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NOTES ON THE STRATIFIED ROCKS OF BUTE INLET MAP-AREA

(excluding Vancouver and Quadra Islands)

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To accompany Open File map, Bute Inlet

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GEOLOGY OF BUTE INLET MAP-AREA, BRITISH COLUMBIA

INTRODUCTION

Cut by three magnificent fjords, Knight, Bute, and Toba Inlets, and numerous narrow waterways, Bute Inlet map-area is perhaps the most scenic in the Coast Mountains. It embraces two major tectonic belts, the Coast Plutonic Complex which underlies all but the southwest corner of the sheet, and the Insular Belt represented by the northeast shoulder of Vancouver Island. The two meet in a long physiographic depression, the Coastal Trough, which, as in southeast Alaska, consists mainly of hummocky islands.

The almost continuous outcrop along the shore was examined in considerable detail, and the interior by helicopter spot stations and ground traverses across pendants, and some of the gneissic complexes. More detailed studies were conducted by Carlisle and his associates on Vancouver Island and Quadra Island, and by Woodsworth whose work in the Mount Raleigh area formed the basis of a doctorate thesis written at Princeton University. Fieldwork in the map-area by Roddick and Hutchison was part of the Geological Survey's Coast Mountains Project which has been conducted, mainly in alternate years, since 1963 with the object of completing the first geological reconnaissance mapping of the Coast Mountains between latitude 55°N and Washington State.

The principal previous publication on the geology of the region is Geological Survey of Canada Memoir 23 by J. A. Bancroft (1913) which was based mainly on a cursory examination of the shoreline in 1907. Bancroft's view of the vast plutonic terrane underlying the Coast Mountains that it consisted of 'immense batholiths ------ which once existed in a liquified or molten state' (1913, p.83-84) was perpetuated in many textbooks. His opinion of the degree of homogeneity of the plutonic rocks was less clear; 'they are heterogeneous in character' (p.83) and 'these rocks possess a remarkably uniform granitoid texture' (p.85). He doubtlessly had different scales in mind when writing those conflicting statements but the latter only was incorporated into later texts. Having a much larger data base, we can easily be critical of earlier efforts, but we share Bancroft's difficulty in making general statements about the Coast Plutonic Complex.

GENERAL GEOLOGY

Except for Vancouver and Quadra Islands most of the area is underlain by plutonic rocks, ranging from gabbro to quartz monzonite. Granodiorite and quartz diorite predominate and unlike most areas in the Coast Mountains, granodiorite is slightly more abundant. The granodiorite forms a broad central belt about 50 km wide, extending from Big Julie Pluton in the southeast to Knight Inlet, with a core area of quartz monzonite between Toba and Knight Inlets. The flanking belts are underlain mainly by quartz diorite but granodiorite and diorite are also well represented. Most of the plutons, excepting the quartz monzonite, exhibit a pronounced northwesterly elongation. This pattern is accentuated by long narrow belts of metasedimentary and metavolcanic rocks. Granitoid gneiss, schist and amphibolite, thought to be correlative with the Central Gneiss Complex farther north, are confined to a region northeast of a ~~line~~ joining the southeast and northwest corners of the map-area.

The southwest contact of the Coast Plutonic Complex is exposed on Hardwicke, West Thurlow, Vancouver and Quadra Islands. These exposures, along with several in the Alert Bay map-area to the west represent the only surface outcrops of the southwest contact in British Columbia. The contact is intrusive in most places, and possibly faulted in some places. Although sharp and simple in most exposures, the contact is locally marked by complex breccia zones. The country rocks at the contact include Upper Triassic Karmutsen volcanics, thin-bedded clastic sediments and carbonates, and Lower Jurassic Bonanza volcanic breccia. Across the northeast shoulder of Vancouver Island and on the north end of Quadra Island, the Karmutsen volcanics are well foliated to schistose near the contact. Alteration of the country rock is not severe, but reaches amphibolite grade within a few feet of the contact. Deformation of massive Karmutsen units is minor but thin-bedded sediments have been strongly deformed along the contact.

Steeply dipping metasedimentary and metavolcanic rocks form narrow bands engulfed in the main mass of the Coast Plutonic Complex. Although interrupted here and there by large plutons they are remarkably persistent along strike and are thought to represent fault slices or grabens along which 'horsts' of plutonic rock were thrust upward. The bounding shear zones in places still exist but synplutonic recrystallization has commonly reduced them to mere foliations or obliterated them entirely. In many places these 'screens' are flanked on one side by diorite and on the other by quartz diorite or, less commonly, by granodiorite. The dioritic rocks may represent remnants of a primitive granitoid basement upon which Karmutsen and later rocks were deposited. Deep burial and subsequent deformation of the eugeosynclinal pile along with the underlying basement was probably in response to compressive forces transmitted through the North America Plate against oceanic crust. Relief came

eventually with the onset of subduction, and plutonic masses, formed before and during the compressive stage, began their movement upwards bounded by synplutonic faults. The open structure of the Karmutsen volcanics on Vancouver Island is in marked contrast with the strongly deformed remnants of these rocks within the Coast Plutonic Complex. The concept of an allochthonous Vancouver Island may account for the difference in deformation but it introduces the problem of suture location which is not readily resolvable with present data.

