun Group. Lapilli illustrated here are accretionary. Field of view is 4 mm left to right.*

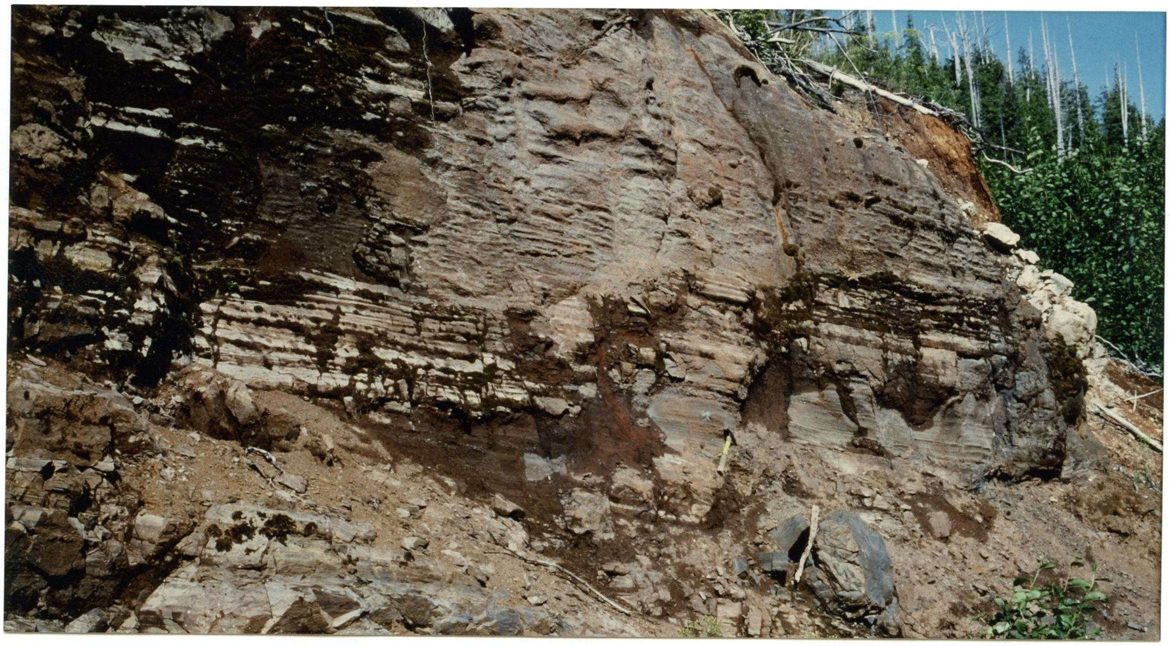

Figure 2.18c: *Well bedded lapilli tuff and epiclastic sedimentary rocks east of Two Mountain Bay.*

Figure 2.18d: *Close up photograph of lapilli tuff and epiclastic sedimentary rock lithology illustrating low angle cross bedding, west of Newcombe Inlet.*

Figure 2.19: *Debris-flow lithology of the Yakoun Group comprises dominantly homogeneous volcanic clasts in light weathering matrix.*

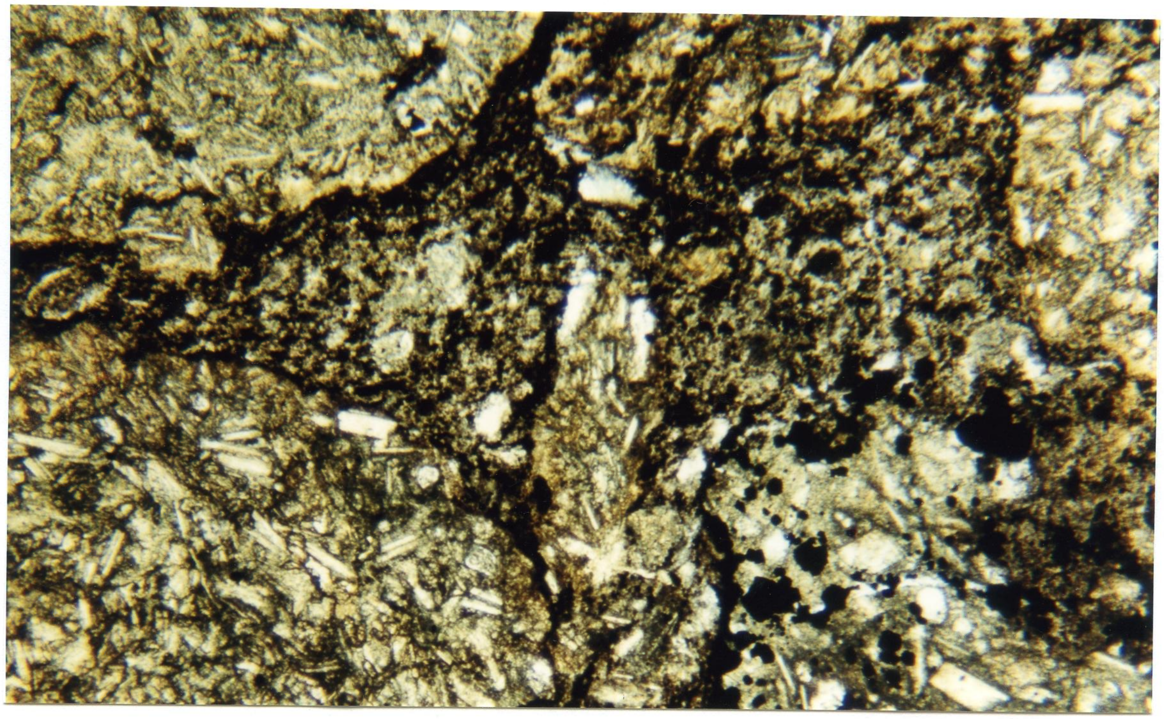

Figure 2.19b: *Photomicrograph of the debris-flow lithology of the Yakoun Group. Muddy matrix surrounds clasts of trachytic volcanic fragments. Field of view is 4 mm left to right. matrix.*

Conglomerate and sandstone

The conglomerate and sandstone facies comprises units bedded on the metre scale. Sandstones exhibit planar laminations, or contain rare ripple marks. Within the conglomerate rocks, clasts range to cobble size, are well rounded, and are compositionally intermediate volcanic rocks (Figure 2.20). Thin section examination reveals clasts which are compositionally similar to the other Yakoun Group volcanic facies. The provenance for the clasts is local: trachytic rock fragments and reworked fragments of lapilli tuff are the most abundant, with rare mud or mudstone clasts of unknown origin (Sandilands Formation ?).

Shale and siltstone

The shale and siltstone facies comprises thick, homogeneous successions of virtually featureless rocks. Black on fresh surfaces, this friable unit often weathers a rustier colour than the older Sandilands Formation, or the younger Cretaceous shales. Close inspection reveals rare thin beds of lapilli tuff with a muddy matrix grading upward into siltstone. The presence of tuff layers allows the differentiation from the other black shale units. These tuffaceous layers do not have the banded appearance characteristic of the Sandilands Formation, and accretionary lapilli are visible. This unit is found mostly the east of Wilson Bay, with only rare outcrops occurring elsewhere. No fossils were observed in this lithotype.

2.4.2 Depositional environments

Recreating the depositional environments extant during Yakoun Group volcanism is a subjective exercise, due to the paucity of continuous outcrops. It is surmised that Yakoun volcanic facies do not have regional lateral continuity, and facies are likely repetitive in the stratigraphic column, as new episodes of volcanism commenced. The

Figure 2.20: *Cobble conglomerate lithology of the Yakoun Group incorporates clasts of the bedded lapilli tuff, west of Newcombe Inlet.*

Figure 2.21: *Shale and siltstone lithology of the Yakoun Group east of Wilson Bay , distinguished by rare layers of lapilli tuff interbedded with green-grey to dark grey shales and silts.*

unstratified lapilli tuffs, and stratified and interlayered tuffs and sedimentary rocks are interpreted to have been deposited in subaerial and submarine environments, and their presence is suggestive of a landscape in which andesitic tuff cones rose out of shallow seas. Elsewhere in the Queen Charlotte Islands, marginal marine deltaic deposits and possibly lacustrine deposits have been identified (Hesthammer, 1991b) – the unfossiliferous shale and siltstone strata may belong to this environment. Conglomerates indicate deposition in channels or shallow marine environments. Lahars unconformably overlying the Sandilands Formation indicate channel or valley deposits distal to the flanks of volcanoes. No contact relations are observed with units other than the Sandilands Formation. The Yakoun Group overlies a varied topography, which cannot be constrained due to unknown offsets on younger faults. This relationship may constrain the amount of uplift occurring post-Sinemurian, and pre-Bajocian.

2.4.3 Jurassic Intrusive Rocks

Two suites of Jurassic plutonic rocks crop out in the Queen Charlotte Islands, the San Christoval plutonic suite (SCPS), and the Burnaby Island plutonic suite (BIPS). These rocks received extensive attention as part of the Frontier Geoscience Program (Anderson, 1988; Anderson and Greig, 1989; Anderson and Reichenbach, 1990, 1991), with the aims of establishing their character and estimating the effect intense plutonic activity had on the thermal maturation of the potentially petroliferous strata. Plutonic rocks exposed in the southern part of the central Moresby Island study area are included within the 172-171 Ma San Christoval plutonic suite (Anderson and Reichenbach, 1991), and represent the northern extent of the San Christoval Mountain Range (Figure 1.2). This suite comprises medium grained, foliated diorites and quartz diorites which are characterized by prismatic hornblende, and rare biotite (Anderson and Greig, 1989).

2.5 Cretaceous Marine succession Longarm Formation and the Queen Charlotte Group

2.5.1 Cretaceous Stratigraphy Introduction

Original descriptions of Queen Charlotte Group lithologies date to Richardson (1873) who described three units: an upper shale and sandstone, a coarse conglomerate, and a lower shale containing coal and iron ores. Dawson (1880) added what is now the sandstone member of the Haida Formation, and mistakenly included agglomerates (now Yakoun Group) and sandstones (now Maude Group) due to difficulty distinguishing lithologies in the field. Clapp (1914) introduced the Image member, which contained Jurassic and Lower Cretaceous volcanic rocks and basal conglomerates, and the Haida, the Skidegate, and Honna members of the Queen Charlotte Series. Sutherland Brown (1968) recognized the stratigraphic distinctions between the Middle Jurassic volcanic rocks, the Yakoun Group, and the unconformably overlying basal sandstone and conglomerate, for which he introduced the name Longarm Formation. The Haida, Skidegate, and Honna members were elevated to formational status in his newly defined Queen Charlotte Group, which comprised a Cretaceous marine succession of sandstone, shale, and conglomerate unconformably above the Longarm Formation. The temporal equivalency of parts of the Honna and Skidegate Formations was recognized, but he placed the Skidegate Formation stratigraphically overlying the Honna Formation, an erroneous interpretation not corrected until Haggart (1987) re-examined macrofossil faunas.

Numerous on going stratigraphic and sedimentological studies of the Cretaceous succession have been undertaken as part of the Frontier Geoscience Program's effort to identify and describe possible hydrocarbon reservoir lithologies (Fogarassy and Barnes, 1988, 1991; Fogarassy, 1989; Haggart, 1989, 1991; Haggart et al., 1991; Higgs, 1988a, 1988b, 1989, 1990; Gamba et al. 1990; Haggart and Gamba, 1990; Indrelid, 1990). These workers have demonstrated that stratigraphic relationships within the Cretaceous succession are more complex than previously understood. Detailed biostratigraphic control has allowed workers to recognize that complex facies relationships replicate identical lithologies throughout the stratigraphic column, and lateral continuity of facies is restricted (Gamba et al, 1990; Taite, 1991a; Haggart et al. 1991). As a result, the simplistic layer cake stratigraphy interpreted before the Frontier Geoscience Program work gave way to a revised and modern process-oriented stratigraphic scheme (see Haggart et al., 1991 for preliminary discussion). Formational names within this new stratigraphic scheme have yet to be formalized. Therefore, this thesis utilizes the formation names for Cretaceous nomenclature as outlined by Sutherland Brown (1968), and as defined as they were understood at the onset of the Frontier Geoscience Program mapping (Woodsworth and Tercier, 1991). The relationship between the formal formations, retained during mapping by the author in the central Moresby Island region, and the revised and interim stratigraphy of Haggart et. al. (1991), is explained within the text (sections 2.4.5 and 2.4.6). An explanation of the relationship between the formal stratigraphy and the revised stratigraphy is included to simplify comparisons with ongoing and future studies of the Cretaceous section in the Queen Charlotte Islands.

The known age range of the Cretaceous rocks in central Moresby Island extends from the Hauterivian to the Turonian, but both younger and older Cretaceous strata have recently been identified in the Cretaceous succession elsewhere in the Queen Charlotte Islands (Gamba, 1991; Haggart and Higgs, 1989). These older and younger strata are thought to be restricted to discrete sub-basins (Gamba, 1991), and therefore have not been included in this discussion.

2.5.2 The Longarm Formation

The Longarm Formation was originally proposed by Sutherland Brown (1968) for previously undescribed Valanginian to Barremian strata which unconformably overlie a variety of lithologies, including the Triassic to Lower Jurassic Kunga Group and the Late Jurassic Burnaby Island plutonic suite intrusive rocks (Anderson and Greig, 1989). Haggart and Gamba (1990) describe six lithofacies within the Longarm Formation, which they relate to depositional environments:

i) A basal transgressive lag deposit consists of poorly-sorted, angular to rounded cobble conglomerate. This lithofacies contains fauna indicative of a shallow marine environment. It contains reworked beach deposits derived from adjacent headlands. Haggart and Gamba (1990) suggest this lithology is indicative of a complex serrated coastline.

ii) An interbedded conglomerate and sandstone lithofacies consists of cross-stratified sandstone, siltstone, and conglomerate, including the black and white pebble conglomerate of Sutherland Brown (1968). These lithologies are conformably overlain by trough cross-stratified greywacke. This sequence is diagnostic of shallow foreshore and storm reworked beach deposits and longshore migrating megaripples.

iii) The bioturbated sandstone lithofacies comprises swaley cross-stratified silty fine-grained greywacke, siltstone, and shale, and contains both terrestrial organic matter (tree trunks and plant debris) and marine fauna. This facies is indicative of a deeper shoreface environment, below fairweather wave base, but still storm influenced.

iv) The sandstone and siltstone storm deposit lithofacies, in general, abruptly overlies the bioturbated sandstone. These deposits are characterized by planar tabular laminated sandstone, and siltstone overlain by densely bioturbated mudstone, the cap of the storm deposits. This unit is indicative of rapid sediment accumulation.

v) A laminated siltstone and mudstone lithofacies contains a basal intraclast pebble conglomerate overlain by horizontal to low-angle laminated sandstone and siltstone, capped by heavily bioturbated mudstone. This unit is indicative of rapid sediment accumulation in a storm-dominated shelf environment.

vi) The turbidite lithofacies is rarely seen but can obtain thicknesses of twenty metres (Haggart and Gamba, 1990). This lithofacies exhibits the Tabc divisions of Bouma with intraclasts near a scoured base, and represents submarine channel and levee deposits.

Within central Moresby Island, rocks of the Longarm Formation were not recognized during the first season by the author (Taite, 1990a); map relationships and the volcanic lithic component in the sedimentary rocks suggested outcroppings of these rocks instead belonged to the Yakoun Group. They were correctly identified when the diagnostic and ubiquitous *Inoceramid* valves were identified as Hauterivian (Haggart, personal communication 1990; Appendix 1), and the higher relative maturity of the sandstones was noted.

The southwesternmost exposure of Longarm Formation strata corresponds to the transgressive lag-cobble conglomerate lithofacies of Haggart and Gamba (1990). The unconformity is clearly exposed overlying both Yakoun Group lithologies and the Sandilands Formation (Figure 2.21). Clasts within the basal sequence are typically derived from the directly subjacent unit throughout the Queen Charlotte Islands. Where this lithology overlies sedimentary rocks of the Yakoun Group, it can be distinguished by its higher relative maturity, the complete absence of lapilli tuff, and the presence of ubiquitous *Inoceramid* valves and prisms.

A laminated mudstone, siltstone, and sandstone facies occurs locally in the southeasternmost exposures of the Longarm Formation. Abundant sedimentary structures, including slump folding, climbing ripples, convolute beds, and fining upward sequences are present, and correspond most closely to the turbiditic lithofacies of Haggart and Gamba (1990). Soft-sedimentary deformation structures also include clastic injection dykes - indicative of material failure due to high pore pressure resulting from rapid burial (Figure 2.22).

The northwesternmost exposures of the Longarm Formation is a matrix-supported boulder conglomerate which fines upward over tens of metres into trough cross-bedded medium- to coarse-grained sandstones (Figure 2.23). The boulders, some greater than two metres in length, are rounded on all sides. This unit is thought to overlie the Yakoun Group, based on the intermediate composition of most of the boulders and the inferred contact relationship; the contact is not exposed. Abundant *Inoceramid* valves, some reaching greater than fifty centimetres in length, provide a Hauterivian age for the outcrop (Figure 2.24). Oyster fragments are common in the interstices between the boulders, and are occasionally attached to the boulders. The matrix varies from a 'hash' of lithic fragments and shell shards to medium- to coarse- grained sandstones. Within

Figure 2.22: *Basal unconformity of the Longarm Formation truncating the Sandilands Formation. The conglomerate lithofacies of the Longarm Formation includes rounded volcanic boulders and locally-derived angular shale clasts.*

Figure 2.23: *Clastic injection dykes and breccias within the Longarm Formation, northeast of Two Mountain Bay.*

***Figure 2.24:** Longarm Formation boulder conglomerate overlain by bioclastic cross-bedded sandstones. This location south of Sewell Inlet contains oyster, inoceramid, and ammonite fragments.*

***Figure 2.25:** Inoceramid mold in sandstone, from locality illustrated in figure 2:24.*

***Figure 2.26** Ichnofossils (chondritres ?) from locality illustrated in figure 2:24.*

***Figure 2.27:** Close up photograph of the cross beds within the sandstone beds shown in figure 2:24. Light coloured fragments are oyster and inoceramid valve fragments.*

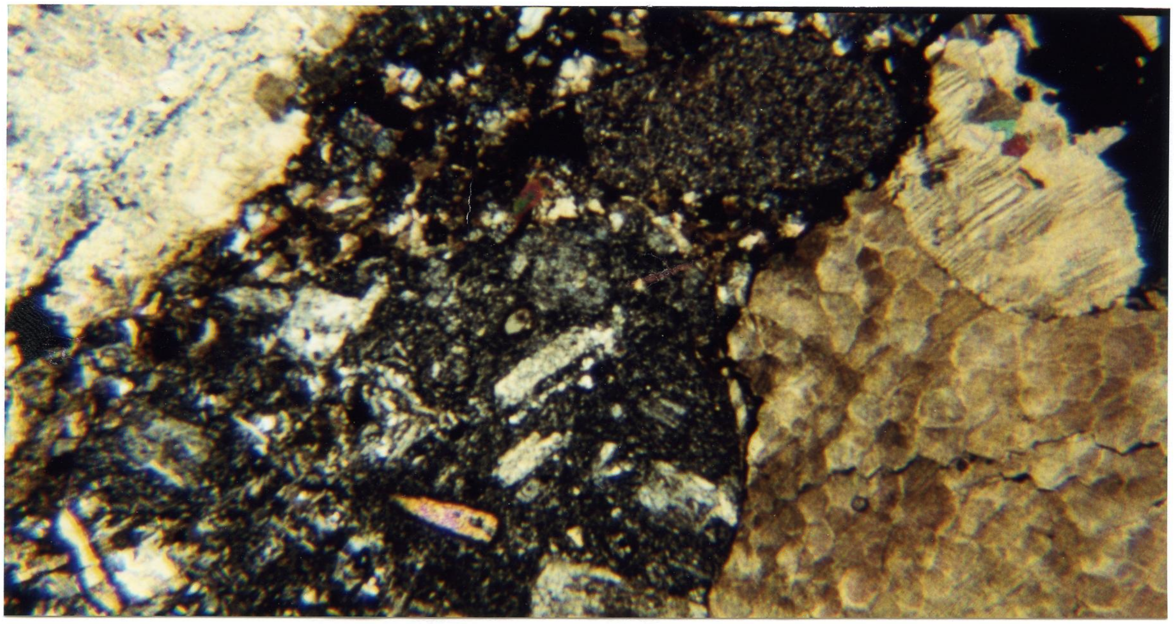

Figure 2.28: *Photomicrograph of Longarm Formation pebble conglomerate. VRF fragment embayed in an inoceramid valve fragment illustrates a pressure solution contact, but no mesoscopic dissolution surfaces are visible.*

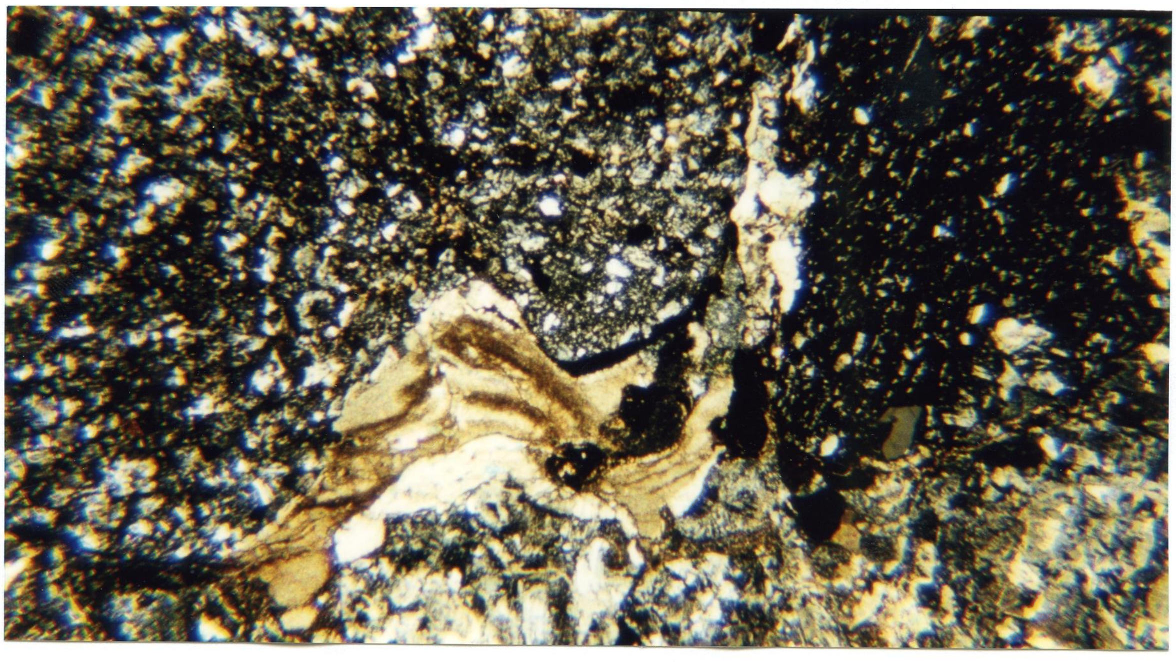

Figure 2.29: *Clastic injection dykes and breccias within the Longarm Formation, northeast of Two Mountain Bay.*

the coarse and medium-grained sandstone cross beds, very large feeding traces resembling *Chondrites* occur – the large size and the coarse clastic substrate are anomalous for *Chondrites* (Figure 2.25).