Minimum final cooling dates from potassium-argon work on biotite and hornblende in granitic rocks show a range from Late Jurassic (153 m.y.) near Johnstone Strait to Eocene (55 m.y.) in the northeast corner of the map-area. The markedly discordant age of 176 m.y. on biotite from quartz diorite on Hardwicke Island (versus 141 m.y. on hornblende) suggests argon enrichment of the biotite. The general decrease in age from west to east is characteristic of the Coast Plutonic Complex between latitudes 50° and 55°N.

Stratified Rocks

For descriptive purposes the rocks within each 'pendant' or complex are grouped together, even though they may be of diverse lithology, age and grade of metamorphism. They form seven narrow discontinuous, northwesterly-trending belts which will be treated sequentially from southwest to northeast, and within each belt from southeast to northwest.

BELT 1: ULLOA ISLAND TO GLENDALE COVE (KNIGHT INLET)

<u>Ulloa Island:</u> The east side of the island consists mainly of a Lower Jurassic metasedimentary sequence intruded by two small bodies of fine to medium-grained quartz diorite. The west side consists of a later leucocratic, coarse-grained biotite granodiorite, which on the the northern part of the island is cut by a swarm of northeasterly trending dykes.

Along the east side of the island the metasedimentary rocks include a thinly bedded sequence of siliceous black argillite, phyllite, quartzite and limestone. The limestone is finely crystalline, partly whitish and partly carbonaceous. At Iron Point it contains fragmentary fossils . Better preserved fossils from the same sequence were found on Hernando Island at the south edge of the map-area.

In most places the metasedimentary rocks are tightly to isoclinally folded. The contact with granodiorite is exposed at the southern end of the island, where the metasedimentary rocks are rusty and cut by dykes of the granodiorite. The thinner dykes are finer-grained and more leucocratic than the main mass of granodiorite. The granodiorite itself is closely fractured near the contact.

The great dyke swarm on the west side of the island does

not pass through the metasedimentary strata on the east side. The swarm is thought to be truncated at the granodiorite contact. This suggests that the dykes were emplaced before the granodiorite moved up to its present position.

Cortes Island Metavolcanic Rocks: These rocks are poorly exposed between Gorge Harbour and Seaford. They appear to consist chiefly of light grey-green to dark green greenstones which are locally porphyritic. In most places they are homogeneous and massive. Tentatively they are correlated with the Karmutsen Formation but their age is very much in doubt.

Cardero Channel: In the vicinity of Cardero Channel small areas of schist and other rocks are exposed on the north and northeast shore of East Thurlow island, on the north corner of Sonora Island and on the west shore near the mouth of Frederick Arm. On the north shore of East Thurlow Island the rocks consist mainly of hornblende schist which grades in and out of irregularly layered gneiss, schlieren gneiss and local agmatite. Very commonly a stockwork of aplite cuts the schist and gneiss. On the east shore of East Thurlow Island about two miles south of Cardero Channel the hornblende schist is intercalated with quartzite and minor thinly bedded marble and calc-silicate rock. These beds are strongly contorted about fold axes plunging 35° northwest. On the north shore of Sonora Island there are two northwesterly trending zones of metasedimentary rocks. The southerly one comprises rusty-weathering quartzite, schist and aplite, and the northerly one chiefly contorted marble and intercalated quartzite and schist. Near the mouth of Frederick Arm marble forms massive buff-weathering beds about 16 m thick, interlayered with thinner (7 to 10 m) beds of grey slaty argillaceous marble. This body of metasedimentary rocks also outcrops on the north shore of Cardero Channel where it consists of marble and interlayered quartzite and schist, similar to those on the north shore of Sonora Island.

Fanny Bay to George Creek: Belt 1 appears to be offset about 7 km northward to Fanny Bay on the west shore of Phillips Arm. In Fanny Bay the rocks consist chiefly of quartz-biotite schist with some marble and skarn. Diopside, wollastonite and andradite garnet were observed in the skarn. Along the north shore of Fanny Bay the rocks consist mainly of chlorite and biotite schist which is finely layered and interbedded with massive greenstone. Locally these rocks are intensely sheared parallel with the belt. On the south shore of the bay the rocks are dominated by pale brown marble beds about 6 m thick with local intercalations of quartzite. The contact with quartz diorite on the north side is marked by a narrow zone of agmatite containing blocks of schist and marble. At the contact the foliation in the plutonic rock is parallel with the layering in the marble.

The metasedimentary band is thought to underlie the elongate depression which connects Fanny Bay with the mouth of George Creek, although outcrops are rare. In the vicinity of George Creek on Loughborough Inlet the rocks consist chiefly of quartz-biotite schist, marble and skarn. The greenstone seen at

Fanny Bay may be present but was not observed. Diopside, wollastonite and andradite garnet were noted in the skarn.

Heydon Bay to Glendale Cove: The belt continues across Loughborough Inlet to just north of Heydon Bay. There it consists of a well-layered sequence of contorted fine-grained gneiss, amphibolite, marble and quartzite. The last two rock-types form beds up to a meter thick. Quartz and aplite veinlets are abundant.

The trough which crosses the peninsula between Loughborough Inlet and Knight Inlet and contains Glendale Lake was apparently developed on the metasedimentary belt. On the east side of Glendale Cove the unit is represented by plastically folded, sandy marble with nodules of chert (now quartzite). These strata do not outcrop on the west side of the cove but appear again on the point east of Siwash Bay, where the limestone and quartz diorite form lit-par-lit structures.