Thin section microscopy of the Longarm Formation lithologies reveals that most of the clasts within the basal lithologies are locally derived. Intermediate composition volcanic rock fragments, presumably derived from the underlying Yakoun Group, are found in all thin sections. Plagioclase laths within the fragments are mostly to completely altered to clay. Abundant *Inoceramid* prisms, and rare oyster valve fragments also appear in thin section. Sedimentary rock fragments make up a volumetrically significant proportion of the rock volume, and most are apparently derived from the Sandilands Formation; however, chert and carbonate fragments are also present, and are likely derived from strata older than the Sandilands Formation. Siltstone clasts are occasionally deformed into pseudomatrix. Pressure solution features, especially sutured boundaries, are obvious in some thin sections (Figure 2.26). Calcite occurs as pore filling cement in all samples, and even in those that are texturally the most mature, visual porosity is nearly zero. The calcite could be precipitated from circulating CO_3 -rich water locally derived from the dissolution of the bioclastic fragments, and dissolution of carbonate is visible along grain boundaries in thin section. Disseminated pyrite is found in all samples, and pore filling chlorite occurs at the expense of volcanic rock fragments and biotite; compaction has locally resulted in the kinking of biotite sheaves. Most of the sandstones are classified as greywackes.

2.5.3 The Queen Charlotte Group

The Haida Formation

The Haida Formation is subdividable into two members, a basal sandstone member, and a shale member. Further lithologic subdivisions have been suggested (Yagishita, 1985; Fogarassy and Barnes, 1988, 1991), but the regional utility of these divisions has not been demonstrated.

The sandstone member is characterized by medium to fine grained, green to grey, cross-stratified sandstone. The tops of the sandstone beds are locally bioturbated (Haggart, 1991). Sutherland Brown estimated the thickness of the unit at 823 metres at the type locality in Bearskin Bay in Skidegate Inlet (Figure 1.1). Haggart (1991) suggested that thickness is tectonically modified, and that the true thickness is closer to 400 metres. The sandstone member of the Haida Formation has not been identified in the central Moresby Island region.

The shale member of the Haida Formation comprises a monotonous succession of black, silty shale containing abundant calcareous concretions with rare fine grained sandstone interbeds. Within the central Moresby Island area, sandstone beds are typically 1-2 metres thick, with thin, bioturbated shale and siltstone interbeds. Grit, or bioclastic shell fragment debris layers are occasionally interbedded. The composite thickness of this unit in Bearskin Bay is approximately 100 metres; the stratigraphic thickness for the unit in central Moresby Island is not known.

The Skidegate Formation

The Skidegate Formation is a lithologically distinct unit in the Queen Charlotte Islands. It is defined by turbiditic sandstone, siltstone, and shale, and the presence of partial to complete Bouma sequences. Beds range in thickness from approximately one centimetre to greater than one metre (rare) (Figure 2.27). In outcrop, these beds form rhythmic grey and black bands representing the sandstone and shale fractions respectively. Grading and cross-bedding are visible in many of the beds. Thin section analysis of sandstone beds reveals poorly to moderately sorted, lithic wacke with subangular to subrounded grains. Matrix in the sandstone fraction is composed of detrital and authigenic clay. Framework grains include chert, calcite, siltstone, and trachytic volcanic rock fragments with partially to completely altered plagioclase laths. Fossil collections made from stratigraphically highest exposures of the Skidegate Formation near Sewell Inlet indicate an Early Turonian age.

The Honna Formation

The Honna Formation comprises interlayered conglomerate and sandstone lithologies. In Cumshewa Inlet, Haggart (1991) estimates the thickness of this unit to be approximately 200 metres; it is likely highly variable regionally. Feldspathic sandstone forms thickly bedded to massive, occasionally cross-stratified intervals. The sandstones are medium to well sorted, subangular to subrounded, and contain a variety of clast types, including plagioclase laths, trachytic volcanic rock fragments, chert, monocrystalline quartz, K-feldspar, and rare biotite and hornblende. The relative proportion of chert in the Honna Formation is greater than that characterized by Fogarassy (1989) in his studies north of the central Moresby Island study area, suggesting regional provenance variability.

The conglomerate lithofacies is a clast supported, pebble to cobble conglomerate with medium to poorly sorted, medium to coarse grained, subangular sandstone matrix. The cobble clasts exposed south of Sewell Inlet are imbricate, and indicate paleocurrents

Figure 2.30a: *Turbidites of the Skidegate Formation south of Sewell Inlet. Light bands are siltstones and sandstones, dark bands are shale.*

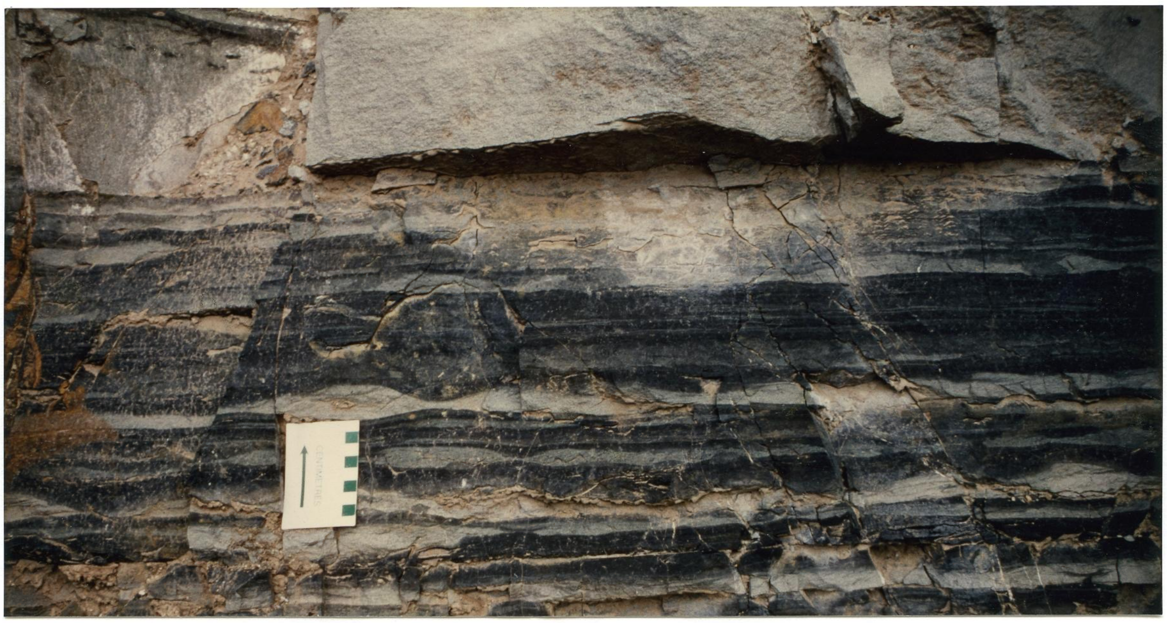

Figure 2.30b: *Close up photograph of turbiditic layering within the Skidegate Formation.*

Figure 2:31a: *Wave cut bench of Honna Formation conglomerate and sandstone, south of Sewell Inlet.*

Figure 2.31b: *Monotis-bearing clast of the Peril Formation within the Honna Formation conglomerate, south of Sewell Inlet.*

from the northwest (Gamba et al., 1990). Clast types include rounded volcanic and granitic cobbles, and rare angular bedded shale and siltstone blocks. Banded tuffaceous clasts of the Sandilands Formation and *Monotis*-bearing angular argillaceous clasts of the Peril Formation also occur (Figure 2.28).

In central Moresby Island, stratigraphic relationships with the other Queen Charlotte Group units are ambiguous. Skidegate Formation turbidites occur interlayered within Haida Formation shales, and locally thin Honna Formation conglomerate beds interfinger with turbidites of the Skidegate Formation (Taite, 1990a; Gamba et al., 1990; Figure 2.29). Differentiating these units at the megascopic level is often impractical. Paleocurrent measurements taken from the base of the Honna Formation south of Sewell Inlet reveal a strong northwestward trend. Paleocurrents from the underlying Skidegate Formation reveal a consistent southwestward trend, at right angles to the overlying Honna Formation (Gamba et al, 1990; Appendix 3).

2.5.4 Depositional Environments

The Longarm Formation and the Haida Formation sandstones represent the basal sequence in a widespread and diachronous fining-upward marine sequence. These richly fossiliferous strata constrain the onset of the marine transgression in the Queen Charlotte Islands to the Valanginian. The coarse sandstones and conglomerate exposed in central Moresby Island represent beach and shallow marine deposits, largely above fair weather wave base. The swaley cross-bedded sandstones are suggestive of offshore sandbar deposits, and the abundant *Inoceramid* valves, oyster fragments, and *Chondrites* ichnofacies are characteristic of shallow marine conditions. Haggart and Gamba (1990) suggest the Longarm Formation deposits formed in shelf and upperslope environments. In the Queen Charlotte Islands, these rocks are conformably overlain by siltstone and shale of the Haida Formation, representing a transition to a deeper water, and further offshore environments. Interfingering relationships between shales and sandstones with grit and shell fragment lag deposits are indications that sedimentation was influenced by storm deposits.

The Skidegate Formation turbidites are representative of a submarine fan setting. Soft-sediment deformational features, such as slump structures, and dewatering structures, are indicative of rapid sedimentation. The Skidegate Formation is interpreted by Gamba et al. (1990), to represent overbank levee deposits formed in a submarine fan environment. Paleocurrent measurements collected from Skidegate Formation turbidites in Sewell Inlet indicate a southwestward directed flow, in contrast to the northwestward directed channelized conglomerates in the overlying Honna Formation. This perpendicular relationship between channels and overbank levee deposits is characteristic of submarine fan complexes (Walker, 1989).

The depositional environment in which the Honna Formation formed has attracted more controversy than perhaps any other unit in the Queen Charlotte Islands. Various interpretations include deep water fan deltas formed in response to thrust faulting (Higgs, 1990), and shallow water deposits formed in response to eustatic sea level changes (Haggart, 1991). Up to the Turonian to Coniacian sedimentation, the older Queen Charlotte Group formations and the Longarm Formation describe a macroscopic fining upward sequence consistent with deposition in a marine transgressive sequence. The appearance of the coarse clastic sandstone and conglomerate units of the Honna Formation herald a different kind of deposition: the eastward-stepping marine transgression is overprinted by aggressive, westward-directed progradation of fan complexes. In part, the cause of the controversy can be explained by the differing stratigraphic relationships the Honna Formation exhibits with older units in the Queen Charlotte Islands. On central Graham Island, the base of the Honna Formation scours into the Haida and Skidegate formations, and unconformably overlies Jurassic Yakoun

Group lithologies on northeast Moresby Island (Fogarassy, 1989; Thompson and Lewis, map). Within central Moresby Island, sandstones and conglomerates of the Honna Formation form thickly- to thinly-bedded, planar to irregular bodies, conformably interstratified with turbidites of the Skidegate Formation. These are representative of channelized conglomerates and overbank levee deposits in a submarine fan environment (Walker, 1984).

The earliest age of Honna Formation deposition is uncertain due to poor biostratigraphic control, however in central Moresby Island, the conformably underlying and presumed genetically related Skidegate Formation turbidites (Gamba et al., 1990) are of early Turonian age (Haggart, 1991). Three hypothesis have been proposed for the impetus for Honna Formation sedimentation. Haggart (1991) notes that the timing of Honna Formation deposition coincides well with established eustatic sea level curves showing global sea level drops in Turonian to Coniacian time (Hancock and Kaufman, 1979; Haq et al., 1987). Thompson et al. (1991) suggest late Cretaceous block-faulting may have resulted in the formation of local fan complexes. Clasts derived from the Sandilands and Peril Formations indicate there was a nearby source for Kunga Group lithologies by Turonian to Coniacian time. A variation on this theme has been proposed by Higgs (1988a, 1990), who suggests Honna Formation deposition may reflect the sedimentary front of a westward migrating foreland thrust system. The merits of these hypothesis will be further discussed in the regional synthesis section (chapter 5).

2.5.5 Problems with Cretaceous nomenclature

The need for revised Cretaceous nomenclature first arose when field workers found the formal Cretaceous stratigraphic divisions were not universally applicable at the outcrop, and could not easily be used in mapping exercises. Existing stratigraphic

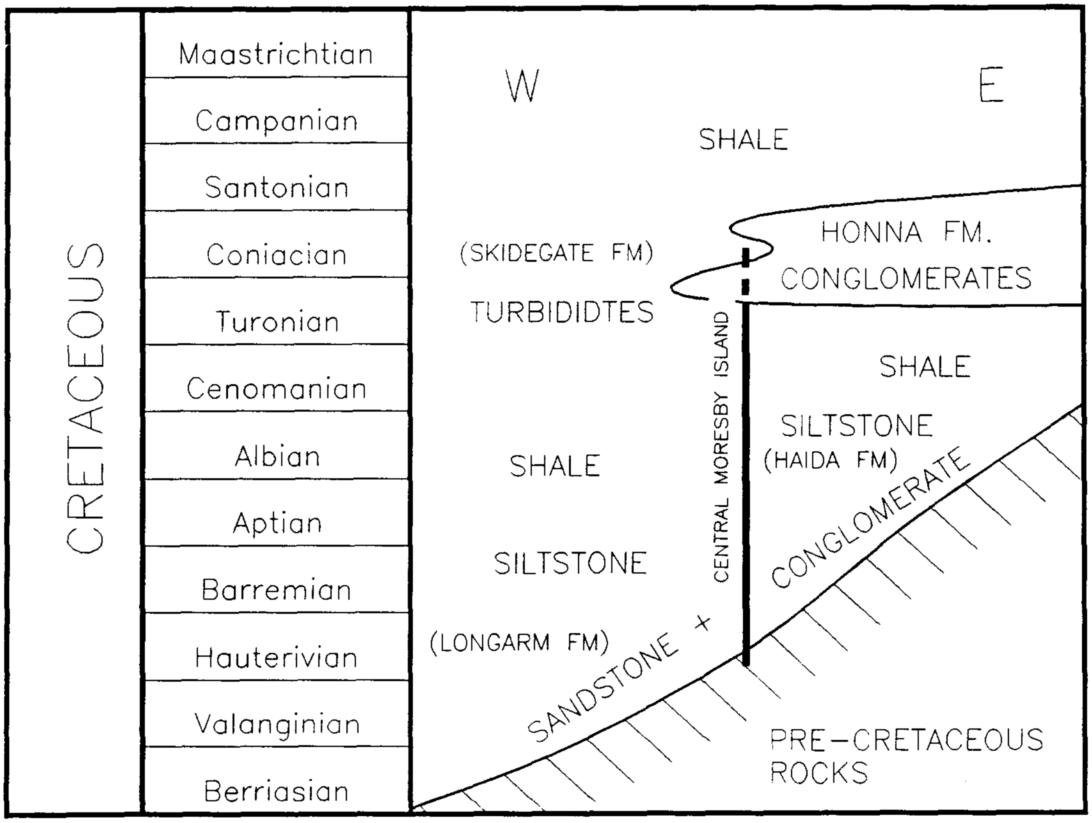

Figure 2:32: *Schematic cross section of the Cretaceous succession in the Queen Charlotte Islands illustrating the idealized relationship between lithotypes, and the location of central Moresby Island.*

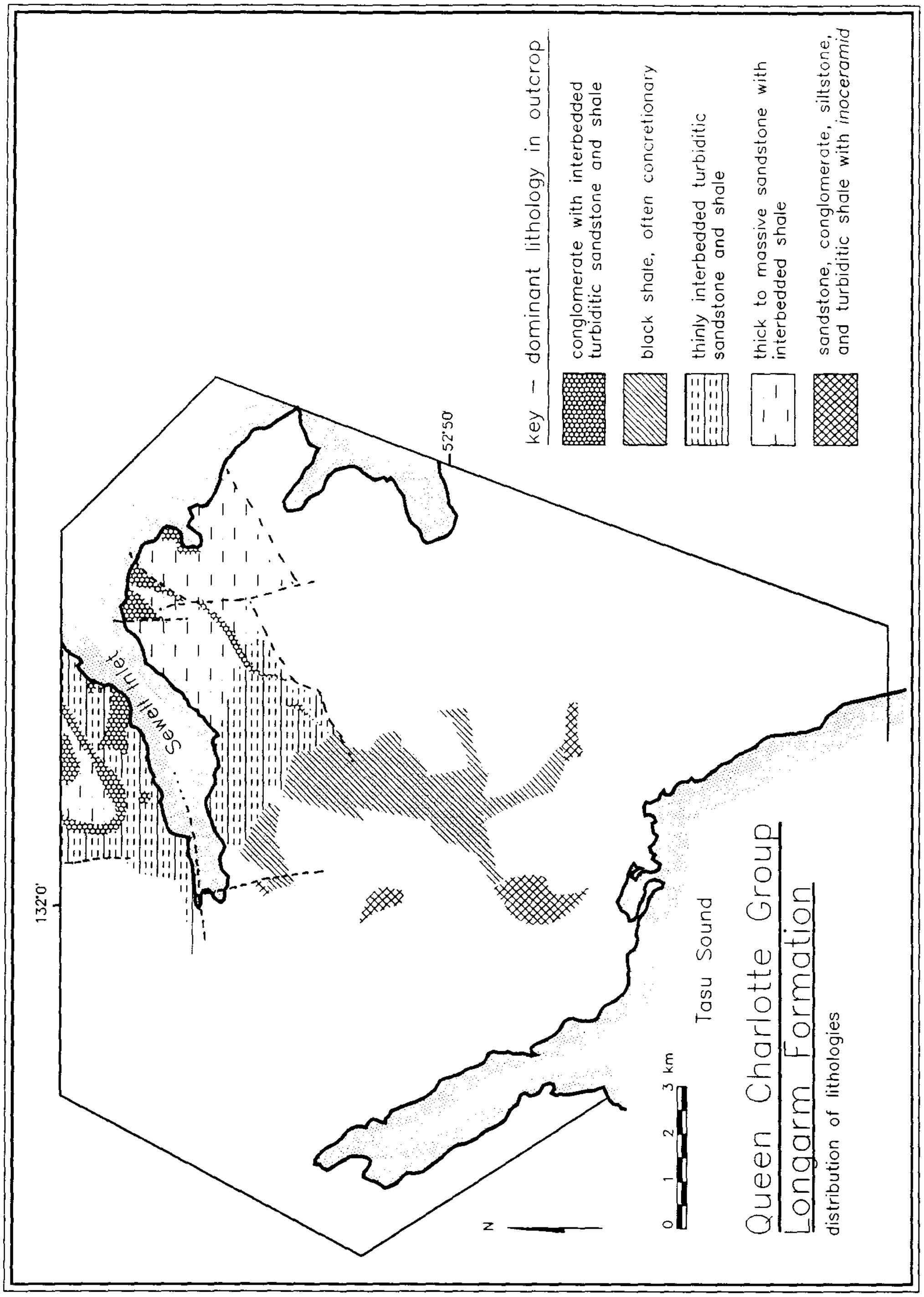

Figure 2.33: *Map illustrating the distribution of the Cretaceous lithotypes. Major faults affecting lithotype distribution are indicated by dashed lines.*

schemes proved to be misleading for both recreating depositional environments, and interpreting map patterns to evaluate post-Cretaceous tectonic activity. For example, Thompson and Lewis (1990a) interpreted a tectonically repeated section of Honna conglomerate north of Sewell Inlet that is in fact a stratigraphic repetition (Taite, 1989), this type of repetition is also demonstrable on the mesoscopic scale in central Moresby Island. A revision of the nomenclature became even more compelling when Haggart (1991) demonstrated that the basal unit of the Cretaceous sequence was diachronous through Valanginian to Aptian time and represented a eustatically controlled marine transgression – the previously inferred Aptian hiatus does not exist, and the Longarm Formation and the Queen Charlotte Group are demonstrably conformable. Depositional environments reflecting a long lasting marine transgression are necessarily complex, and a representative stratigraphy would illustrate interrelated and interdependent facies in both time and space.

2.5.6 Generic Stratigraphy

To circumvent the problems caused by the formal nomenclature, as outlined above, a generic stratigraphy was developed concurrent with the present study. This generic stratigraphy is included in this study to aid future workers in reconstructing Cretaceous depositional models. This stratigraphic scheme divided the Cretaceous succession into mappable lithologic components, with no reference to chronostratigraphy (Haggart et al. 1991; figure 2.30). Three major lithologic units were defined: shallow water sandstone, deeper water shale, and Honna Formation sandstones and conglomerates. These units were further subdivided: the Cretaceous sandstone lithofacies comprises sandstone, siltstone, and the basal transgressive conglomerates (including the Longarm Formation, and the Haida Formation sandstones), the Cretaceous shale lithofacies comprises black shale, and the turbiditic sandstone and shale (including the Haida Formation shale, and the Skidegate Formation). The Honna Formation is considered lithologically and genetically distinctive, and the name is retained. Haggart et al. (1991) hoped this scheme, when combined with available chronostratigraphic data, would allow the Cretaceous evolution and depositional environments of the Queen Charlotte Islands to be reconstructed. Figure 2.31 illustrates the position of the Cretaceous stratigraphic column in central Moresby Island in a schematic illustration of facies relationships, and figure 2.32 illustrates the distribution of the Cretaceous lithofacies in central Moresby Island.

The Honna Formation conglomerate lithofacies contains minor turbiditic sandstone and shale (Skidegate Formation). The dark grey to black shale lithofacies is the shale member of the Haida Formation. The turbiditic sandstone and shale are equivalent to the Skidegate Formation. The interbedded thick to massive sandstone with turbiditic shale represents interbedded Skidegate Formation turbiditic sandstone and shale with Honna Formation sandstone and conglomerate - neither the formal nomenclature nor the interim stratigraphy of Haggart et al. (1991) have a division which represents this lithotype. Finally, the basal transgressive lithofacies corresponds to the Longarm Formation in central Moresby Island.

2.6 Tertiary Volcanism

2.6.1 History and Nomenclature

Tertiary volcanic rocks were first recognized in the Queen Charlotte Islands by Clapp (1914), but received no detailed attention until Sutherland Brown's (1968) study. Sutherland Brown included all Tertiary volcanic rocks in the Masset Formation, which he subdivided into three facies based on lithologic character and age. The Tartu Facies was defined as comprising two main rock types: dominant aphanitic to rare phenocrystic and microphenocrystic basalt with basalt breccias, and sodic rhyolites with feldspar and pyroxene phenocrysts. The Dana Facies comprised tuff breccias of mixed basalt and rhyolite clasts. The Kootenay facies comprised acidic, bedded pyroclastic rocks ranging from agglomerates to welded ashflows interlayered with foliated spherulitic rhyolites.

Hickson (1988, 1989, 1991) further examined the Tertiary volcanic rocks, and recognized two distinct assemblages: a Neogene unit, for which she retained the name Masset Formation, and an older unnamed Paleogene suite. The Kootenay facies of Sutherland Brown (1968), which contains the felsic pyroclastic rocks and interbedded rhyolites, lithologically corresponds to the Neogene Masset Formation. The Masset Formation is compositionally distinctive; it lacks large feldspar and hornblende phenocrysts in the felsic units, and lacks olivine phenocrysts (or normative olivine) in mafic units. The Dana and Tartu Facies of Sutherland Brown (1968) are compositionally more heterogeneous, are commonly porphyritic with feldspar and amphibole phenocrysts, and are representative of the unnamed Paleogene suite. The work of Hickson (1991) concentrated on rocks of the Masset Formation; the Paleogene suite remains poorly understood.

2.6.2 Tertiary Volcanic Rocks in central Moresby Island

Tertiary volcanic rocks lie unconformably on all older lithologies in the central Moresby Island area. The basal contact is not exposed, and no attempts at estimating stratigraphic thickness were made. Rocks assigned to the Tertiary volcanic suites in the central Moresby Island comprise a wide range of lithologies. The subdivision of the Tertiary rocks into two suites (Hickson, 1991) initially proved problematic to this field investigation; lithologies representative of both suites are apparently present. This study proposes that both suites occur within central Moresby Island, based on lithologic descriptions and thin section microscopy. The observations that suggested this hypothesis were made during laboratory investigations, and no attempt was made to correct mapping retroactively by differentiating the suites. A definitive determination of this hypothesis will require a more systematic survey of these rocks, including geochemical and geochronological analysis coupled with detailed facies analysis.

The most abundant lithologies within the Tertiary volcanic rocks are debris flows with subangular to subrounded heterolithic volcanic and accidental fragments (Figure 2.33). Bedding surfaces are often discernable in the field, although no internal stratification is developed. Clasts of volcanic origin range from aphanitic to feldspar and hornblende phyric. Angular shale and mudstone accidental clasts locally form a significant portion of some units. Clasts range in size from less than one centimetre to boulder-sized blocks. These rocks correspond lithologically and compositionally to the Paleogene assemblage. In thin section, this lithology reveals abundant secondary calcite, silica, authigenic chlorite, serpentine minerals replacing mafic phenocrysts, and finely disseminated epidote (Figure 2.34). The wide range in commonly-found clast sizes, and the heterolithic population of clasts including the abundant accidental clasts, both serve as useful field tools to distinguish these rocks from the mainly monolithologic debris flows of the Yakoun Group.

Figure 2.34: *Debris flows in Tertiary volcanic rocks, south of Lagoon Inlet., contact is north dipping.*

Figure 2.35: *Tertiary debris flow south of Lagoon Inlet. Clasts include volcanic fragments, and angular argillites and sandstone blocks., .*

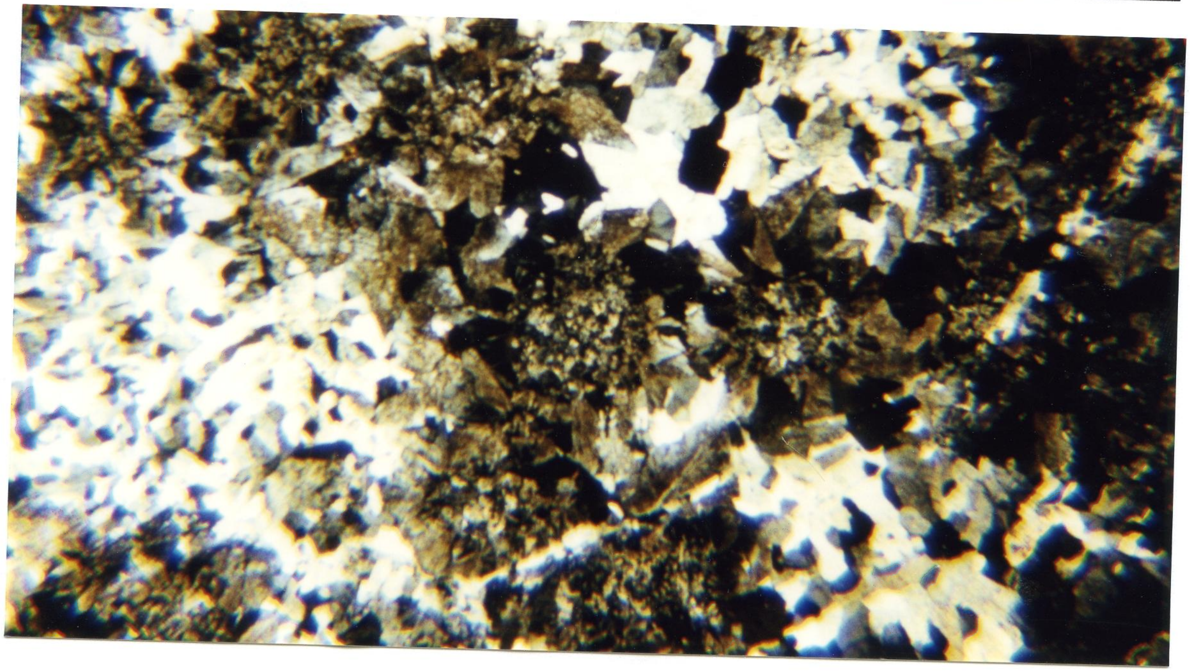

Figure 2.35a: *Photomicrograph of Tertiary flow banded rhyollite of probable Neogene age showing devitrification of glass . Field of view is 4 mm left to right.*

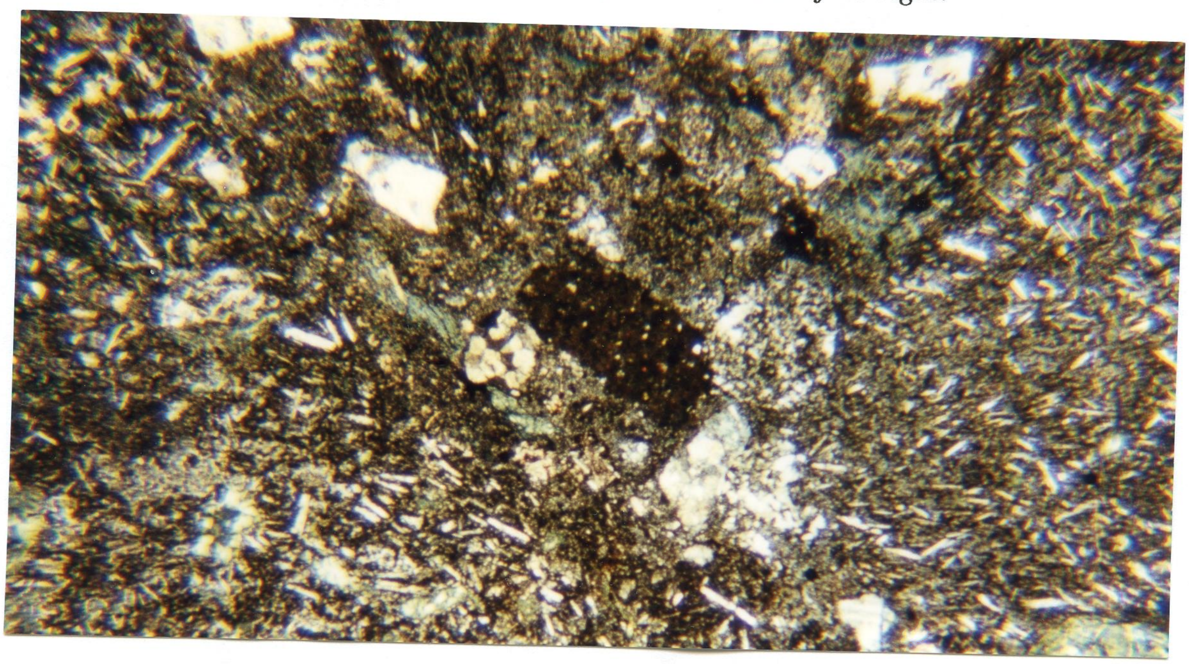

Figure 2.35b: *Photomicrograph of Tertiary debris flow lithology of probable Paleogene age. Extensive alteration includes chlorite and serpentine group minerals. Field of view is 4 mm left to right.*

Another distinctive lithotype observed in the Tertiary volcanic rocks is the spherulitic rhyolite, which corresponds lithologically to the Neogene Masset Formation (Hickson, 1991). These rocks appear bright white to greenish-white in outcrop, spherulites are one to three millimetres in diameter, and flow banding is observable on a sub-centimetre scale. In thin section, devitrification features are not observed, instead these rocks are characterized by pervasive recrystallization of the groundmass, consistent with local hydrothermal alteration, to the extent that primary igneous textures are completely obscured (Figure 2.35).

Vein, fracture, and joint sets are abundant in both the Paleogene and the Neogene suites and orientations are not regionally consistent. Calcite and quartz both form vein filling phases, and epidote veins occur within Paleogene lithologies. Thin section analyses of the Tertiary volcanic rocks emphasizes the pervasive alteration in central Moresby Island. The most interesting result obtained from examination of thin sections is that two apparent degrees of alteration exist, a lower greenschist-grade metamorphism of the Paleogene succession, and hydrothermal alteration, characteristic of alteration proximal to volcanic vents of Neogene lithologies. While this apparent disparity of alteration levels is not, in itself, sufficient to categorize volcanic suites, it does support the hypothesis of two episodes of Tertiary volcanism.

2.6.3 Tertiary Intrusive Rocks in central Moresby Island

Tertiary intrusive rocks in the Queen Charlotte Islands include plutonic bodies of the Kano Plutonic suite (Anderson and Reichenbach, 1991), and regionally abundant dykes (Souther and Jessop, 1991). Dykes and plutons of the Kano Plutonic suite have been identified in the central Moresby Island area. Both dykes and plutons are spatially associated with the greatest accumulations of Tertiary volcanic rocks, and are considered cogenetic. Dykes of the Queen Charlotte Islands were studied in detail as part of the

Frontier Geoscience Program, in order to estimate the influence of intrusive bodies on the thermal maturation of potential hydrocarbon source rocks (Souther and Bakker, 1988; Souther 1988, 1989; Souther and Jessop, 1991). Two distinct populations of dykes occur within the central Moresby Island study area: the Tasu swarm, and the Selwyn Inlet swarm. These swarms are defined by differing orientations (Souther and Bakker, 1988; Souther and Jessop, 1991). Dykes of the Tasu swarm, situated most commonly north and east of Tasu Sound, dominantly trend northerly, and are basaltic to rhyolitic in composition. The Selwyn Inlet swarm extends from Sewell Inlet south to Talunkwan Island, and dykes within it have a predominantly easterly trend in contrast to all other swarms on Moresby Island. They also range compositionally from basaltic to rhyolitic. Tertiary intrusions can generally be distinguished from Jurassic intrusions because of composition range and amount of deformation. Jurassic intrusions are intermediate in composition, and dykes are occasionally folded.

2.6.4 Depositional Environment

Mapping and dating of Tertiary volcanic rocks suggests there may have been many phases of Tertiary volcanism on the Queen Charlotte Islands (Hickson, 1991). Thickest accumulations of rocks correspond spatially to areas of most intense intrusive activity. Souther (1988) suggests original accumulations of volcanic rocks may have been restricted to these areas, and present accumulations may correspond to original accumulations around discrete centers. The Paleogene suite was subject to conditions sufficient for metamorphism to lower greenschist grade. Minimum temperatures required for this are greater than 375^{o} - 400^{o}C (Winkler, 1979).

It is not known if the Neogene Masset Formation rocks were deposited conformably on the Paleogene volcanic rocks. The outcrops which contain the hydrothermally altered rocks occur spatially close to those of greenschist metamorphic grade. This could be the result of erosion of the metamorphosed Paleogene strata before the onset of Masset volcanism, or it could reflect subsequent structural complications juxtaposing different grades of Tertiary rocks during Tertiary tectonism; evidence for Tertiary tectonism will be discussed in Chapter 4.

3 STRUCTURAL GEOLOGY OF CENTRAL MORESBY ISLAND

3.1 Introduction, previous work and the evolution of objectives:

As with the stratigraphic studies, early observations pertaining to the structural evolution of the Queen Charlotte Islands date back to the pioneering work done early on this century, and late in the last (Dawson, 1880; Clapp, 1914). It is humbling to see many of the earliest observations these first workers made on the structural evolution of the islands vindicated by their contemporary counterparts (Lewis and Ross, 1991; Thompson et. al., 1991, and others). Dawson recognized a chronology of tectonic events in the Queen Charlotte Islands which included a post Triassic "period of disruption", a period of great volcanic activity synchronous to Yakoun Group deposition, succeeded by quiescent sedimentary deposition (the Cretaceous section), and a final post-Cretaceous pre-early Tertiary "period of disruption". Clapp (1914) recognized the uplift and erosion marked by the pre-Yakoun Group unconformity.

The synthesis of tectonic history by Sutherland Brown (1968) marked the first detailed and regional synthesis of the Queen Charlotte Islands. He believed that faulting and crustal fractures were the dominant tectonic influence on the evolution of the Queen Charlotte Islands, and major regional scale fault systems controlled the distribution of the stratified units, as well as the emplacement of intrusive units. These major fault systems included the Renell Sound - Louscoone Inlet fault systems, and the Sandspit Fault. The timing of movement and the offset history on these fault systems is poorly constrained, but Sutherland Brown (1968) hypothesized these faults had a complex history coupling predominantly dextral strike slip movement with subsidence of the eastern block. He surmised the Rennell Sound fault zone - Louscoone Inlet fault system was likely active in Early Cretaceous or possibly Late Jurassic time, again in the late Tertiary, and possibly in recent time. The Sandspit fault is less well exposed, and thus less well constrained.

Sutherland Brown (1968) suggests it was active in the Cretaceous, and again in the post-Pleistocene.

Sutherland Brown (1968) considered folds to be mainly secondary features in the Queen Charlotte Islands, and suggested that they are confined to localized zones. He recognized four ages of fold systems, Triassic-Jurassic, Cretaceous, early Tertiary, and late Tertiary. He speculated that some folds formed in response to fault block movement, while others formed without any obvious relation to faults.

No additional field research aimed at constraining the tectonic evolution of the Queen Charlotte Islands was conducted between Sutherland Brown's 1968 work and the onset of Frontier Geoscience Program research. However, interim studies employed Sutherland Brown's tectonic interpretations to synthesize the evolution of the Queen Charlotte Islands and, in particular, the Tertiary Queen Charlotte Basin. Yorath and Chase (1981), and Yorath and Hyndman (1983) considered the Louscoone Inlet and the Sandspit fault systems to be remnants of a single dextral strike slip fault that had been offset by the dextral Rennell Sound fault zone in Tertiary time.

The next significant field research into the tectonic evolution of the Queen Charlotte Islands came with the onset of the Frontier Geoscience Program in 1987 (Figure 1.3). Thompson et al. (1991) outline the state of knowledge as understood at the end of the 1988 field season. Frontier Geoscience Program workers in northern Moresby Island and central Graham Island recognized four major tectonic events of regional significance. The earliest recognizable event is a southwest-directed shortening event of Aalenian to Bajocian age, and is characterized by northwest-trending contractional folds and faults (Lewis, 1991b; Lewis et al, 1991; Lewis and Ross, 1988a, 1988b, 1991; Thompson et al., 1991). The Late Jurassic to Cretaceous was characterized by widespread block faulting, which controlled the preservation of Middle Jurassic and

Cretaceous strata (Thompson et al., 1991). A second, northeast-directed contractional deformation event occurred in Late Cretaceous to Tertiary time (Lewis, 1991b; Thompson et al., 1991). Tertiary block faulting post-dated deposition of the Masset volcanic rocks. Subsequent research was able to constrain a complex Tertiary tectonic history. Lewis (1990) was able to delineate four distinct deformation events of unknown regional significance affecting newly identified Paleogene strata in Long Inlet: (1) Late Cretaceous to early Tertiary shortening; (2) early Tertiary extensional faulting; (3) mid-Tertiary shortening; and (4) late Tertiary to Holocene extensional faulting.

Frontier Geoscience Program workers also established a rough chronology for the timing of deformation of the major tectonic elements in the Queen Charlotte Islands. The Long Inlet Deformation Zone (LIDZ), a northwest-trending belt of folds and faults extending over northern Moresby and Graham islands (roughly coincident with the Rennell Sound fault zone of Sutherland Brown, 1968; Figure 1.2), was active in Cretaceous and Tertiary time (Lewis, 1991b). Stratigraphic contacts proved mappable without offset across this zone (Thompson 1988b), and thus this fault zone was instead recognized as an intense zone of northeast- and southwest-directed compressional deformation and extensional block faults, with little or no strike slip offset. Lewis (1991b), hypothesizes that deformation within this zone reflects reactivation of basement structures. It was informally renamed the Rennell Sound fold belt by Thompson and Thorkelson (1989) and later the Long Inlet deformation zone by Lewis (1991b; Figure 1.2).

An additional observation made arising from field mapping during the first two years of the Frontier Geoscience Program was that discreet fault-bound blocks in the islands preserve different stratigraphic successions. The proposed explanation for this observation is that a multiple movement history on block-bounding faults alternately led to preservation and erosion of the sedimentary strata (Thompson and Thorkelson, 1989;

Thompson et. al., 1991). Clearly, understanding the mechanisms which resulted in variable preservation of potential source and/or reservoir strata is paramount for the development of a hydrocarbon exploration model.

Initial reconnaissance work in central Moresby Island was initiated by Sutherland Brown and Jeffery (1960), and was elaborated upon by Sutherland Brown (1968). Since then, most regional geologic and structural studies in the Queen Charlotte Islands have concentrated on Graham Island and northern Moresby Island. This work represents the first significant detailed study of the geology of central Moresby Island.

Ongoing studies by Frontier Geoscience Program workers immediately preceding and concurrent with this study helped define this study's objectives. Because of the rapid synthesis of geologic ideas by FGP workers within the time period of this study, initial objectives occasionally lost emphasis, and subsequent areas of inquiry were made obvious. This section discusses the evolution of objectives for the structural investigations of this study. The initial objectives of the study, firstly to document the structural characteristics of central Moresby Island, and secondly to test the regional applicability of tectonic models developed by Frontier Geoscience Program workers, remained unchanged throughout the duration.

During the 1989 field season, R.I. Thompson of the Geological Survey of Canada mapped an area including Louise Island and the mouth of Sewell Inlet (Thompson and Thorkelson, 1989; Thompson and Lewis, 1990a, 1990b). He noted both anomalous trends for major structures, and anomalous amounts of deformation in Cretaceous strata relative to structural styles documented on northern Moresby Island and central Graham Island (R.I. Thompson, personal communication, 1989). While elsewhere in the Queen Charlotte Islands structures in Cretaceous strata trend northwest, coaxial with the Middle Jurassic deformation, in Cretaceous strata at Sewell Inlet, northeast-trending structures dominate (Thompson and Lewis, 1990a; Sutherland Brown, 1968). The additional goal of ascertaining the significance of the northeast-trending structures was defined.