BELT 2: LOUGHBOROUGH INLET TO ADEANE POINT

This belt consists of only one segment and crosses the peninsula between Loughborough and Knight Inlets. The three traverses made across it revealed somewhat different assemblages. The exposures on Loughborough Inlet are limited and both contacts are marked by cobble beaches. There, however, most of the strata consist of intercalated, thinly bedded, black argillite and crystalline limestone, both of very low metamorphic grade.

West of Loughborough Inlet where the belt crosses Bazalgette Range the principal rock is a grey weathering massive greenstone which resembles granitic rock from the air. It contains skarny layers and pods (but no diopside or garnet). In places the greenstone seems to contain indistinct pillows. The northern contact is sharp against gneissic diorite and the southern contact is likewise sharp, but against granodiorite which has a foliation that gradually disappears away from the contact.

Around Adeane Point on Knight Inlet the strata consist mainly of greenstone, some porphyritic, some vesicular and some laminated. The greenstone is interbedded with strikingly reddish-weathering, crystalline limestone containing quartz nodules, and biotite-chlorite schist which seems to have been a tuff. Both north and south contacts on Knight Inlet are sharp, against strongly foliated diorite and quartz diorite, respectively.

The belt continues for a short distance beyond the west side of Knight Inlet. There it consists of thinly layered, biotite schist or phyllite, porphyritic greenstone and thin intercalations of light-weathering quartzite. The greenstone is commonly schistose and heavily epidotized in narrow zones. The northern contact is sharp against a quartz dioritic gneiss containing amphiblitic screens. To the south feldspathic

stringers and patches gradually increase and the rock becomes a mixed agmatite which persists for about 70 meters before passing into a dark medium to coarse-grained quartz diorite with comparatively few inclusions.

BELT 3: SKWIM LAKE TO MOUNT WATSON AND BEYOND

Although interrupted here and there by substantial plutons this belt crosses the entire map-area from corner to corner.

Skwim Lake: The dominant lithologies in this area include well-layered tuffs, greenstone, volcanic breccia and dark argillite. The beds are vertical and strike northerly. The tuufs are pale grey except for local rusty zones and have beds from 1 mm to 5 cm thick. They commonly grade into volcanic breccia which forms layers 3 to 15 m thick. The fragments may be angular or well flattened, and up to a meter across although most are much smaller. The greenstone is partly dioritized. Rhyolite is a minor lithology, in places well bedded and in places massive. The contact between the metavolcanic rocks and the diorite is intrusive. At one place the tuff and volcanic breccia are cross-cut by the diorite.

Beartooth Mountain Area: The volcanic rocks in this area are divided into four northwesterly trending bands by a dark heterogeneous diorite. The southern body consists of massive grey-green greenstone and volcanic breccia, commonly epidotized and locally pyritized. In places the fractures are filled with K-feldspar, in spite of the fact that the surrounding plutonic rock is diorite. The breccia contains fragments that are chiefly greenish grey, feldspar porphyry, but some are purple, and some are light grey dacite.

The lithologies of the fragments are present as flows on the ridge south of Beartooth Mountain. There the volcanic breccia is more spectacular. It has a dark green matrix and rounded clasts up to 30 cm across which are slightly epidotized. The flows are dominantly dacitic to andesitic, feldspar-hornblende porphyries. Some have quartz and epidote amygdules and possibly some prehnite. Minor beds of white weathering rhyolite with prominent quartz eyes are also present.

On the east shoulder of Beartooth Mountain the third body consists chiefly of massive dark-weathering greenstone, which is indistinguishable from the air from the dioritic country rock. This band crosses the west end of the ridge north of Beartooth Mountain, where it is mainly volcanic breccia with conspicuous whitish dacite or rhyolitic fragments, and some greenstone which appears to be metamorphosed almost to amphibolite.

The fourth body lies north of McMillan Creek. The eastern part of that assemblage is made up mainly of basalt and greenstone. These rocks are massive but in places contain good pillows, with interstices filled by garnet-epidote-calcite skarn (see photograph in Roddick and Woodsworth, 1977). Locally the rock includes minor, thinly bedded, limy argillite and limy

quartzite. At one place they are cut by a 30 m-thick dyke of quartz diorite. Near Big Julie Pluton the rock is chiefly rusty-weathering, thinly bedded, acid tuff and massive light grey dacite with conspicuous feldspar phenocrysts. These rocks are faulted against the pillow lavas. All the rocks in this area are cut by andesitic dykes.

The western part of the body consists chiefly of light-weathering dacite which is identical to, and probably the source of the fragments in the breccia on the ridge south of McMillan Creek. This dacite overlies the pillow lavas, the tops of which face west.

The pillow lavas are indistinguishable from Upper Triassic Karmutsen volcanics. The dacitic flows, tuffs and breccia may be equivalent to the Lower Jurassic Bonanza volcanics or the Lower Cretaceous Gambier Group, although they are more acid than either of those. They are tentatively assigned to the Gambier Group on the basis of an age determination (82 m. y.) on similar rocks on Mount Hayes .