Thompson and Thorkelson (1989) describe a post-Cretaceous block faulting event which controlled the preservation of Cretaceous strata on northern Moresby Island and central Graham Island. Faunal evidence in Cretaceous strata of northern Moresby Island suggested the presence of an additional "post Haida Formation - pre Honna Formation" deformation event (Thompson et al., 1991). The Cretaceous strata around Sewell Inlet proved to be a possible testing ground for both the regional significance of the Late Cretaceous block faulting event, and the possibility of a syn-Cretaceous deformation event.

Subsequent re-examination of faunal collections from northern Moresby Island, which provided the initial evidence for syn-Cretaceous tectonic activity, suggested pre-Honna Formation faulting was not well supported, (J. W. Haggart, personal communication, 1990). The poor exposure and extensive disruption of the Cretaceous strata in central Moresby Island, combined with the lack of stratigraphic or biostratigraphic markers, resulted in the objective of testing possible syn-Cretaceous tectonism losing relative importance.

The second field season conducted in central Moresby Island for this study was concurrent with a project initiated along the Louscoone Inlet fault system in the southern Queen Charlotte Islands (Lewis, 1991a). Lewis documented structural styles fundamentally different from those on central Graham Island. The southwest-directed shortening event apparently did not extend into the southern islands. Instead, a zone of intense north-striking, dextral faulting (the Louscoone Inlet Fault) separated a 'rigid' block to the west from an extended half-graben style region to the east. This was interpreted to be related to Tertiary tectonic activity, synchronous with the formation of the Tertiary Queen Charlotte Basin (Lewis, 1991a). Central Moresby Island represents a structural transition zone between regions dominated by the southwest-directed shortening event, such as central Graham Island, and regions which displayed dominantly Tertiary wrench fault features, such as Burnaby Island and southern Moresby Island. An additional objective for this study was formulated: to determine the relative influence of the different tectonic styles documented on central Graham Island and the southern Queen Charlotte Islands to the structural development of central Moresby Island.

3.2 Structure of the central Moresby Island area

Megascopic structures in central Moresby Island are dominated by north- and northeast-striking faults. Northwest-trending folds and northwest-striking faults are observable as both mesoscopic and megascopic features. Mesoscopic folds and faults extensively disrupt bedding locally, and as a result bedding measurements in outcrop are difficult to use to outline megascopic structures. Unequivocal offset markers are nonexistent in central Moresby Island for major faults: offset histories have occasionally been constructed from extrapolation of movement histories of geometrically similar faults observed in outcrop. Major structural features are inferred from outcrop distribution, except for rare occurrences where they can be observed directly. Confidence levels for contact relationships in central Moresby Island are, of course, directly proportional to outcrop density. The space between outcrops ranges from tens of metres in recently logged areas, to hundreds of metres. Minor faults are ubiquitous in all lithologies, megascopic structures are only interpreted when they best explain outcrop distribution. Strain accommodation in central Moresby Island is very inhomogeneous – areas of intense deformation alternate abruptly with relatively undeformed strata, and areas of intense strain often coincide with volumetrically significant intrusions which both alter the lithologic characteristics of host strata and obscure mesoscopic structures.

3.3 Structural Domains in central Moresby Island

Central Moresby Island is divided into three mainly fault-bound domains (western, central, and eastern), which are defined by the internal preserved stratigraphic successions (Plate 1). The western and eastern domains are characterized by rocks of the Triassic and Jurassic Karmutsen Formation and Kunga and Yakoun groups, all unconformably overlain by Tertiary volcanic rocks. The central domain contains Cretaceous rocks unconformably overlain by Tertiary volcanic rocks. The Cretaceous and the Tertiary strata unconformably overlie the Jurassic Sandilands Formation and Yakoun Group at the mouth of Sewell Inlet and in the southern region.

3.4 Domain Boundaries

Domain boundaries are generally defined by faults or inferred fault systems, some of which are informally named (Plate 1). Tectonic activity on these faults is thought to have resulted in differential preservation of the stratigraphic sequence within each domain. The boundary separating the western and central domains is defined by the inferred north-striking fault or system of faults (the Crazy Creek Fault, Plate 1) which separates Tertiary volcanic rocks unconformably overlying Triassic and Jurassic strata to the west from the area containing Tertiary volcanic rocks overlying Cretaceous lithologies to the east. This fault zone is obscured along its northern extent by Tertiary volcanic rocks, and contact relationships do not indicate whether this fault cuts the base of the Tertiary volcanic rocks or is restricted to pre-Tertiary strata.

The northern boundary between the central and eastern domains is defined along northeast- and north-striking, steeply-dipping faults which separate Cretaceous strata to the north from Tertiary strata to the south. The position of the western edge of the eastern domain is the north-striking Boundary Fault which can be constrained along its southern extent, where it separates Cretaceous Longarm Formation to the west from the

Triassic Karmutsen Formation. The northern extension of this fault can be inferred with varying degrees of confidence: the Cretaceous Haida Formation is separated from the Sandilands Formation along Pacofi Creek (Plate 1). To the south of the eastern domain, apparent offset on faults is less, and the domain boundary is consequently poorly defined. It is arbitrarily defined in a southeast-trending lowland covered mainly by Quaternary alluvium.

3.5 Structure of the eastern and western domains

The eastern and western domains are characterized by Triassic and Jurassic rocks of the Karmutsen Formation, and the Kunga and Yakoun groups, all overlain by Tertiary volcanic rocks. In the western domain, oldest lithologies are exposed in the northwest area, and strata progressively young to the south. This regional southern tilt is consistent with southeast-plunging megascopic structures, such as the Newcombe Inlet Anticline (Plate 1), but is seldom reflected by mesoscopic structures or regional bedding measurements. Tertiary volcanic rocks crop out extensively in the northern region, where they unconformably overlie all lithologies except the Yakoun Group. The Tertiary strata are consistently tilted $20° - 40°$ to the north and northwest.

The eastern domain displays no such southerly regional tilting of the oldest lithologies; instead, the Karmutsen Formation, and the Kunga and Yakoun groups are faulted along north, northeast, and east-striking faults. Tertiary volcanic rocks are abundant in the eastern domain, and are consistently tilted $20° - 40°$ to the north or northwest. The basal contact does not demonstrate a regional northerly tilting; this is thought to reflect tilting and extension being accommodated by abundant closely-spaced normal faults with moderate offsets that are not observable in the field.

Structures in both domains are dominated by north- and northeast-striking faults, with faults of other orientations being subordinate. These faults are mappable in the

Triassic and Jurassic lithologies based on offsets of the well-defined stratigraphy. In Tertiary rocks, movement histories along faults are much less constrainable - the stratigraphy is not well understood, and sparse outcrop density often prevents determining if the basal contact is offset. Map-scale faults in Tertiary rocks are therefore only inferred if offset of the basal contact can be documented beyond reasonable doubt. Mesoscopic faults of different orientations are ubiquitous in all lithologies, folds are not identified in Tertiary strata.

3.5.1 Faults

Northerly-striking faults

The Newcombe Inlet fault zone

The Newcombe Inlet fault zone (Plate 1) is exposed at the head of Newcombe Inlet, where anastomosing north-striking fault surfaces bound slivers of the Sandilands and Peril formations between Karmutsen Formation to the east and Sadler Limestone to the west. The fault-bound slivers are intensely and disharmonically folded, minor fold axes are both subhorizontal and subparallel to the fault zone, and are vertically- to north and south shallowly-plunging, and associated axial planar surfaces are subparallel to the fault zone boundaries (Figure 3.1). Karmutsen Formation rocks adjacent to the fault zone contain weakly-developed, north-trending, steeply-dipping foliation defined by the parallel preferred orientation of chlorite.

The Blunt Point fault

The Blunt Point fault is a steeply-dipping, north-striking fault approximately three kilometres east of the Newcombe Inlet fault zone (Plate 1). It extends for at least five kilometres north from Blunt Point on the northeast side of Newcombe Inlet and appears as a steep-walled valley where the fault has weathered recessively. Rocks within

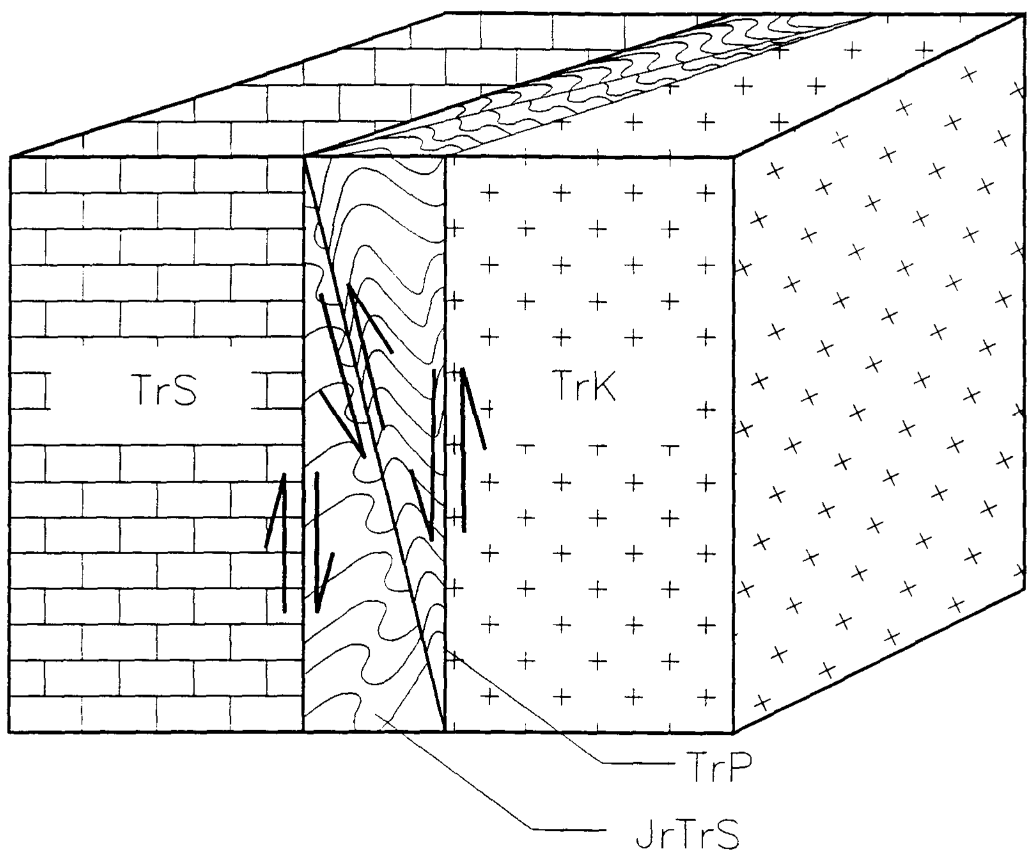

Figure 3.1: *Sketch showing fault styles in Triassic and Lower Jurassic strata where fault surfaces bound intensely folded slivers of limestone and argillite, head of Newcombe Inlet. Modified from Lewis and Ross (1991).*

the fault zone are not exposed (Figure 3.2). At its northern known extent the Blunt Point fault separates Sadler Limestone to the east from Sandilands Formation to the west. North-trending slivers of Karmutsen Formation and steeply-dipping Sadler Limestone are bound by northern fault splays. No mesoscopic structures within these slivers can be attributed to activity along the fault. Farther north, this fault is covered by, or occurs within, Tertiary volcanic rocks; offset of the basal Tertiary contact is indeterminate.

The Tasu Creek fault

The Tasu Creek fault occurs in the northern part of the western domain. At its southern extent, it forms a valley within Tertiary volcanic rocks. Along the central extent, it separates basalts of the Karmutsen Formation (west) from Tertiary pyroclastic rocks (east), and truncates two northeast-striking faults (Plate 1). At the northern limit of the study area, this fault separates Sandilands Formation to the east from Karmutsen Formation to the west. Within the creek bed of Tasu Creek, extensive Tertiary intrusive bodies crop out.

The Boundary fault

The Boundary fault (Plate 1) defines the north-trending boundary separating the central and eastern domains and extends a minimum of five kilometres. Apparent offset is best constrained along its southern extent, where it separates Cretaceous Longarm Formation on the west from the Triassic Karmutsen Formation. The Karmutsen

Formation occurs east of and approximately 150 metres topographically above the Cretaceous rocks. The Karmutsen Formation at this location is the glomeroporphyry lithofacies, which Sutherland Brown (1968) suggests occurs some 60 – 150 metres below the stratigraphic top of the Karmutsen Formation throughout the Queen Charlotte Islands. If his stratigraphy is regionally applicable, minimum apparent offset includes

Figure 3.2: *The Blunt Point Fault is a steep walled topographic lineamint which separates Sadler Limestone to the west from Sandilands Formation to the east. Photograph is looking north.*

the stratigraphic thickness represented by the top of the Karmutsen Formation, and the Kunga Group and Yakoun Group present before deposition of the Cretaceous strata, as well as the offset of Tertiary strata. More apparent offset is inferred within Triassic to Cretaceous strata than within Tertiary strata, and Cretaceous strata is only observed west of the fault, indicating tectonic activity on this fault both before and after deposition of Tertiary volcanic strata.

North-striking faults in the eastern domain

Other megascopic north-striking faults are constrained by outcrop distribution in the eastern domain. They occur approximately 750 – 1500 metres apart, and in at least one location demonstrably cut the basal Tertiary contact. Outcrop distribution is consistent with these faults having a steeply- to vertically-dipping attitude. These faults are interpreted to truncate northeast-trending contacts and faults. Mesoscopic north-striking faults are common in outcrop, where they are steeply to vertically dipping. Tertiary intrusive bodies are commonly associated with these faults.

Northeast-striking faults

The second most predominant set of faults within the western and eastern domains is northeast striking, and is inferred to be southeasterly dipping. Faults of this set are rarely observed in the field, and fault positions are determined through distribution of outcrops. Fault geometry is interpreted to be the same as uncommon south-dipping mesoscopic faults with the same strike orientation observed in outcrop.

The Dass Creek fault

The Dass Creek fault intersects the study area in the northern part of the western domain (Plate 1). It separates hornfelsed Sandilands Formation to the north from Tertiary rocks to the south. It is observable in air photographs as an obvious topographic lineament, extends to some ten kilometres northeast of the study area, and terminates where it intersects Carmichael Inlet (P.D. Lewis, personal communication, 1990).

Northeast-striking faults within the western and eastern domains

Other northeast-striking faults are mapped east and west of Newcombe Inlet. They are generally inferred from outcrop distribution; however, north of Two Mountain Bay, they can be mesoscopically observed separating Jurassic Yakoun Group rocks from Sandilands Formation strata, with vertical offsets of tens of metres. The majority of these mesoscopic faults have normal, south-side down offset, but rare northwest-dipping, north-side down faults are also observed. Northeast-striking faults in the eastern domain are interpreted to be truncated by north-striking faults based on outcrop distribution. Megascopic faults are not interpreted to cut Tertiary strata – this may be an artifact of the lack of stratigraphic control in Tertiary strata. Mesoscopic northeast-striking faults are rarely observed in outcrop.

Northwest-striking faults

The third orientation of faults in central Moresby Island occurs mainly in the western domain, and are best exposed west of Newcombe Inlet. These faults are northwest-striking, and shallowly- to moderately-dipping. They are best exposed west of McAlmond Point, where they place Sandilands Formation over Yakoun Group with several metres to tens of metres of offset. These faults are also observed in outcrop within the Sandilands Formation and Peril Formation, where they form layer-parallel slip and ramp thrust faults. Sense of movement is generally top to the southwest, however, both senses of vergence occur.

A megascopic northwest-striking fault occurs west of and parallel to Newcombe Inlet. It is best constrained at its southern extent by outcrop distribution; Sandilands Formation occurs topographically above Yakoun Group exposed along the shore. This fault is poorly constrained along its northern extent, and map pattern interpretation suggests this fault is steeply-dipping.

3.5.2 Folds

Two orientations of folds occur within Kunga and Yakoun group strata: a dominant set with northeast-trending axial traces is evidenced by mesoscopic folds, stereonet plots, and regional dips both east and west of Newcombe Inlet. A second set of folds with northwest-trending fold axes is observable in disharmonically folded outcrops, and inferred by stereonet plots of Kunga Group bedding. This second set of folds is not considered important to the development of megascopic structures. No folding is observed in Tertiary strata.

Northwest-trending folds

The Newcombe Inlet anticline

The best exposed northwest-trending megascopic fold is the Newcombe Inlet anticline, exposed on the northeast shore of Newcombe Inlet. The Newcombe Inlet anticline folds strata of the Sadler Limestone and the Peril and Sandilands formations about a southeast-plunging fold axis. Bedding within the Sadler Limestone is exposed at sea level along the shore of Newcombe Inlet where it is steeply dipping to vertical. Approximately one kilometre farther east, the Sadler Limestone dips 25° – 35° south to southeast at an elevation of 150 metres, thus providing a unique indication of the magnitude of megascopic folds in central Moresby Island. The eastern limb of this parallel fold may be only partially exposed, and the interlimb angle subtends approximately 60°. The wavelength and amplitude of this structure cannot be determined, both the eastern and western limbs have been disjoined by north-striking faults. Although no sense of asymmetry is obvious, the steeply-dipping western limb suggests southwest vergence. This anticline, together with the Newcombe Inlet fault zone, defines a lobate/cuspate geometry.

Mesoscopic folds with northwest to west-northwest-trending axial traces within the study area are concentrated in zones of more intense deformation, and are limited to the Peril Formation, the Sandilands Formation, and the Yakoun Group. Intensity of folding varies within these units: Kunga Group lithologies are characterized by tight to open, upright to overturned buckle folds, Yakoun Group rocks are gently warped and upright. Characterization of buckle fold profiles typically correspond to 1B to 1C type folds of Ramsay (1967; Figure 3.3), and range from tightly folded chevron folds to rounded and open concentric folds, and rare isoclinal folds with rounded hinge zones. The wavelength of folds within the Sandilands Formation is generally within the metre to ten metre range, and fold amplitude is commonly a metre to several metres. Overprinting of these features by northeast-trending folds forms disharmonic structures.

Both northeast- and southwest-verging folds occur within the western and eastern domains, with southwest-verging ones being the most common. This is reflected in the weakly defined concentration of poles to bedding in the northeast quadrant of the stereonet plot for bedding both west of Newcombe Inlet, and in the eastern domain (Figures 3.4 and 3.5).

Mesoscopic chevron folds are often associated with ramp and layer parallel slip structures, and northwest-striking thrust faults are occasionally folded, indicating a genetic link between folds and faults of this orientation (Figure 3.6).