Although the northern and southern bodies do not extend to Powell Lake the other two outcrop there, and consist of the same assemblage of volcanic breccia, tuff and greenstone. The wider band extends across to the west side of Powell Lake where breccias predominate.

Mount Aiken: The rocks in this area consist chiefly of dacitic or rhyolitic breccia with subangular fragments up to 10 cm across, and light-weathering rhyolite porphyry flows. The rocks are massive in most places and epidotized. The breccias are correlative with those in the Beartooth Mountain area.

This body is interrupted by a fine-grained quartz monzonite pluton but appears again on the east shore of Bute Inlet north of Brettell Point . There it consists mainly of rusty-weathering banded rhyolite intercalated with dark-weathering greenstone breccia. Relations are greatly complicated by a swarm of andesitic dykes which actually form most of the shore outcrop.

Toba Inlet to Bute Inlet: This segment forms a narrow band which crosses the peninsula between Toba and Bute Inlets and passes through Mount Powell . Limited exposure on the west side of Toba Inlet reveals only massive greenstone and a complex of dykes. The oldest dykes are dark grey aphanitic andesite and are highly fractured and locally sheared. They are cut by ochre-weathering light grey dacite and by light grey feldspar porphyry. Northwest of Quatam River the band consists mainly of light grey, highly shattered volcanic breccia. The fragments are siliceous and angular. Also present is a flow breccia of banded rhyolite which is clearly intruded by agmatitic quartz diorite. The volcanic breccia is well exposed on Mount Powell. There the fragments are angular and up to a meter across. They consist of various lithologies ranging from andesite to well-banded rhyolite. All of the fragments are volcanic; no plutonic rocks are represented. This is in contrast to Mount Hayes where the

breccia is similar but some of the clasts are clean medium-grained quartz diorite containing about 1% K-feldspar and 9% quartz. A K-Ar determination on hornblende from the matrix of the volcanic breccia yielded an age of about 82 m.y.. This age is anomalous, as the younger(?) Quatam Pluton yielded an age of 94 m.y. on biotite.

On the southeast shore of Bute Inlet the rock nearest the northern contact (which is not exposed) the rock consists of about 70% metabasalt, 20% rhyolitic breccia and 10% tuff. There seems to be about five separate bands of breccia, but shear zones are common and repetition by faulting is possible. Farther south the main rock is chlorite phyllite or schist, with about 10% intercalated blackish laminated argillaceous and calcareous chert, and about 15% rhyolitic breccia. Nearer the southern contact is a 60-foot bed of andesitic breccia. The clasts are sub-angular to rounded and up to 2 meters across. This breccia is rusty weathering and highly fractured, with the fractures filled with epidote.

The southern contact is a major shear zone. The granodiorite is intensely sheared at the contact and chloritized up to 150 m away. The shear zone is strongly epidotized. The volcanic rocks are also sheared, and minor dragfolds indicate that the plutonic mass moved upwards with respect to the volcanic band.

Mount Gardiner to Moh Creek: This segment extends from Bute Inlet to Phillips River where it appears to die out. It passes just east of Mount Gardiner and underlies the western slopes of lower Moh Creek valley. On Bute Inlet it consists of greenstone and rhyolite breccia identical to that on the east side of Bute Inlet. On the peak btween the east end of Estero Basin and Moh Creek, the breccia looks more like a conglomerate with strongly elongated clasts. There it is intercalated with hornblende schist. Farther northwest fragmental rocks were not seen again, and the band consists chiefly of grey to rusty-weathering amphibolite and thinly laminated, chlorite-quartz schist and phyllite. Here and there the strata contain parallel zones of heterogeneous diorite and quartz diorite.

East Of Mount Pratt: This segment comprises both rusty-weathering and grey to dark grey schist and amphibolite. The rusty-weathering schists are chiefly biotite-chlorite rocks, locally with garnet. The grey-weathering schists grade into amphibolite and into zones of diopside-garnet skarn. The western contact with quartz diorite is a lit-par-lit complex.

Mount Watson Segment: This segment lies west of Knight Inlet and is more granitoid than other segments in the belt. It consists chiefly of biotite schist, biotite gneiss and gneissic diorite and quartz diorite. The biotite schist and gneiss are in places well layered and elsewhere massive. They are commonly rusty weathering. The biotite schist is intercalated with layers of granular quartz and feldspar. The granitoid gneiss is strongly folded, in places a fluidal structure has formed. Some zones

contain boudins of amphibolite up to about 1 m wide.

On the east side of Knight Inlet, about 3 km south of Tsukola Point , is a small body of amphibolite and gneiss which may be continuous beneath Knight Inlet with the Mount Watson segment. At the northern contact, which is sharp, it consists of regularly banded gneiss made up of biotite granodiorite gneiss and bands of amphibolite striped with quartzofeldspathic layers. The whole is cut by quartz-feldspar and pegmatite veins. The gneiss passes within a few meters into a massive dark biotite-bearing amphibolite with feldspar porphyroblasts. This amphibolite is commonly finely granitoid in texture and may contain dark elongate inclusions of finer-grained amphibolite. Zones within it are closer to gneissic quartz diorite than to amphibolite. Good examples of transition from amphibolite to quartz diorite are exposed along the shore. The southern contact is gradational into massive diorite and then into granodiorite containing prominent sphene. A similar transition involving the main part of the Mount Watson body is exposed on the west shore of Knight Inlet.