Northeast-trending folds

Northeast-trending folds in Kunga and Yakoun group lithologies are evidenced by rare open folds and by superposition of northeast-trending folds on northwest-

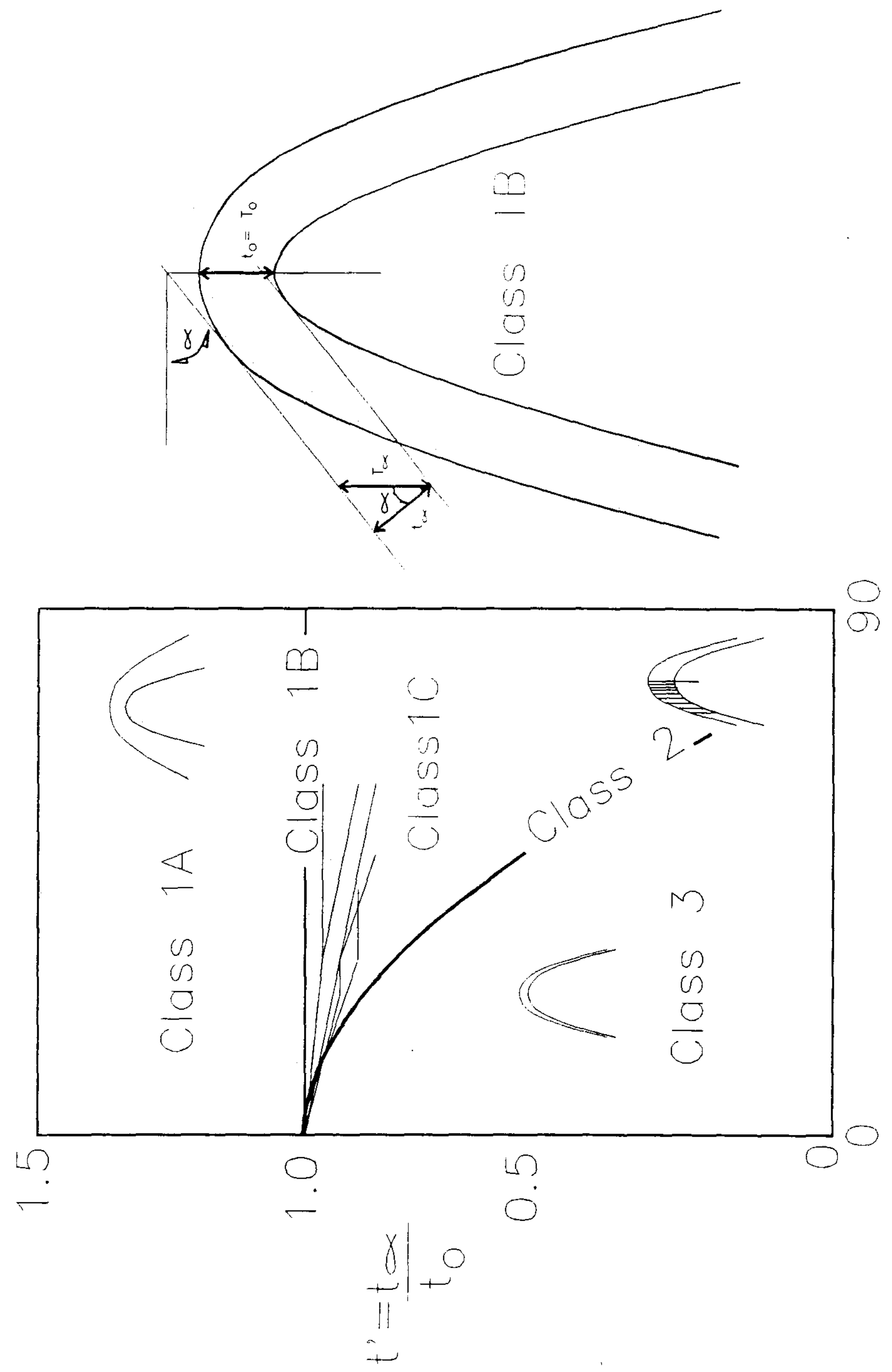

Figure 3.3: *t' vs. α plot showing variation of layer thickness within folds of Kunga Group lithologies. All plot in the 1C field, corresponding to moderate thickening of hinge zones.*

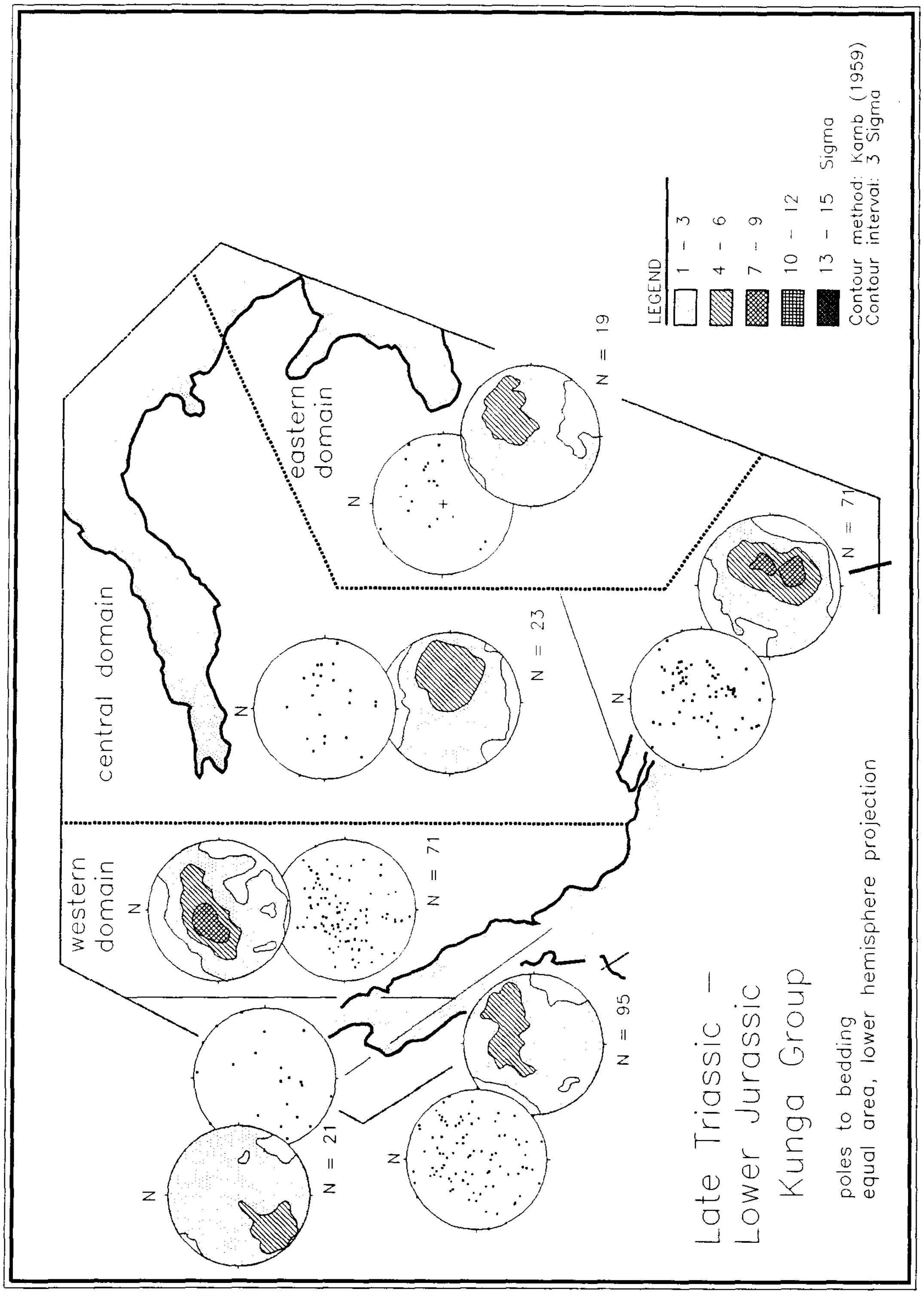

Figure 3.4: *Stereographic plot of poles to bedding for Kunga Group strata, see appendix B for statistical data.*

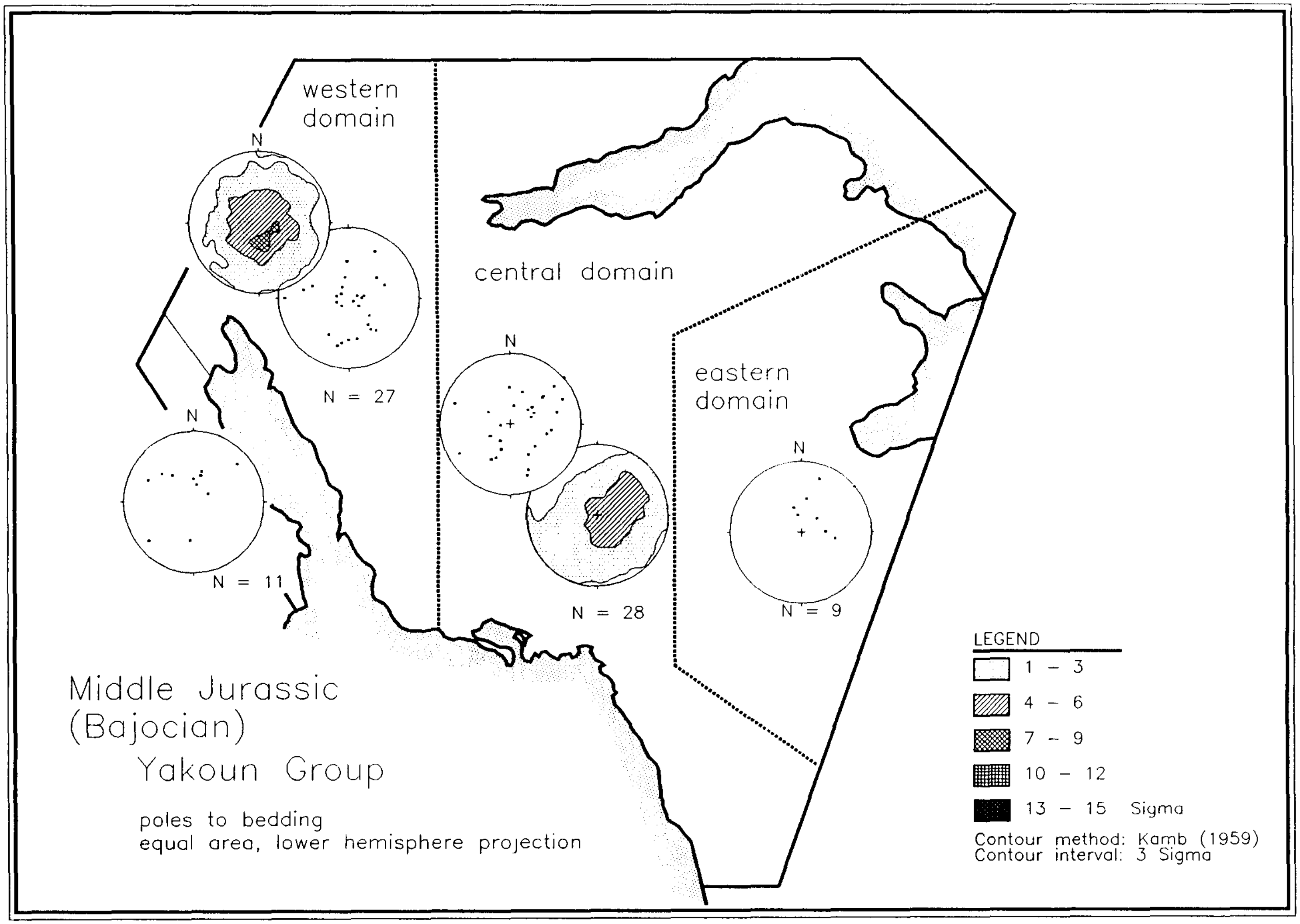

Figure 3.5: *Stereographic plot of poles to bedding for Yakoun Group strata, see appendix B for statisitical data.*

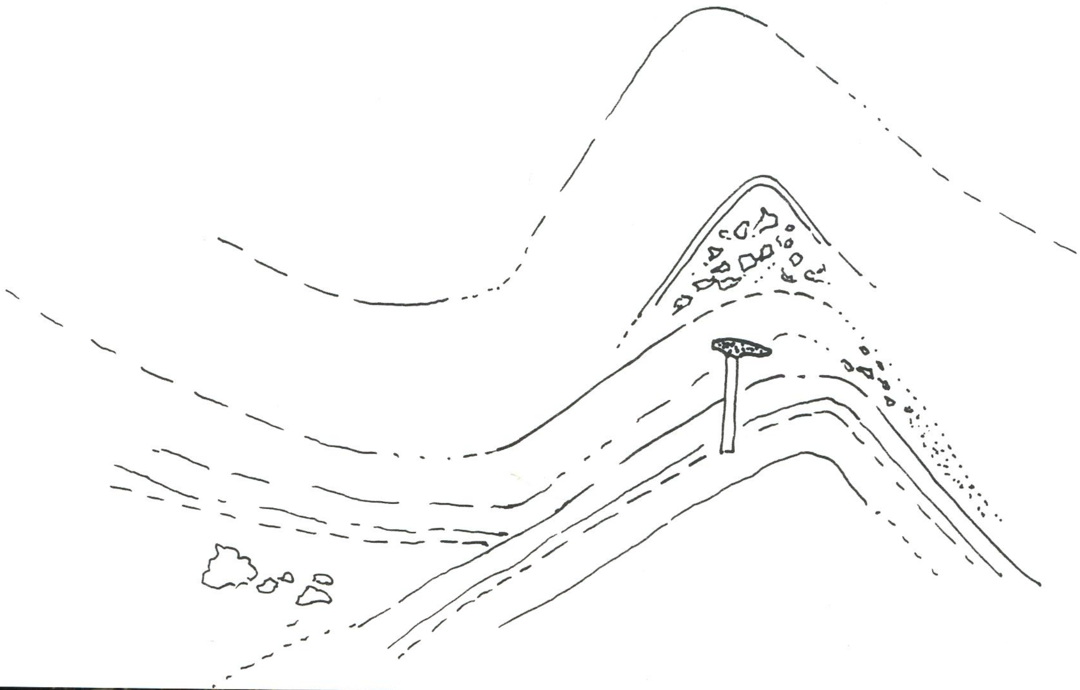

Figure 3.6: *Top to the northeast thrust fault is refolded about northwest trending fold axis. Plane of photograph is approximately 040°, west of Newcombe Inlet. Estimated amount a shortening from bed length measurements is 25%, no attempt was made to estimate shortening accommodated by the fault.*

trending folds. The significant variation in bedding orientations, observable in the field and on stereonet representations, reflects the superposition of the two orientations of folds.

3.6 Structure of the Central Domain

Rocks of the Cretaceous Haida, Skidegate, Longarm, and Honna formations are exposed in the central and northern parts of the central domain, where they unconformably overlie "basement" rocks of the Sandilands Formation and the Yakoun Group. The oldest basement strata are exposed at the mouth of Sewell Inlet in the northern area of the central domain, and stratigraphic exposure youngs to the south, analogous to the trend for the same stratigraphic level in the western domain. In general, the oldest Cretaceous strata (the Hauterivian Longarm Formation) are exposed south and west of younger Cretaceous formations (Plate 1), and Cretaceous rocks young to the north. Turonian turbidites of the Skidegate Formation occur south of Sewell Inlet (Haggart, 1991) and thick accumulations of Honna Formation sandstones and conglomerates (undated) occur stratigraphically above the Skidegate Formation north and south of Sewell Inlet. This northerly-younging trend is consistent with the northerly dips commonly found in Cretaceous strata south of Sewell Inlet, and with the north and northeast-plunging fold axes common in folded Cretaceous rocks.

Faults are the most common structures in Triassic and Jurassic strata. Mesoscopic faults are ubiquitous and commonly associated with intrusive bodies, megascopic faults are inferred on the basis of outcrop distribution. No megascopic folds are interpreted in the Kunga or Yakoun Group strata. Mesoscopic folds are locally abundant, and considerable variation in bedding orientation exists throughout the central domain.

The Cretaceous succession is characterized by stratigraphic repetition of lithologies and interfingering facies relationships. With the exception of the Longarm

Formation, no unequivocal stratigraphic markers exist, such as the easily recognizable formational contacts in Triassic and Jurassic strata. It is therefore likely that the number of faults, and their offsets are under represented and underestimated respectively. For this reason, structures in the central domain will be discussed according to stratigraphic levels in which they occur. Tertiary strata in the central domain consistently tilt 20° – 40° to the north or northeast. Tertiary strata are not folded, but are commonly faulted.

3.6.1 Faults

Faults in Triassic and Jurassic strata

Structures in Kunga and Yakoun group strata exposed in the central domain are dominated by north- and northwest-striking faults. North and east of Barrier Bay, relatively planar Sandilands and Yakoun group strata are faulted along northeast-striking, steeply south- or rare north-dipping surfaces, which are interpreted on the basis of stratigraphic distribution to represent south-side and north-side down movement respectively. These faults are observed on the mesoscopic scale, and are inferred on the megascopic scale by outcrop distribution. Rare northwest-striking faults are observed in outcrop, and a megascopic fault is inferred north of Barrier Bay, based on outcrop distribution and stratal dips. East of Wilson Bay, mesoscopic faults are dense, exhibit a random orientation, and are generally cospatial with intrusive bodies.

Faults in Cretaceous and Tertiary strata

Two major fault sets occur in Cretaceous and Tertiary strata: northeast-striking, steeply-dipping, south-side-down faults, and north-striking, steeply-dipping faults. These megascopic faults are entirely inferred from outcrop distribution. In general, the northeast-striking set is truncated by the north-striking set on both mesoscopic and megascopic scales, however the reverse relationship is rarely observed. Mesoscopic faults are rare – intrusive bodies often obscure probable fault zones, and bedding is commonly rotated parallel to intrusive contacts. A megascopic north-striking fault occurs north of Sewell Inlet along Waterfall Creek, where it separates Tertiary strata to the west from hornfelsed Cretaceous strata to the east. Intrusions of magmatic material are abundant on this fault, bedrock in Waterfall Creek is almost entirely composed of Tertiary intrusions. The second megascopic fault occurs in the central part of the central domain, where it offsets the basal Tertiary contact. It is interpreted to dip to the southeast, and based on mesoscopic fault geometries, the simplest offset history involves south-side-down movement. This fault is aligned with a fault of the same orientation to the northeast, and these two may form a single continuous feature.

3.6.2 Folds

Folds in Triassic and Jurassic strata

Kunga Group strata in the central domain exposed at the head of Sewell Inlet are inhomogeneously deformed. South of Sewell Inlet, quarry exposures show moderately easterly-dipping strata of the Sandilands Formation with no evidence of folding, faulted against Yakoun Group strata exposed to the west along a steeply-dipping north-trending fault. The Peril Formation exposed approximately 500 metres east display an intensely folded anticline with steeply-dipping north-trending cataclastic faults in the core (Figure 3.7). This inhomogeneous partitioning of strain is typical of structural styles developed within the study area. Lack of exposure between outcrops precludes more detailed analysis of strain partitioning.

East of Thorsen Creek and south of Sewell Inlet rocks are chaotically deformed, and are commonly steeply dipping. Adjacent to megascopic north-striking faults, bedding is steeply dipping to overturned, and strikes are parallel to fault traces. Intrusions obfuscate structures.

Figure 3.7: *Intensely folded and faulted strata in the core of an anticline, south of Sewell Inlet. Fault zones are north-trending, folds are about both northwest- and northeast-trending axis. Plane photograph is approximately 090°.*

Folds in Cretaceous strata

Folds in Cretaceous strata south of Sewell Inlet are characterized by broad, megascopic warps with north to northeast-trending axial traces. Fold hinges are not exposed, fold geometry is inferred from stratal dips and rare formational contact relationships. The trends interpreted for these megascopic features are corroborated by stereonet data (Figure 3.8).

Strata exposed in Thorsen Creek south of Sewell Inlet have consistent north and northeast dips of 30° – 50° for over a kilometre, and are interpreted to represent the east limb of a megascopic north- to northeast-trending and north to northeast-plunging anticline - syncline pair with a wavelength of approximately one to two kilometres (Plate 1). A northeast-trending fold on the north shore of Trotter Bay is defined by both contact relationships between the Honna and the Skidegate formations and bedding orientations. South of Sewell Inlet, contact relationships between the Honna Formation and the Skidegate Formation, and bedding orientations commonly trend northeasterly and are parallel to both fold axial traces, and megascopic faults. Whether the Trotter Bay structure represents the north limb of a macroscopic fold that has been subsequently bisected by the northeast-striking fault, or bedding rotated parallel to the fault in response to movement along it is unclear.

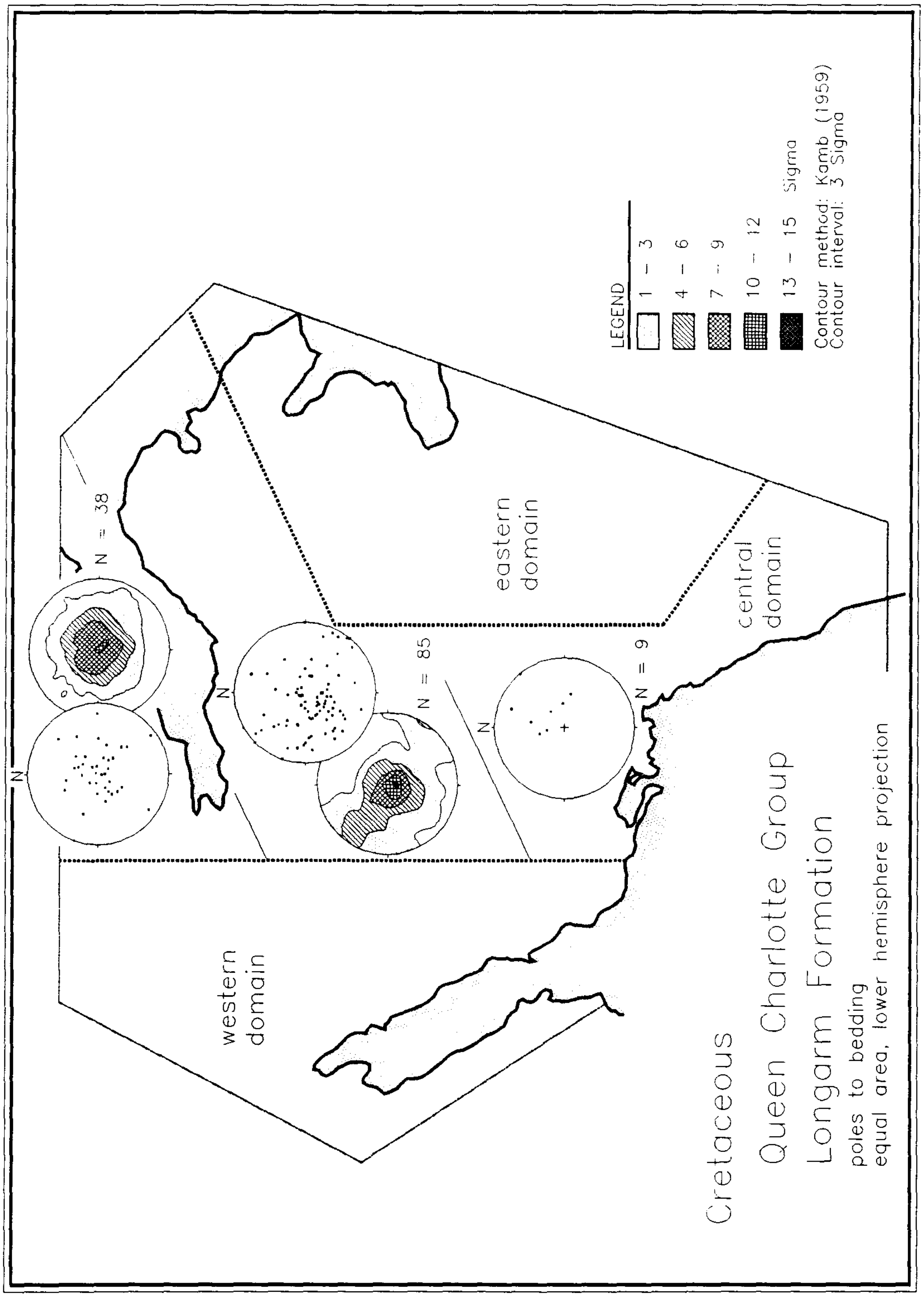

Figure 3.8: *Stereographic plot of poles to bedding for Cretaceous strata, see appendix B for statistical data.*

4 STRUCTURAL SYNTHESIS FOR CENTRAL MORESBY ISLAND

4.1 Introduction

This chapter presents interpretations that are derived from research completed in central Moresby Island for this study. No reference to, or comparison with, other work is made with the exception of ages of units determined from paleontological evidence in central Moresby Island, which help constrain the timing of deformation events. Events described in this chapter will be integrated with regional models in chapter 5.