BELT 4: MOUNT GRAZEBROOK TO MOUNT HILLS

Mount Grazebrook: This body consists mainly of grey-weathering dacitic breccia and porphyritic flows of dacite and andesite. Most of the fragments are only about 2 cm across but some are much larger. Some of the clasts look rhyolitic but staining showed no K-feldspar, so most are probably dacite. In places the rock is finely porphyritic. Because of their light weathering, the volcanic rocks cannot be distinguished from the quartz diorite from the air. The eastern contact on Mount Grazebrook is sharp. No evidence of shearing was seen in either rock. The volcanic rocks were not greatly affected by the intrusion, although right at the contact they are thoroughly recrystallized, and in places have become a fine-grained diorite. A 30 cm-wide dyke, which cuts the volcanic rock about 70 m from the contact, is interesting in that it contains no K-feldspar, whereas the main mass of quartz diorite contains about 3% K-feldspar, and right at the contact about 12% (where the rock is technically a granodiorite). This suggests that the K-feldspar metasomatism in the quartz diorite took place after intrusion but did not extend into the apophyses of the plutonic rock.

The volcanic rocks are much the same on the east shore of Bute Inlet but the northeastern contact there is strongly sheared.

Southwest Of Face Mountain: Little is known about this band but it extends from Quatam River almost to Toba Inlet. It consists chiefly of dacitic breccia. The clasts are light grey and subrounded, and up to 10 cm across. Also present are older shattered dacite (or rhyolite) flows. They are rusty owing to finely disseminated pyrite, and contain minor chalcopyrite. Although the volcanic band appears to be faulted-off before reaching Bute Inlet, in the area where the band would otherwise project some of the inclusions in the diorite consist of various types of volcanic rock rather than the more usual amphibolite.

South Of Clipper Point, Bute Inlet: Lithologies in this segment differ from place to place. In the valley of upper Quatam River, it consists of a rusty assemblage of thinly layered meta-andesite, inpure quartzite and graphitic argillite. On the ridge to the northwest the band is chiefly light green dacite (or rhyolite), grey marble in beds up to 15 m thick, and light coloured greenstone. The southwestern contact is faulted, and the shearing there has converted the rock to chlorite schist. On the east shore of Bute Inlet the band consists of a complex of amphibolite, chlorite schist and rusty, thinly-layered dacite. Here and there the band contains zones of irregularly layered gneiss and dioritic complexes. Both contacts are marked by shear zones, the northern one containing andesitic dykes. Attitudes are near vertical in the band. It seems to be older than the volcanic breccia on Mounts Powell and Hayes.

Cosmos Heights: This segment extends from Bute Inlet northwestward across Cosmos Heights to Apple River. On Cosmos Heights the band consists chiefly of thin-bedded dark argillite or tuff, and more massive dacitic feldspar porphyry. Fine-grained biotite appears in the metasediments and some of the more calcic layers contain diopside. Bedding is well developed but foliation is weak or absent. The northern contact is sharp against fine to medium-grained granodiorite which is unchanged up to the contact. Hornfelsing of the argillite seems to have produced cordierite within a few centimeters of the contact. The granodiorite does not vein the pendant, but some pegmatitic stringers cut the strata. The southern contact was not examined on the ridge and is not exposed on the shore of Bute Inlet.

Between Phillips River and Cosmos Heights the pendant consists chiefly of pale grey through purplish to pale green quartzite, and biotite schist. The schist is commonly veined by quartz, and in most places rusty weathering. On the main summit between Phillips and Apple Rivers the schists are pale grey and contain hornblende, biotite and locally chlorite. These schists are mostly well-layered rocks with beds 1 to 3 m thick. Also present on this summit is a 35 m-thick bed of conglomerate containing strongly stretched clasts up to 20 cm long. Most of the clasts consist of pale-coloured volcanic rock, feldspar porphyry, and rarely granitoid rock. Most of the last-named are either aplitic or unusually coarse-textured; not typical of the common varieties in the Coast Plutonic Complex. Farther northeast on the ridge, quartzite and amphibolite dominate the biotite schists.

The exposures in Apple River are poor, and comprise well-layered biotite schist and intercalated quartzite.

BELT 5: MOUNT ALFRED TO MOUNT HILLS

Mount Alfred: The southern part of this pendant underlies Mount Alice, where it consists mainly of shale, slate, argillite and spotted fissile schist. The argillite and schist are rusty weathering and thinly laminated, and contain about 5% intercalated quartzite. At one point about 3 km northeast of Mount Alice the shale contains poorly preserved specimens of *Trigonia* of possible Late Jurassic or Early Cretaceous age (T. P. Poulton, personal communication, 1972).

On the west shoulder of Mount Alfred and on the ridge extending to the southwest, the rocks consist of conglomerate and andesitic flows and breccia. Unless repeated by faulting, the conglomerate is at least 1500 m thick. It is grey weathering and made up mainly of volcanic pebbles, but plutonic clasts are locally common. The clasts are well rounded, and although slightly deformed the metamorphic grade is low. The flattening of the pebbles is parallel to the bedding as indicated by layers of argillite. Most of the clasts are dacitic and many of these exhibit phenocrysts of plagioclase and less commonly hornblende. Some of the clasts exceed 2 m in length but most are 10 cm or less.