Five deformation events can be constrained by geological relations in central Moresby Island. The earliest recognized event is characterized by northwest-trending folds and faults, and is marked by the pre-Yakoun Group unconformity. The second involves block faulting constrained to post-Yakoun Group and pre-Longarm Formation deposition. Post-Cretaceous folding characterized by open northeast-trending structures is evidence for a third deformation event. Post-Cretaceous block faulting represents the fourth recognizable event, and normal block faulting and tilting of Tertiary strata mark the fifth event.

4.2 Middle Jurassic Deformation: northeast-directed shortening

The earliest recognized event in central Moresby Island is characterized by northwest-trending flexural slip folds and contractional faults, and by steeply-dipping northeast-trending (transfer ?) faults in the Karmutsen Formation, and the Kunga and Yakoun Group rocks. Kunga Group strata have accommodated more shortening than those of the Yakoun Group. Vergence of folds is dominantly to the northeast.

The Middle Jurassic deformation event is marked most notably by the pre-Yakoun Group angular unconformity, which separates moderately- to steeply-dipping beds of the Sandilands Formation from the overlying, relatively undeformed Yakoun Group strata. The youngest Sandilands Formation rocks in central Moresby Island are Sinemurian, Yakoun Group strata are Bajocian. Rocks of the Yakoun Group are only observed overlying Sandilands Formation rocks, never older strata. Folds within the Yakoun Group are open northwest-trending structures, coaxial with the older structures. This suggests the deformation event lasted into, or was reactivated syn- or post-Yakoun Group deposition.

Structures in the Kunga Group strata formed during this event are inhomogeneously distributed. Areas of intensely folded and faulted strata alternate with relatively unfolded strata. Areas of most intense folding may be the surface expression of steeply-dipping reverse faults in basement rocks. Northeast-vergence of folds in Kunga Group cover strata suggests faults in basement strata may be southwest-dipping (Figure 4.1), but are not mappable due to lack of exposure and stratigraphic markers in the Karmutsen Formation.

Fold geometry in Kunga Group strata varies according to lithology, and is controlled by layer thickness. In the thickly-bedded Sadler Limestone, flexural slip folds generally have rounded profiles. Thinly-bedded limestones and argillites exhibit chevron to round folds.

The ductility contrast between the Karmutsen Formation basement and the Kunga Group cover has resulted in a regional cuspate/lobate structural geometry along the junction between basement and cover. To the west of the axial trace of the anticline, the cuspate closure at the head of Newcombe Inlet contains slivers of sheared Sandilands Formation strata. This geometry is never observed within rocks younger than Sandilands Formation, and the timing of the shortening event which formed these structures is thus thought to predate Yakoun Group deposition.

Figure 4.1: *Schematic diagram illustrating how the geometry of basement structures within the crystalline Karmutsen Formation controls vergence of structures developed in the stratified Kunga Group. Adapted from Gratier and Viallon, 1980.*

Regional strain is difficult to quantify, but several different methods can be used to make strain measurements, and derive maximum and minimum values for strain experienced by rocks locally. The first is to palinspastically restore local sections from photographs and field sketches, and the second is to measure strain directly from deformed strain markers. This results in two 'types' of strain being analyzed: restored sections reveal strain magnitudes accommodated by layer parallel slip and folding mechanisms, whereas deformed strain markers record finite strain suffered on the grain and subgrain scale. Several field book sketches and photographs of structures in Kunga Group strata have been restored and the results compiled in figure 4.2. Rare ammonites molds found in situ record finite strain of the host rock, and two measurements have been included 4.3.

4.3 Post-Yakoun Group deposition, and pre-Cretaceous deposition: block faulting

A post-Yakoun Group deposition and pre-Cretaceous deposition faulting event is evidenced in central Moresby Island. The Cretaceous succession lies unconformably on either Kunga Group strata, or Yakoun Group, indicating uplift of discreet fault bound blocks, and the stripping of Yakoun Group strata from the elevated fault bound areas. An alternative explanation, that Yakoun Group strata was originally inhomogeneously distributed is not supported. Original depositional edges should show facies changes towards thicker depocentres, a trend not noted in the central Moresby Island area. Instead, thick accumulations of tuff, shale and other lithologies end abruptly at faults (Figure 4.4). These faults are overlapped by Hauterivian Longarm Formation, a relationship directly observable in the field north of Two Mountain Bay. North-trending faults are the dominant block -bounding structures, northwest trending faults were likely also active at this time. Northwest-trending faults are common to Karmutsen Formation, Kunga Group, and Yakoun Group strata, and are rare in Cretaceous or Tertiary strata.

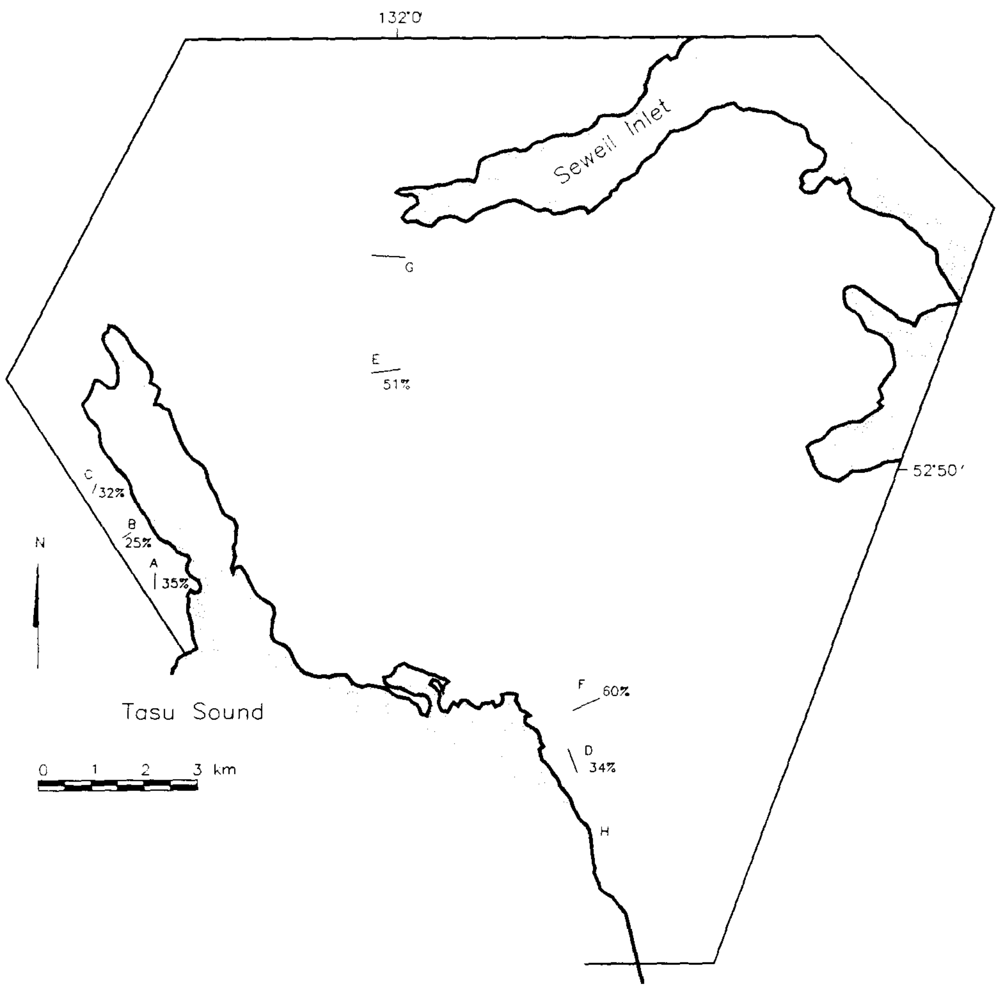

Figure 4.2a: *Estimated amounts and directions of shortening within Kunga Group strata in the central Moresby Island area. The planes of the photographs in figures 4.2b - f are perpendicular to the dominant fold axis and parallel to the shortening direction, unless otherwise indicated. All shortening estimates are based on bed length measurements only. Photographs of individual outcrops on following pages illustrates wide variation in fold styles throughout the area.*

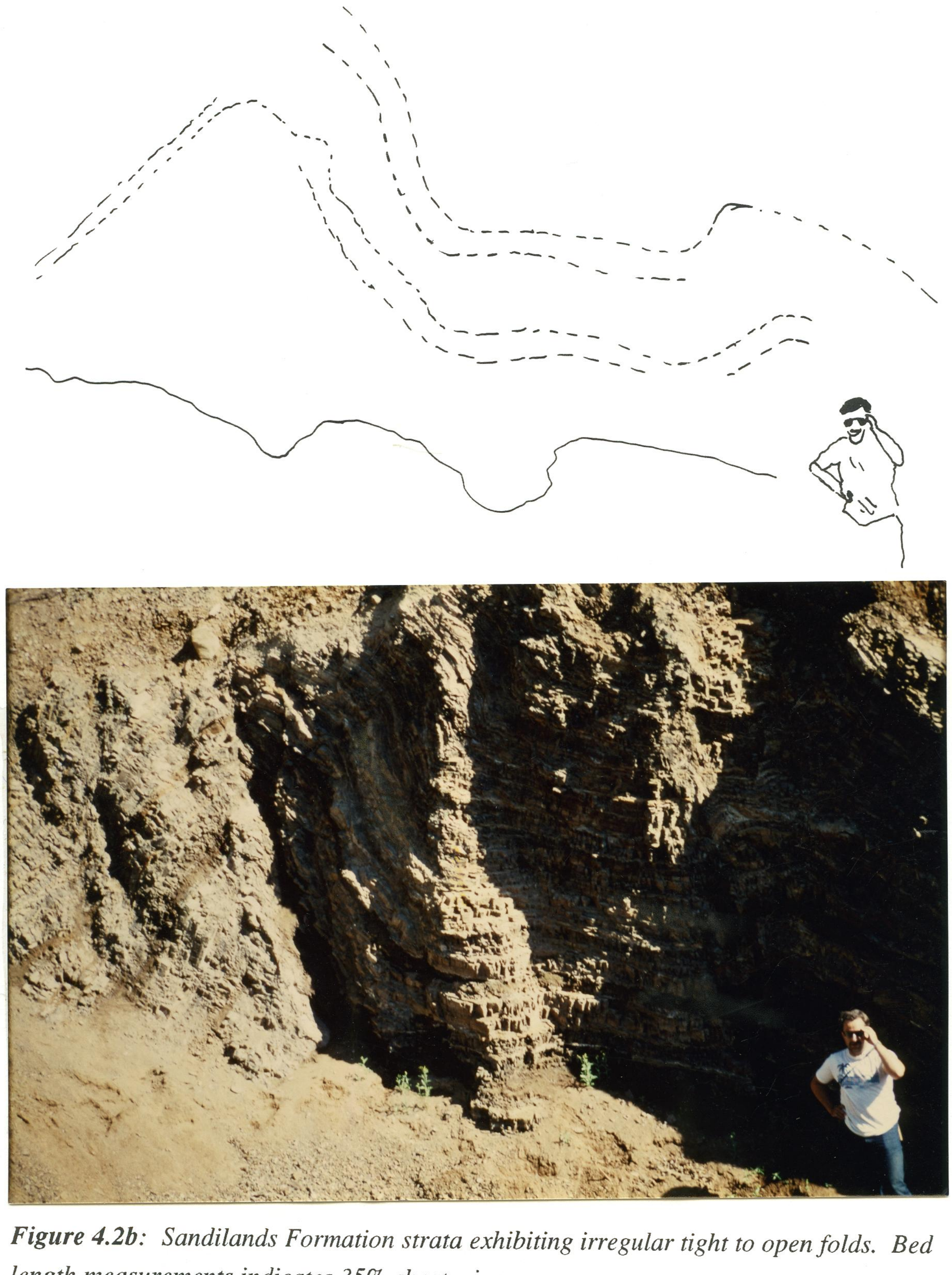

***Figure 4.2b**: Sandilands Formation strata exhibiting irregular tight to open folds. Bed length measurements indicates 35% shortening.*

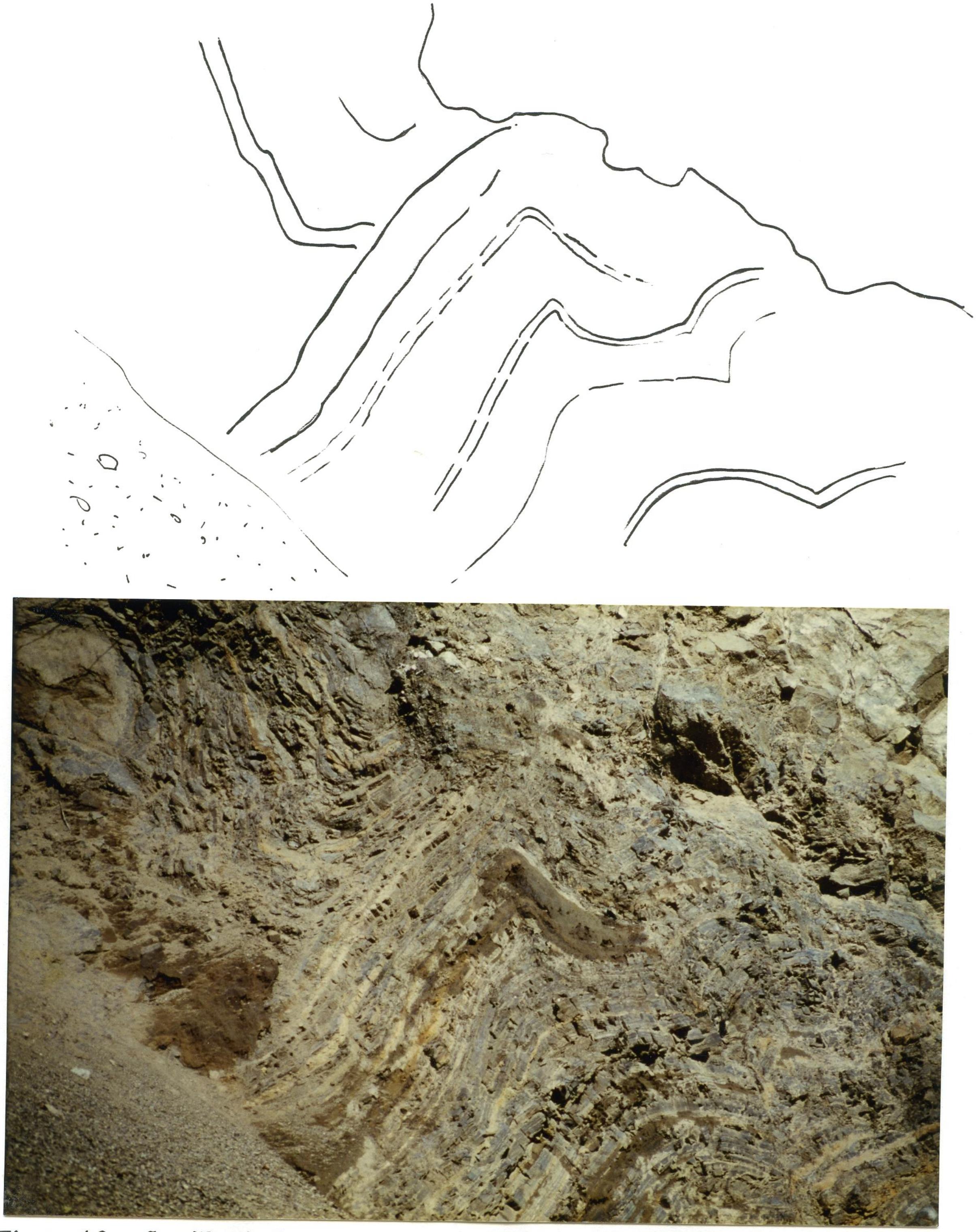

Figure 4.2c: *Sandilands Formation strata exhibiting irregular tight to open folds with both rounded and angular hinge zones. Folds in this diagram plotted within the 1C category in figure 3.3. Bed length measurements indicates 32% shortening*

Figure 4.2d: *Sandilands Formation strata exhibiting chevron to round folds with contractional fault surfaces parallel to axial planes. Photograph is approximately 10 metres across. Bed length measurements indicates 51% shortening, no attempt was made to estimate shortening accommodated by fault surfaces.*

Figure 4.2e: *Sandilands Formation strata exhibiting open fold with rounded hinge zone. Bed length measurements indicates 35% shortening. Fold in this diagram plotted within the 1C category in figure 3.3.*

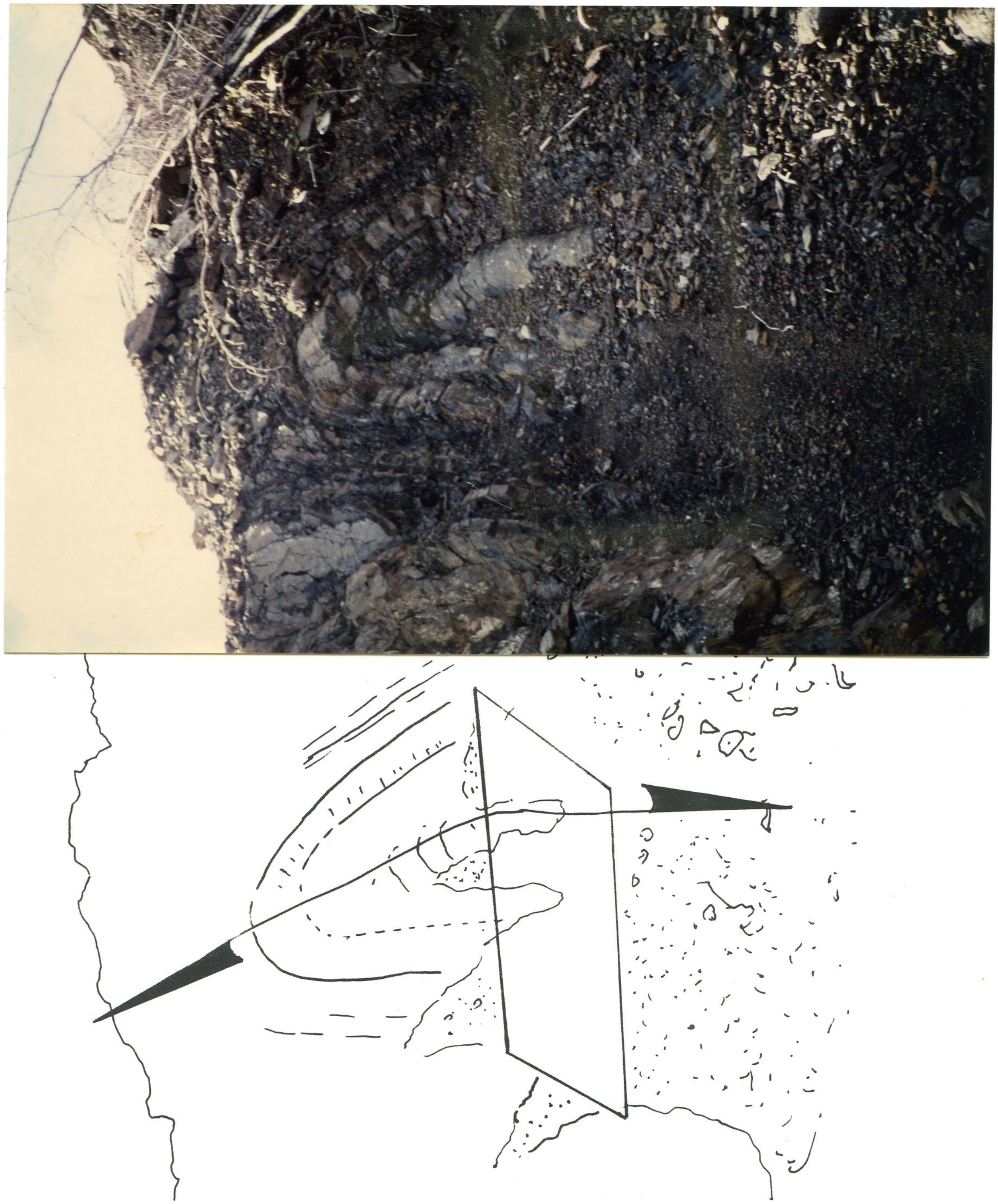

Figure 4.2f: *A rare field example of a tight fold with a northwest-trending axial plane refolded about a northeast-trending axial surface. Northwest-directed shortening estimated from bed length measurements is 60%. This photograph is facing southeast*

Figure 4.3: *East-trending fault separating the debris flow lithotype (left) from the lapilli tuff lithotype of the Yakoun Group. Fault zone has been intruded by a felsic and presumably Tertiary dyke.*