On the ridge just east of the headwaters of Eldred River the rock is dominated by garnet-biotite schist, amphibolite and tuff, indicating a considerable range in metamorphic grade. North of Mount Alfred about 40% of the clasts are plutonic, and appear to be fresh leucocratic quartz monzonite, derived possibly from the upper levels of the earliest phases of Big Julie Pluton.

The north end of the pendant is exposed in the vicinity of Pilldolla Creek and consists of marble, schist and metavolcanic rocks, an assemblage that differs considerably from that on Mount Alfred. The marble and schist form a narrow north trending projection of the pendant. The marble is buff-weathering and locally contains wollastonite and garnet. In places the marble is conglomeratic, but is commonly so sheared that the 'clasts' may actually be boudins. The marble beds are up to 3 m thick and are intercalated with thinly layered rhyolite and schist. On the summit north of Pilldolla Creek the marble is strongly contorted. The metavolcanic rocks which are actually dominant in most places, consist of rhyodacite, volcanic breccia greenstone and chlorite schist. The siliceous volcanic rock is commonly pyritiferous and rusty weathering. On the east end of the ridge north of Pilldolla Creek, the metavolcanic rocks exhibit a complex relationship with a fine-grained diorite, in places apparently dioritized and cut by diorite, and elsewhere cutting the diorite.

Head Of Toba Inlet: This segment crosses the northeast end of Toba Inlet and is separated from the Mount Alfred pendant by Big Julie Pluton. The northeastern part of the body is exposed on the ridges southwest of Julian Peak where it consists of grey-weathering irregularly layered gneiss and biotite schist, and lit-par-lit granitoid layers. The sequence dips steeply to moderately northeastward beneath Big Julie granodiorite at the exposed contact on the west shoulder of Julian Peak. At the contact the rock forms a complex of elongate agmatite, irregularly layered gneiss and granodiorite.

On Toba Inlet the central part of the body consists of isoclinally folded, quartz-biotite-garnet schist, quartzite, diopsidic layers and amphibolite. To the southwest this assemblage overlies about 1300 m of conglomerate. The clast:matrix ratio is about 4:1, with most of the clasts being subangular, partly flattened cobbles and boulders up to 2 m across (but most less than 20 cm), embedded in a schistose biotite-garnet-bearing, meta-arkose matrix. About 80% of the clasts are quartz diorite, and the remainder are chiefly quartzite (or rhyolite) and biotite schist. On the southeast shore of Toba Inlet, the conglomerate appears to be in unconformable contact with a quartz diorite that is identical to that forming some of the clasts. The actual contact, however, cannot be discerned as the matrix becomes increasingly granitoid as the contact is approached, and distinguishable clasts become rare and finally disappear. The conglomerate thus seems to grade without a break into the underlying plutonic rock (see Roddick and Woodsworth, 1973 conflicting relations appear on the northwestern shore of the inlet where the quartz diorite is separated from the conglomerate by a zone of biotite schist, quartzite and gritty arkose, which is penetrated by veins emanating from the quartz diorite. On the ridge northwest of Toba Inlet the assemblage is represented by well-layered chlorite and sericite schist, pale-weathering rhyodacite and interbedded conglomerate in beds 30 cm to 3 m thick. The clasts there are chiefly volcanic but also include about 20% plutonic and metasedimentary rocks. The rhyodacite is tightly folded about near vertical axes.

Head of Brem River to south of Mount Sir Francis Drake: This segment of Belt 5 is long and narrow at the extremeties but widens in the central area between the head of Larson Creek and Orford River . The southern end consists of conglomerate, biotite-hornblende schist, rusty-weathering rhyodacite (locally granitized), and granitoid gneiss which contains dark inclusion trains, which appear to represent partial granitization of permeable zones in the schist. At one place the conglomerate is cut by a dyke of quartz diorite. Although the metamorphic grade is higher and the conglomerate less abundant, the rocks are similar to those on the ridge northwest of Toba Inlet. The central part of the pendant consists of crudely layered rusty feldspathic biotite schist and quartzite with some layers of graphitic schist. Isolated outcrops show that the pendant also contains considerable amphibolite and thinly layered rhyolitic or dacitic tuff. Locally knots of diopsidic skarn appear in the

schist, along with a few garnetiferous layers. Conglomerate appears to be absent. Near the northeastern contact of the mid-section of the pendant lenses and layers of quartz diorite appear, producing a banded gneiss which grades into irregularly layered gneiss at the contact. The contact is otherwise sharp and appears to cross-cut the layering. The granodiorite at the contact is fine to medium-grained and extremely siliceous, although k-feldspar amounts to only 6 to 10%. It is well foliated roughly parallel with the contact.

The pendant appears to cross the valley of upper Orford River but the lack of outcrop there leaves some uncertainty.

South of Mount Sir Francis Drake the northern part of the pendant consists of whitish-weathering silicic volcanic breccia with angular clasts that are flattened parallel with the bedding, intercalated conglomerate with 90% siliceous clasts and a few definite plutonic clasts (mostly less than 2 cm across), and schistose dark grey marble with rusty intercalations of muscovite schist. The southern part is chiefly dark grey to rusty, banded amphibolite with minor siliceous tuff. The beds are steeply dipping to vertical, but show little small scale folding. The granodiorite south of the pendant is a minor lithology in the dioritic complex which underlies most of that region. Near the contact the granodiorite is intensely foliated and contains small garnets and abundant schlieren. The foliation is perpendicular to the contact, an unusual relationship in the map-area.