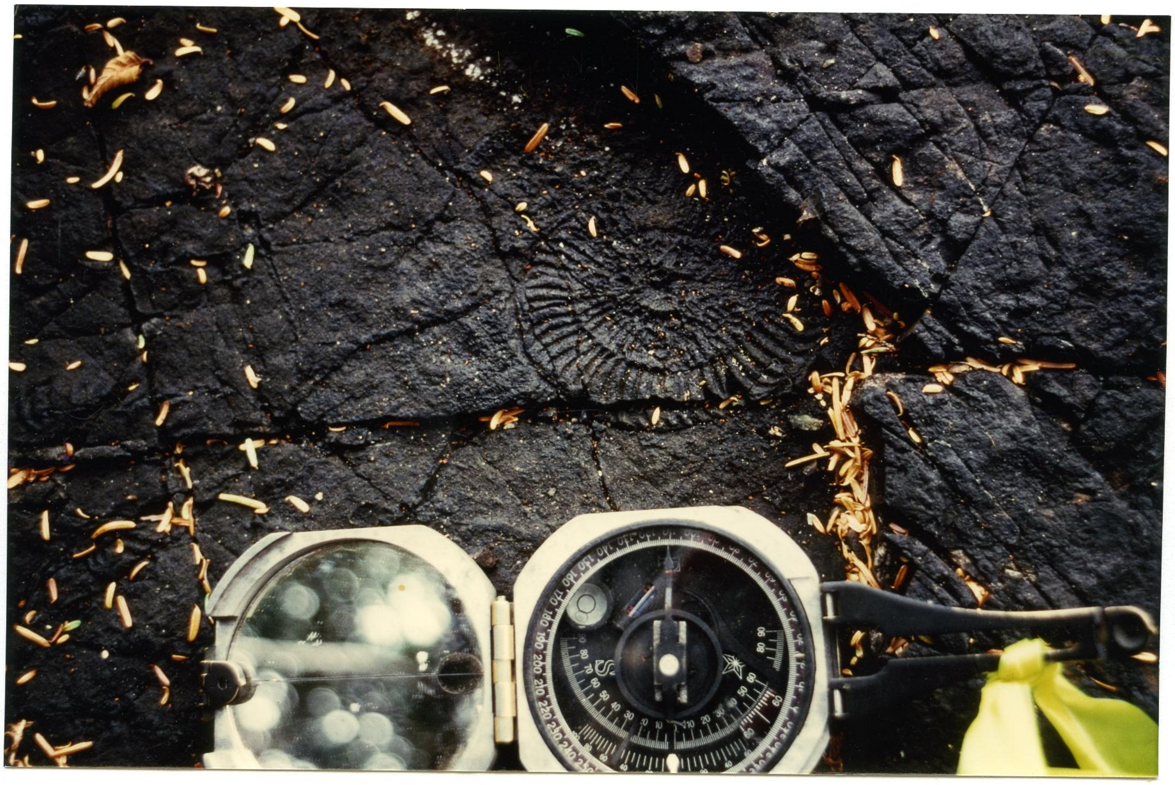

Figure 4.4: *Deformed ammonite in the Sandilands Formation shows evidence of mesoscopic layer parallel shortening. Strain ratio $1+e_1/1+e_3 = 1.31$. Rare deformed ammonites indicate that shortening by mechanisms other than folding and faulting occurs locally.*

4.4 Syn-Cretaceous Tectonism

No direct evidence either supporting, or refuting the presence of syn-Cretaceous tectonic activity was discovered. Indirect evidence for tectonism during Honna Formation deposition exists, however. Large angular blocks of fragile *Monotis*-bearing Peril Formation are found within the Honna Formation conglomerates, suggesting a nearby uplifted point source for Kunga Group strata. The lithologic uniqueness of the Honna Formation rocks also reveals a very different provenance from underlying Cretaceous clastic rocks. Source material for Longarm Formation sandstones is invariably locally derived, while Honna Formation sandstones contain significant quantities of quartz, including chert, that have no known source in the stratigraphy exposed in central Moresby Island. Paleocurrent vectors measured in channelized Honna Formation conglomerates in central Moresby Island indicate an eastern to southeastern source direction (Gamba et al., 1990). Rocks directly underlying Honna Formation conglomerates have been dated as Turonian by molluscan fauna (Haggart, 1991). A syn-Cretaceous tectonic event is not unequivocally supported by this study.

4.5 Post-Cretaceous deposition and pre-Tertiary deposition: folding

Cretaceous strata in central Moresby Island have been demonstrably subject to one episode of shortening, which resulted in the formation of northeast-trending open macroscopic folds. Formation of northeast-trending folds in Cretaceous "cover" strata likely occurred when contraction occurred along northeast-trending faults, already present in the older "basement" strata, analogous to the model presented for the basement control of cover folding in the Middle Jurassic shortening event. This folding is most obvious south of Sewell Inlet. North of Sewell Inlet, strata are relatively undeformed, suggesting structures in basement strata are not homogeneously distributed.

Northeast-trending folds are also present in Kunga and Yakoun Group strata, where they have been superimposed on the northwest-trending structures. As with the northwest-trending folds, these northeast-trending structures are rare, and occur only locally. They are likely the source of the significant scatter found in stereonet plots of poles to bedding for the Triassic and Jurassic units, in which northwest-trending structures are refolded about a northeast-trending fold axis.

This event also constrains the timing of the shortening event experienced by the Yakoun Group strata which studies elsewhere in the Queen Charlotte Islands have been unable to do. Structures in the Yakoun Group are coaxial with those found in the Kunga Group. Cretaceous structures trend perpendicular to those found resulting from the Middle Jurassic shortening event and no evidence for northwest-trending structures exist in Cretaceous strata . Therefore the northwest-trending folds in the Yakoun Group predate the deposition of the Cretaceous strata.

4.6 Post-Cretaceous and pre- (syn ?) Tertiary volcanic rock deposition: block faulting

Post-Cretaceous to Tertiary block faulting followed the post-Cretaceous shortening event, and is the event which defined the domains in central Moresby Island. The effect of block faulting is best illustrated by the differential preservation of Cretaceous strata. The dominating north-trending, steeply-dipping faults formed at this time, and the central domain was dropped relative to the eastern and western domains along north- and northeast-striking faults. The northeasterly-trending faults may be reactivated tear faults which were formed during the Middle Jurassic shortening event, and were reactivated during the Cretaceous shortening event. The relative amount of vertical movement was equivalent to at least the entire thickness of the Cretaceous section: no Cretaceous strata have been found in either the western or eastern domains, and all must have been eroded in this event. A regional northerly-tilting of Cretaceous strata may also have accompanied this event, leading to the preservation of the oldest Cretaceous strata are exposed in the southern and western regions of the central domain. South of Sewell Inlet, there is a consistent north to northeast tilt of $30° - 40°$, which is significantly greater than dips found commonly in Tertiary rocks.

The timing of both the onset of this event, and the preceding Cretaceous shortening event are poorly constrained. They occurred after the deposition of the Cretaceous strata, the youngest of which are at most Turonian in age. It is possible that the contractional event and the block faulting event occurred in reverse order to that stated here, there are no data which allow the certain determination of order in central Moresby Island. The simplest constructible geologic history would have the shortening event prior to the onset of block-faulting. This is supported by the linear traces of the north-trending fault traces which extend over several kilometres, and appear to be unaffected by a later contractional deformation event.

4.7 Syn (?) to post-Tertiary deformation: block faulting and extension

Youngest faults in the central Moresby Island area cut and offset the base of the Tertiary succession. Lithologic evidence suggests both Paleogene and Neogene Tertiary volcanic rocks are present in central Moresby Island. Constraining tectonic activity in Tertiary rocks is problematic – the pre-Tertiary unconformity was not likely horizontal, and exposure in Tertiary rocks is poor, even relative to general levels of exposure in central Moresby Island.

North- and northeast-trending faults are both present in the Tertiary rocks in central Moresby Island. The basal contact of the Tertiary succession is demonstrably offset in several areas. Neogene "Masset Formation" rocks in the central domain are at the same elevation and only several hundred metres from Paleogene strata across the

Boundary fault. The most compelling evidence for post-Tertiary tectonism is the north- to northwest-tilting, ubiquitous in Tertiary strata.

The gentle north- and northwest-tilting of the Tertiary strata combined with the northeast-trending, southerly-dipping, and south-side-down normal faults are indicative of a south-directed, asymmetric extension, and block rotation, analogous to domino style or bookcase faulting, which occurred after the deposition of the Tertiary strata.

Two sets of dykes, defined by orientation, intrude all lithologies including the Tertiary volcanic rocks. One set of dykes trends $080° - 120°$ and is generally steeply to shallowly southerly-dipping. This set is most common in the western domain. The other set is steeply-dipping, trends $340° - 010°$, and occurs mainly in the western domain. Dykes locally compose up to 80% of the rock volume in outcrop.

5 REGIONAL SYNTHESIS

5.1 Introduction

The most recent synthesis of the regional evolution of the Queen Charlotte Islands is presented in Lewis (1991b), who integrates structural, stratigraphic, magmatic, and geophysical elements of work done by Frontier Geoscience Program and other workers. Because of the immense volume of recent data, and to prevent the reiteration of models presented elsewhere, this chapter will focus on presenting the evolution of central Moresby Island in a regional context. It presents only those aspects where information derived from this study will help illuminate the larger regional picture, or where events observed elsewhere can help constrain the history of central Moresby Island. These events will be described chronologically.

5.2 Pre-Middle Jurassic Deformation

The Karmutsen Formation basalts and Kunga Group carbonate and clastic rocks of the Wrangellian succession were deposited in a tectonically quiescent basin (Tipper et al., 1991). Maude Group lithologies, present on Graham Island, northern Moresby Island, and elsewhere are absent from central Moresby Island (Taite, 1989a, 1990a). Local hiati in Maude Group rocks on Skedans Rock, east of Louise Island, indicate local uplift during the Toarcian to Aalenian (Jakobs, 1989). Tipper et al. (1991) speculate regions of the southern Queen Charlotte Islands may have been emergent by this time. Coarse clastic sedimentary rocks present in the Sandilands Formation of central Moresby Island are indicative of deposition in a submarine fan environment. Faunal and lithologic evidence suggests a shallow water source for these sediments during the Sinemurian, consistent with emergence at a slightly younger date. The volcanic component of clastic lithologies in the Peril and Sandilands Formation indicate a volcanic source in Norian to Sinemurian time.

5.3 Middle Jurassic Deformation: southwest and northeast directed shortening

The Middle Jurassic deformation event is evident throughout central Graham Island and northern Moresby Island. Lewis (1991b) interprets a northwest-trending deformation front extending across Moresby Island, which evidently extended into central Moresby Island. Middle Jurassic deformation is absent from southern Moresby Island (Lewis, 1991a). While elsewhere in the Queen Charlotte Islands, structures are southwest-verging, in central Moresby Island, northeast-verging structures are dominant, possibly reflecting the geometry of faults within the basement strata in central Moresby Island.

The onset of this event is only constrainable to post-Sinemurian in central Moresby Island. On central Graham Island, the presence of Maude Group strata allows the timing to be bracketed to late Aalenian to early-Bajocian. This event is correlated with the possible assembly and accretion of outboard Cordilleran terranes onto North America (Lewis, 1991b).

Jurassic Yakoun Group strata represent arc volcanic rocks and derivative sedimentary rocks. Throughout the Queen Charlotte Islands, Jurassic Yakoun Group rocks have been subject to southwest-directed shortening; however, elsewhere the timing of the Yakoun Group deformation could not be constrained due to a superimposed coaxial event. In central Moresby Island no shortening events younger than the Yakoun Group are coaxial with the Middle Jurassic event. Thus the southwest-directed shortening event lasted into, or through the Bajocian, and ended before the onset of Cretaceous sedimentation.

A regional southerly tilting of Triassic and Jurassic strata occurred after the deposition of the Yakoun Group in central Moresby Island. A similar style and magnitude of tilting is described on south Moresby Island (Lewis, 1991a), and may have formed concurrently.

5.4 Post-Yakoun Group and pre-Cretaceous: block faulting

Thompson et al. (1991) describe block faulting in north Moresby Island which uplifted discrete fault-bound blocks and stripped them of Yakoun Group strata prior to deposition of the Cretaceous section. This event is demonstrable on central Moresby Island, where is can be constrained to post-Bajocian and pre-Hauterivian. On northwest Graham Island, Gamba (1991) describes a fault-bound Tithonian basin which may have formed syn-tectonically, and as such would further constrain the timing of this event.

5.5 Deposition of the Cretaceous succession

The Longarm Formation and the Haida Formation lithologies represent deposition in a tectonically quiescent shelf environment which developed in response to rising sea level (Haggart, 1991). The onset of coarse clastic Honna Formation sedimentation marks a change in depositional rates, and provenence of clasts. The post-Turonian age in central Moresby Island is better defined as Coniacian on north Moresby Island (Haggart, 1991). Haggart (1991) suggests Honna Formation deposition was also eustatically controlled, and corresponded to a Turronian-Coniacian sea level drop. Lewis (1991b) speculates that the Honna Formation may represent the progradation of submarine fan complexes from the east, the result of foredeep deposits related to the westward migration of the Prince Rupert thrust system (Rubin, et al., 1990). Higgs (1990) suggests the Sandspit Fault may represent the leading edge of the thrust belt, a proposition not supported by field evidence (Lewis, 1991b). In central Moresby Island, the Cretaceous succession is interpreted to represent a submarine fan environment. The prograding Honna Formation is interbedded with Skidegate Formation turbidites, representing submarine channels and overbank levee deposits.

5.6 Cretaceous shortening

Throughout central Graham Island and northern Moresby Island, shortening of Cretaceous strata was southwest- and northeast-directed – coaxial with the Middle Jurassic deformation (Indrelid, 1991). The structural style in central Moresby Island marks a significant departure from this geometry. In central Moresby Island, shortening has resulted in northeast-trending structures – proposed here to be the higher level manifestation of contraction on pre-existing northeast-trending faults in 'basement'. The regional significance of this change of orientation is uncertain. Tertiary strata are not folded in central Moresby Island, thus this event is constrained as post-Turonian and pre-Paleogene.

5.7 Post-Cretaceous block faulting

Thompson et al. (1991) describe the uplift of fault-bound blocks resulting in the erosion of the entire Cretaceous section. This event extended into central Moresby Island, and resulted in the domain divisions recognized in this study. The map-dominating north-trending faults formed during this event; no evidence exists which suggests these features are older. North-trending features are also observed in Tertiary Masset Formation rocks on Graham Island (Hickson, 1991) and in the offshore Queen Charlotte Basin (Rohr and Dietrich, 1990) and may have originally formed simultaneously with north-trending structures in central Moresby Island.

5.8 Tertiary Block Faulting

Lewis (1990; 1991a) describes an elegant and complex tectonic history for the Tertiary Queen Charlotte Islands involving multiple extensional and compressional events related to the formation of the Queen Charlotte Basin. Tilting of Tertiary strata observed in on central Moresby Island is compatible with the asymmetric, south-directed extensional event described for southern Moresby Island (Lewis, 1991a). This has direct bearing on his model estimating amounts of extension along the Louscoone Inlet fault. In this model, the western domain (to the west of the Louscoone Inlet fault system) which includes central Moresby Island in the 'rigid' block, behaves has a rigid block, and accommodates no extension. The presence of south-directed extension in central Moresby Island indicates amounts of shear displacement estimated for Louscoone Inlet fault may be overestimated by this model, and the absolute amounts of extension in central and southern Moresby Island may have been underestimated. Total extension occurring in central and southern Moresby Island is an aggregate of extension experienced by the 'rigid' block, and the amount estimated in eastern 'extended' block.

5.9 Conclusions

1. Clastic lithologies present in the Jurassic Sandilands Formation in central Moresby Island indicate shallow marine influences different from that documented elsewhere in the Queen Charlotte Islands.

2. The Middle Jurassic shortening event extended into central Moresby Island, and structural styles developed are consistent with deeper structural control. Vergence of structures in central Moresby Island indicates this event was northeast-directed, in contrast to the southwest-directed event described elsewhere in the Queen Charlotte Islands.

3. The Middle Jurassic shortening event lasted into or was re-activated post-Bajocian and pre-Hauterivian.

4. Lithofacies in the Yakoun Group are not laterally continuous on a regional scale, and are not usable to define formal formations.

5. Uplift and partial erosion of Yakoun Group strata occurred before the onset of the Cretaceous marine transgression.

6. Cretaceous sedimentation in central Moresby Island commenced in the Hauterivian. Sediments of the Honna Formation may represent foredeep deposits related to the Prince Rupert thrust system.

7. Cretaceous lithofacies are complex and are not regionally continuous.

8. Post-Cretaceous block-faulting, such as documented on northern Moresby Island and central Graham Island, extends into central Moresby Island.

9. Two episodes of Tertiary volcanism affected central Moresby Island, and are recognized on the basis of lithologic differences.

10. Asymmetric south-directed extension occurred in central Moresby Island in Tertiary time.

11. Tertiary volcanism was accompanied by widespread hydrothermal alteration.

12. The structural evolution of central Moresby Island is a composite of styles observed on central Graham Island and southern Moresby Island.

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APPENDIX 1

Clast orientation data from which paleocurrent directions are interpretted from the Honna Formation and the Skidegate Formation, south of Sewell Inlet

Disk measuresents are of the AB plane in clasts with a greater than 3:3:1 aspect ratio
Rods: measuresents are of the A-axis direction in clasts with a greater tan 3:1:1 aspect ratio

Station 386

AB plane
232/72
048/85
255/46
235/82
242/76

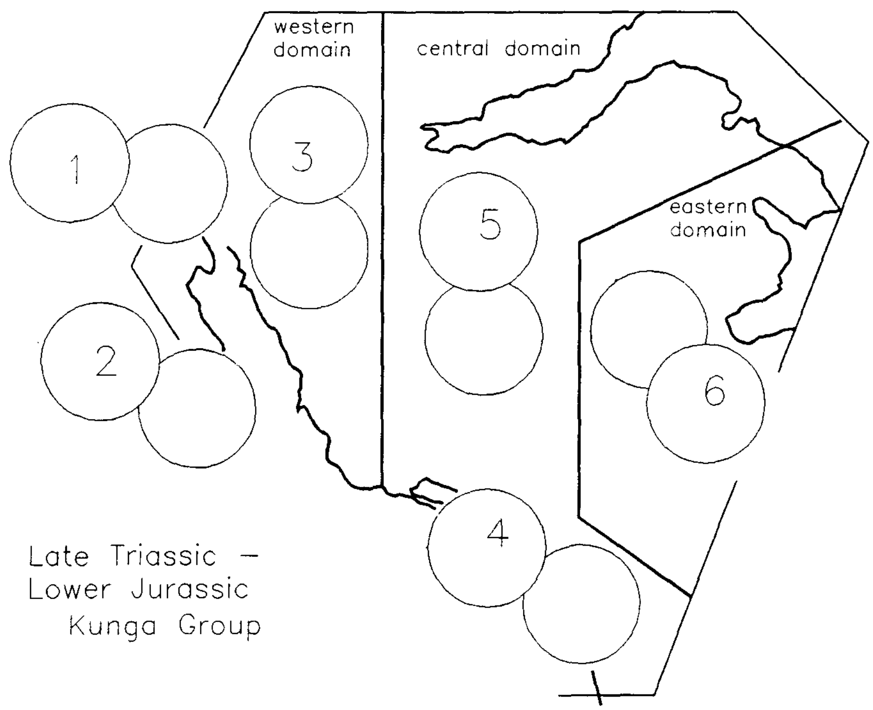
A axis
22 -035
24 -046
32 -269
30 -048
26 -062

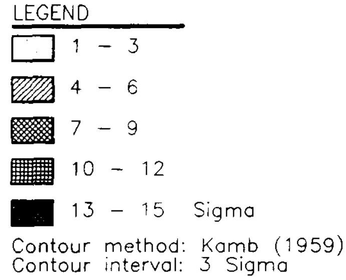
Station 386, 2nd bed
186/80
214/60
170/65
204/62
196/58
200/50
188/35
185/45
225/45
230/80
220/50
190/70
220/66

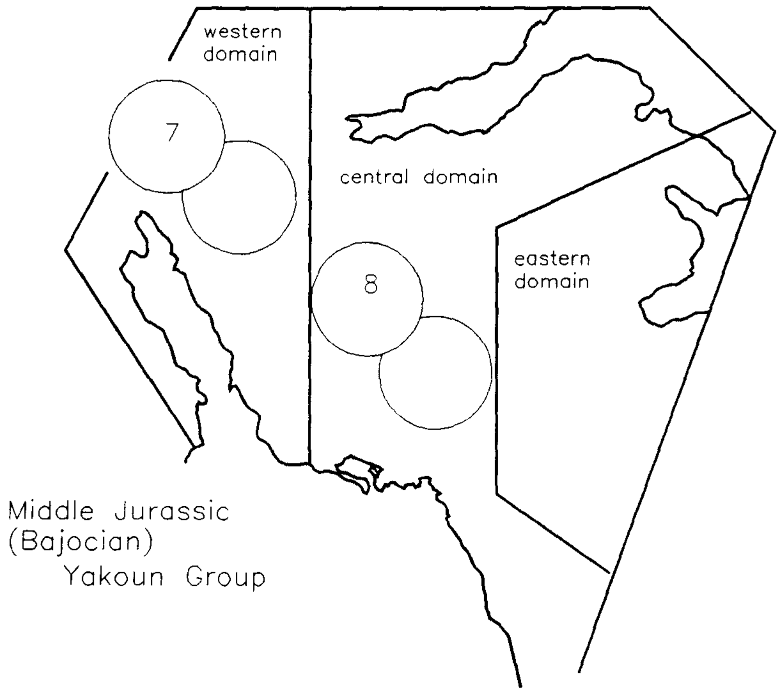
A-axis
22 -205
14 -208
38 -230
50 -004
25 -008

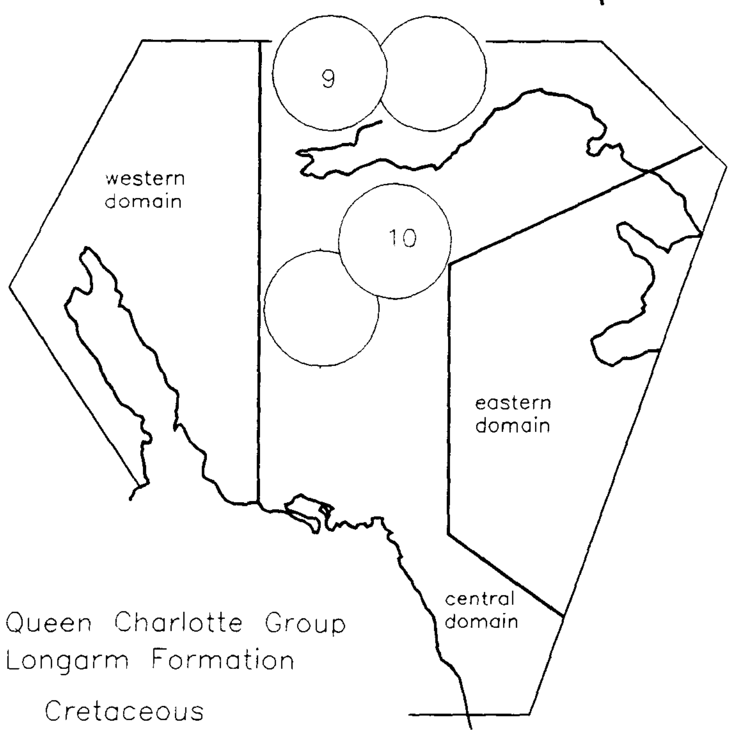
A Axis, 2nd bed
8 -204
26 -314
25 -235

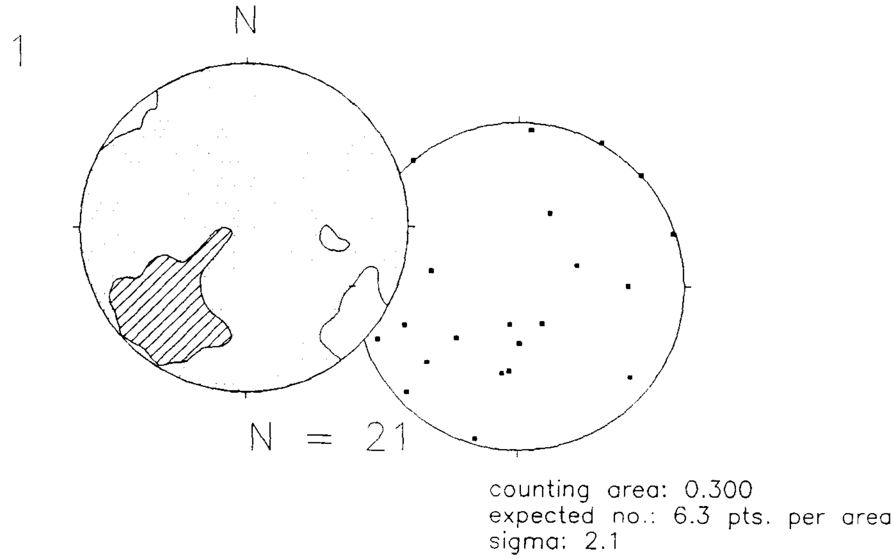
Appendix 2: Stereographic projections of structural orientation data

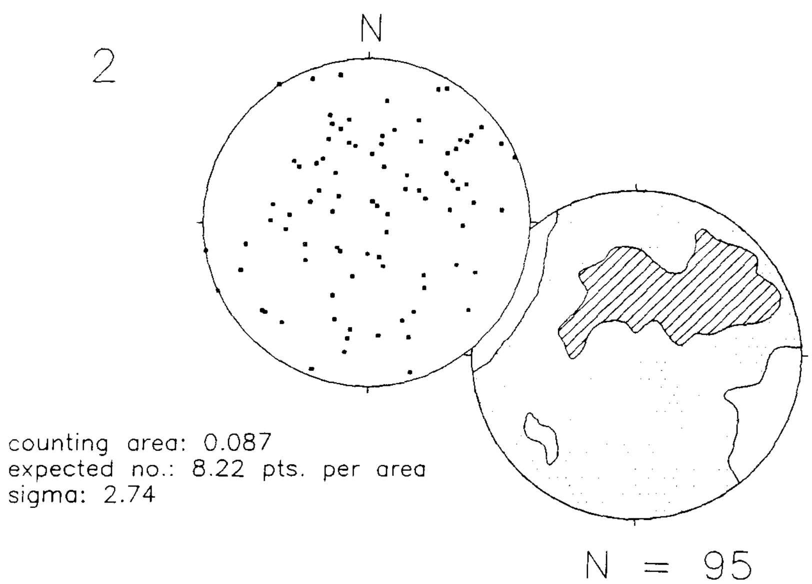





western
domain
7
central domain
eastern
domain
8
Middle Jurassic
(Bajocian)
Yakoun Group


9
western
domain
10
eastern
domain
central
domain
Queen Charlotte Group
Longarm Formation
Cretaceous

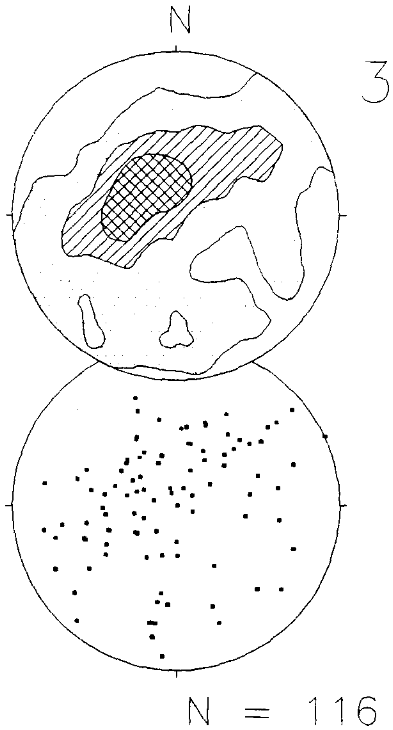


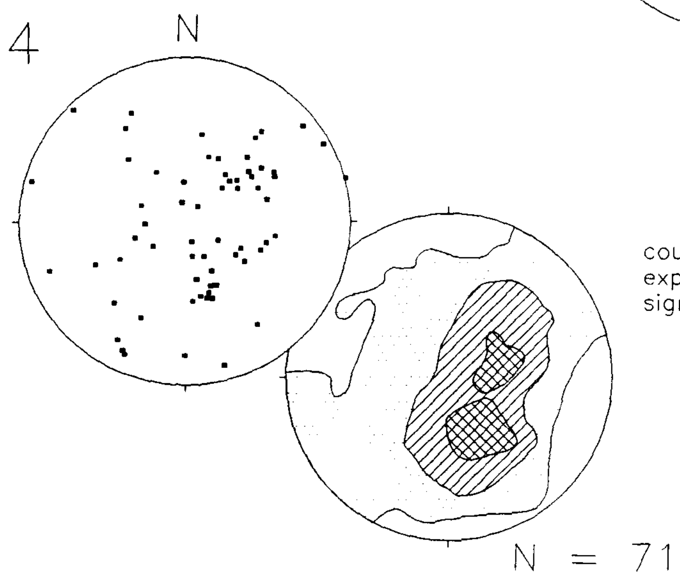


Late Triassic –
Lower Jurassic
Kunga Group

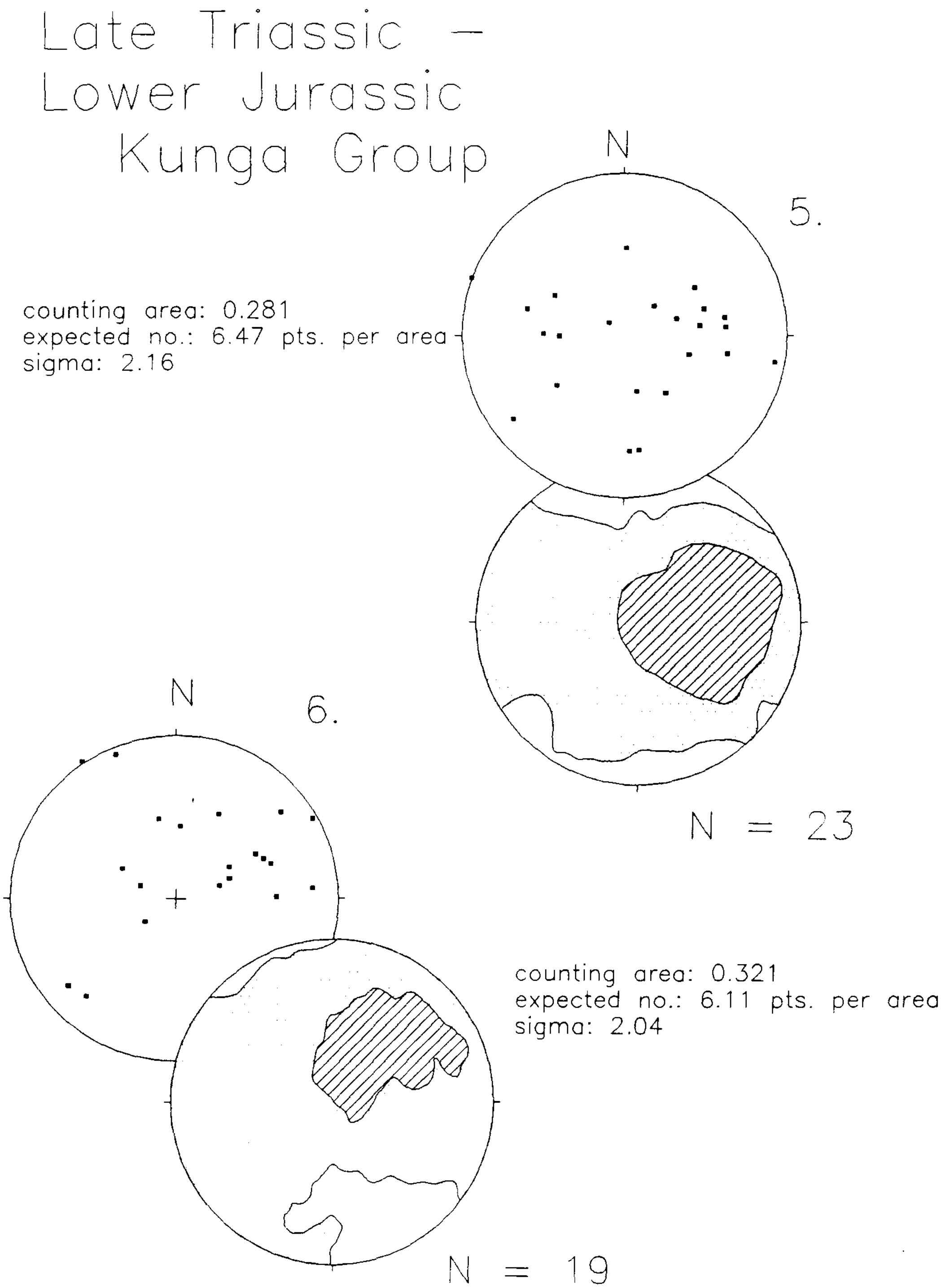
Late Triassic –
Lower Jurassoc
Kunga Group

counting area: 0.072
expected number: 8.35 pts. per area
sigma: 2.78

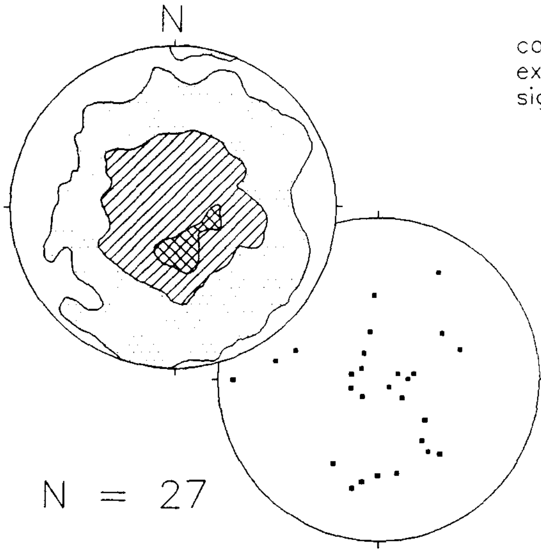




counting area: 0.112
expected no.: 7.99 pts. per area
sigma: 2.66

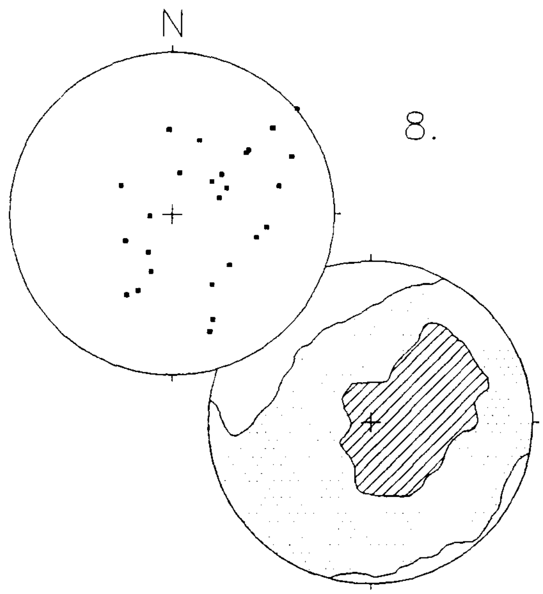

Late Triassic –
Lower Jurassic
Kunga Group
N
5.
counting area: 0.281
expected no.: 6.47 pts. per area
sigma: 2.16
N = 23
N
6.
counting area: 0.321
expected no.: 6.11 pts. per area
sigma: 2.04
N = 19

7.



counting area: 0.250
expected no.: 6.75 pts. per area
sigma: 2.25

N = 27



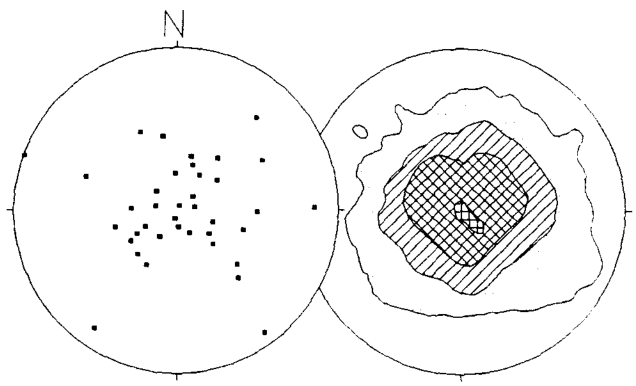
8.

counting area: 0.243
expected no.: 6.81
sigma: 2.27

Middle Jurassic
(Bajocian)
Yakoun Group

N = 28

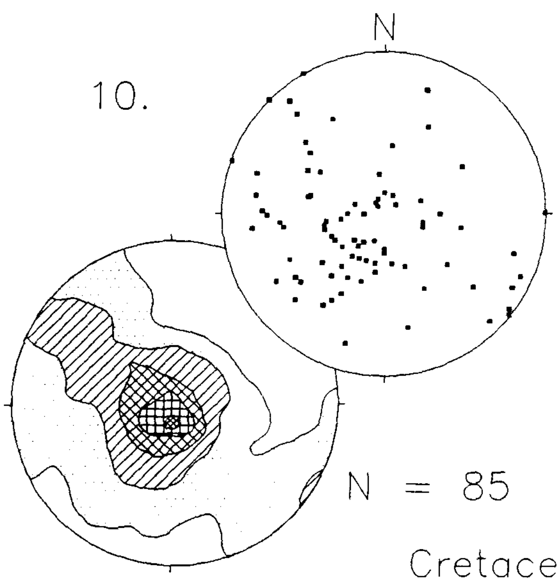
9.



N = 38

counting area: 0.191
expected no.: 7.28 pts. per area
sigma: 2.43

10.



counting area: 0.095
expected no.: 8.15 pts. per area
sigma: 2.72

N = 85

Cretaceous

Queen Charlotte Group
Longarm Formation

Appendix 3: Cretaceous fossil identification information

Report on Cretaceous fossils from the Queen Charlotte Islands, B.C. (NTS map-areas 103 B, C), requested to be identified by Susan Taite of the University of British Columbia, Vancouver (6 lots).

All references to paleontologic data and age determinations must quote the authorship of the report, and the unique GSC locality number of the fossil collection.

Reference to, or reproduction of, paleontologic data and age determinations in publications must be approved by the author of the fossil report prior to manuscript submission. Substantial use of paleontologic and age data in publications should be reflected in the authorship.

IDENTIFICATIONS

Field No.HFB-89-210aM GSC loc.**C-156690**

Locality: British Columbia, Queen Charlotte Islands
Lat. - N; Long. - W
NTS: 103 B/13-B/14 (Louise Island)
UTM: Zone 9, 298500 E, 5861800 N
Hillside west of Clint Creek, on logging road ("Fossil Hill")
Possible Longarm Formation
Coarse-grained feldspathic sandstone

Fossils: *Inoceramus* cf. *paraketzovi* EFIMOVA, 1963

Age: Although the specimens do not include a preserved beak to firmly differentiate them from Jurassic species of the *Retroceramus* group, the form, general outline, coarse ribbing, and lack of strong constrictions suggests that they are probably related to the *I. paraketzovi* species group. The range of this species is Hauterivian in NE USSR (Efimova, 1963; Vereschagin *et al.*, 1965) and the form *I.* cf. *paraketzovi* is widespread in the western Canadian Cordillera in rocks of approximately Hauterivian age (Jeletzky, 1970; Haggart, 1989). The probable age of the fossil supports correlation with the Longarm Formation.

Field No.HFB-90-238M GSC loc.**C-187349**

Locality: British Columbia, Queen Charlotte Islands
Lat. - N; Long. - W
NTS: 103 C/16 (Moore Channel)
UTM: Zone 8, 701900 E, 5855250 N
Just north of saddle in ridge north of Two Mountain Bay
Longarm Formation, lower part
Fine-grained sandstone/siltstone, locally with single pebbles

Fossils: *Inoceramus* cf. *paraketzovi* EFIMOVA, 1963
whole pinnate leaves
inoceramid prisms

Age: Hauterivian. See comments under GSC loc.**C-156690**, above.

Field No.HFB-90-239M GSC loc.**C-187350**

Locality: British Columbia, Queen Charlotte Islands
Lat. - N; Long. - W
NTS: 103 C/16 (Moore Channel)
UTM: Zone 8, 701850 E, 5855850 N
Ridge north of Two Mountain Bay
Longarm Formation
Fine-grained sandstone/siltstone

Fossils: *Inoceramus* cf. *paraketzovi* EFIMOVA, 1963
Lytoceras aulaeum ANDERSON, 1938?
belemnite molds, indeterminate
inoceramid prisms

Age: Hauterivian. See comments under GSC loc.**C-156690**, above. The large ammonite fragment is similar to material from the Hauterivian of northern California described as *L. aulaeum* by Anderson (1938).

Field No.HFB-90-242M GSC loc.**C-187361**

Locality: British Columbia, Queen Charlotte Islands
Lat. - N; Long. - W
NTS: 103 C/16 (Moore Channel)
UTM: Zone 8, 701700 E, 5856100 N
Highest exposures on ridge north of Two Mountain Bay
Longarm Formation
Fine-grained sandstone/siltstone

Fossils: *Inoceramus* cf. *paraketzovi* EFIMOVA, 1963
Entolium? sp.
mactrid? bivalve, indeterminate

Age: Hauterivian. See comments under GSC loc.**C-156690**, above.

Field No.HFB-90-243M GSC loc.**C-187362**

Locality: British Columbia, Queen Charlotte Islands
Lat. - N; Long. - W
NTS: 103 C/16 (Moore Channel)
UTM: Zone 8, 701750 E, 5855800 N
Ridge north of Two Mountain Bay
Longarm Formation
Medium-grained, poorly indurated sandstone

Fossils: *Inoceramus* cf. *paraketzovi* EFIMOVA, 1963

Age: Hauterivian. See comments under GSC loc.**C-156690**, above.

Field No.HFB-90-268M GSC loc.**C-187387**

Locality: British Columbia, Queen Charlotte Islands
Lat. - N; Long. - W
NTS: 103 B/13-B/14 (Louise Island)
UTM: Zone 9, 302500 E, 5855200 N
In bed of logging road, north side of valley draining west from Redtop Mountain
Longarm Formation, float occurrence
Fine-grained sandstone

Fossils: *Inoceramus* cf. *paraketzovi* EFIMOVA, 1963

Age: Hauterivian. See comments under GSC loc.**C-156690**, above. This float occurrence indicates that Longarm Formation is present somewhere in the vicinity, probably the quarry just east of the junction of this spur with the Metric Main.

GENERAL COMMENTS

The presence of Hauterivian strata in this region of the Queen

Charlotte Islands has not been previously demonstrated. During the 1991 field season, I noted that the Cretaceous succession containing the fossil localities GSC loc.**C-187349, C-187350, C-187361,** and **C-187362** is a fining-upward one, with a basal transgressive-lag conglomerate (unconformably overlying the Sandilands Formation), coarse- and fine-grained sandstone in the middle portion, and fine-grained sandstone interstratified with shale at the top. This sequence therefore is very similar to the standard Hauterivian-Barremian Cretaceous succession of the islands, as previously described by Haggart (1989, 1991) and called the Longarm Formation.

The presence of the Longarm succession in this part of the islands supports Haggart's (1991) interpretation of eastward-directed transgression across the Queen Charlotte Islands during Cretaceous time. All of the deposits studied in the geographic area covered by this fossil report represent the basal part of this transgressive sequence. The younger, deeper-water part of the succession is preserved to the northeast, in the valley of Thorsen Creek and along the shores of Sewell Inlet, where shales and interstratified turbiditic sandstone of Albian to Turonian age have been identified.

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Geological Survey of Canada
March 8, 1991