On the east shore of Bute Inlet just north of Purcell Point the pendant at the northern contact consists mainly of biotite schist and lesser amounts of biotite-hornblende schist and biotite-garnet schist. The schists are highly contorted and the plutonic rock is intensely sheared.

Farther south a monotonous sequence of micaceous (biotite), thinly layered quartzite, biotite schist, and minor gneissic and garnetiferous layers is exposed along the shore. The thinly layered strata are commonly contorted and exhibit small isoclinal folds. The inlet is embayed in the less competent bands. The southern part of the pendant is characterized by impure grey to buff-weathering limestone with beds ranging from 1 to 30 cm thick. Much of the limestone is micaceous and forms zones 3 to 18 m thick. It is intercalated with quartzite layers, and locally contains thin beds of conglomerate, bearing clasts of chert and aplite. The central part of the shore exposure has been intruded by a clean fine to medium-grained granodiorite, whose northern contact is marked by a spectacular agmatite. The southern contact of the granodiorite is sharp and vertical. Dykes of the granodiorite penetrate the adjacent metasedimentary rocks.

The southern contact of the pendant is occupied by a beach, then a wide migmatitic zone that consists of about 40% granitoid material and 60% metasedimentary rocks. Most of the migmatite is agmatitic or gneissic.

Mount Smith: The Mount Smith segment extends from the west shore of Bute Inlet to the headwaters of Apple River , crossing Mount Smith. On the west shore of Bute Inlet, south of Mellersh Point , the rocks are dominantly thinly-bedded rusty-weathering schist which contains biotite, hornblende and locally garnet, and minor skarn. Quartzite is also present here and there. The assemblage on the whole is similar to that on the east side of Bute Inlet. In places the schist is interrupted by zones of irregularly layered gneiss. Veining by plutonic rock is more common than on the east shore, and may form as much as 40% of some outcrops.

North of Mellersh Point, migmatites are even more abundant, but the metasedimentary rocks are essentially the same.

A good section is exposed on Mount Smith. It consists of grey to rusty weathering biotite schist, micaceous quartzite, amphibolite and crystalline limestone. Minor diopsidic and tremolitic skarn is also present. Most of the assemblage is thinly bedded and has an overall moderate dip to the south. Internally, however, tight small folds are common. If the sequence as a whole is right side up, the upper part is the more limy. At one place indeterminant fossil fragments (crinoidal, bivalves) were noted. Thin dykes of granodioritic rock cut the metasedimentary sequence.

North End Of Knight Inlet: This part of the belt is extremely complicated and the metasedimentary rocks of Mount Smith and farther southeast are enveloped as slices in granodioritic gneisses and dioritic complexes.

On the east side of Knight Inlet two bands of metasedimentary rocks are separated by a narrow zone of dioritic complex. The northern band consists of sandy, thinly bedded, crystalline limestone, feldspathic quartzite and biotite schist, and the southern band is mainly schist and limestone. The nature of the northern contact of the northern band is not known. The southern contact is marked by sheared green chlorite schist which is somewhat dioritized and crosscut by the dioritic complex. The metamorphic rocks show some complex dragfolding. This contact may be a fault. The northern contact of the southern band is sharp against biotite-rich diorite. Some feldspar porphyroblasts have developed in the schist, but it is otherwise little affected by the emplacement of the plutonic rock. The inclusions in the diorite are elongate and amphibolitic rather than schist. The southern contact is between biotite schist and limestone, and a well-foliated granitoid gneiss of quartz dioritic composition (at the contact at least). The schist is cut by pink veins of calcite containing blebs of pyrite and by thin pegmatite stringers. The limestone has been metamorphosed to a garnet-diopside-wollastonite (or tremolite) skarn.

On the west side of Knight Inlet four bands of metasedimentary rocks are exposed. The northern band consists of biotite schist, thinly bedded, brownish-weathering quartzite and rusty (pyritiferous) crystalline limestone. The schists are

isoclinally folded. The southern contact is sharp but the metasedimentary rocks contain dioritic zones, making the main contact difficult to establish.

The second band outcrops on Transit Head where it consists mainly of slaty biotite-quartz schist or micaceous quartzite. The band is made diffuse by lit-par-lit zones of granitoid material.

The third band outcrops west of Transit Head and consists of intercalated beds of greenish diopsidic quartzite (3 to 150 cm thick). The limestone weathers negatively producing a slotted outcrop. This band is about 500 m wide on the shore, and grades into a low-contrast screen gneiss and into irregularly layered gneiss. The better preserved metasedimentary layers are sparsely pyritized.

The southern band is exposed on Ahnuhati Point and consists of rusty thinly bedded, micaceous gritty quartzite and minor dark amphibolite. The contact is sharp between amphibolite (veined by pegmatite) and granodiorite with zones of banded gneiss.

BELT 6: ICEWALL CREEK TO CUMSACK MOUNTAIN

Icewall Creek to Mount Bute and beyond : Southwest of Icewall Creek is a narrow band of vertically dipping interlayered schlieren gneiss, fine-grained biotite-hornblende schist and medium-grained diorite. Locally very coarse hornblendite has developed with some crystals of hornblende exceeding 15 cm in length. These patches are actually hornblende pegmatites, and the plagioclase associated with the amphibole is also coarse-grained. In most places the band separates diorite to the northeast from quartz diorite to the southwest.

An apparent continuation of the band outcrops three kilometers southwest of Mount Bute . There it consists of irregularly layered gneiss, made up of 80% amphibolite and 20% granodiorite which forms thin layers lenses and rare crosscutting veins. The amphibolite grades in and out of gabbro and hornblende pegmatite. The unit trends northwesterly and is steeply dipping. To the southwest is a grey quartz diorite containing elongate inclusions and about 5% amphibolitic screens. On one of the screens, however, is a garnet-epidote skarn about 30 cm thick. Small red garnets are common in the quartz diorite, which in that respect, resembles the core unit of the Central Gneiss Complex east of Mount Grenville.

South Of Cumsack Mountain: West of the head of Bute Inlet a section of mainly volcanic rocks is exposed. Although vertical in most places the strata are thought to be south-facing on the basis of a greenstone which contains well-preserved pillows. The base of the sequence consists of massive to foliated amphibolite and laminated hornblende schist. These rocks contain zones of agmatite and are locally dioritized. They are cut by veins and dykes of fine-grained granodiorite. The amphibolite and schist gradually lose their layering and the rocks take on the character of greenstone. Within the greenstone is a 100 m-thick bed of intermediate to acid volcanic breccia containing subangular fragments up to 50 cm across. The matrix is schistose but the fragments are not. Above the breccia is a 7 m-thick bed of pillow lava. The pillows are somewhat flattened, and the interstices are filled with quartz. The tops of the pillows face south.

On the basis of the pillows, these rocks are tentatively assigned to the Karmutsen Formation and the somewhat more acid sequence above them to the Gambier Group. The latter sequence is also mainly greenstone but it contains considerable rhyodacite and some spotted argillite. Layers of volcanic breccia in the greenstone are common. The upper part of the assemblage dips about 60° to the north, indicating overturning, but the structure is not well understood. The southern part of the section is terminated by a fault which brings up a gneiss agmatite complex.

The partly dioritized greenstone body to the southwest between the northern branches of Bear River is thought to be correlative with the lower part of the Cumsack Mountain section.

BELT 7: TOBA PEAK TO MOUNT GRENVILLE

This belt cuts across the northeast corner of the map-area and extends into Pemberton map-area to the east, and into Mount Waddington map-area to the north.

Mount Raleigh To Mount Grenville: This is the only substantial segment of the belt in the map-area. The oldest rocks in the segment, and probably the oldest rocks in the entire map-area, underlie the area extending from east of Mount Grenville southeastward across the valley of Southgate River. They consist mainly of granitoid gneiss, and form part of a broad belt which extends diagonally across Mount Waddington map-area. On the east shoulder of Mount Grenville the complex is represented by a pale pink, streaky, strongly foliated granitoid gneiss. The mafic minerals are segregated into laminae and small euhedral garnets are present. The leucocratic phase is equivalent to a granodiorite, having about 20% k-feldspar and 15% quartz, and a density of about 2.63. The composition, however, is variable and k-feldspar ranges from zero to 40%, and quartz may form up to 50% of the rock. Schlieren and rusty screens of amphibolite are common. The structure is not yet understood, but in most places the gneisses trend northwesterly and dip gently to moderately southwest. They are in fault or intrusive contact with much

darker weathering quartz diorite to the southwest which is characterized by vertical dips.

About three miles northeast of Mount Grenville, the Central Gneiss Complex consists of spectacularly folded fluidal and schlieren gneiss (see photographs in Roddick and Woodsworth, 1977). The leucocratic phase there is mainly biotite quartz diorite (40% K-feldspar, 18% quartz, density of 2.71), and dark layers of biotite schist. It is veined by white weathering, aplitic leucocratic biotite quartz monzonite containing scattered clear pink garnets. The folds trend southwest are recumbent to the northwest. Beneath the gneisses, apparently conformably is a much less foliated light-weathering, garnetiferous, biotite granodiorite (12% K-feldspar, 33% quartz, density of 2.66). Most of this granodiorite lies north of the map-area.

On the south side of the valley of Southgate River, west of Mount Raleigh, the base of an assemblage of metavolcanic and metasedimentary rocks, tentatively correlated with the Gambier Group, consists of conglomerate with clasts of acid plutonic rock and quartz-muscovite schist. The conglomerate becomes more highly metamorphosed downward until the clasts are only vaguely visible. Although not actually exposed, this rock is thought to lie unconformably on the underlying schlieren gneiss, screen gneiss and amphibolite of the Central Gneiss Complex. There is, however, no marked angular discordance, as both units trend northerly and dip about 65° to the east.

The Mount Raleigh assemblage of Gambier Group rocks consists of 2500 to 4500 m of green andesitic volcaniclastic rocks, black argillaceous breccia, conglomerate, graphitic pelitic schists, black amphibolite, feldspathic schist, and minor marble and calc-silicate rock. The grade of metamorphism ranges up to sillimanite facies, and the isograds are not related to the contacts with surrounding plutons. More details of of this area appear in Woodsworth (in press). At Princeton University (1974).

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