GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 66-33

PRINCE RUPERT AND SKEENA MAP-AREA, BRITISH COLUMBIA

(103 I W1/2, 103 J E1/2)

(Report, 2 figures and Map 12-1966)

W. W. Hutchison

Price, $1.50

1967

CANADA

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W. W. Hutchison

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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Price subject to change without notice

ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada
1967

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ABSTRACT

Prince Rupert (east half) and Skeena map-areas cross the Coast Mountains of British Columbia between latitudes 54° and 55° N, and abut the Alaska Panhandle. They are underlain mainly by a northwest-trending zone of gneiss and migmatite that is flanked and penetrated by large bodies of plutonic rock. Sediments and volcanics in the western half of the area are of uncertain age, but are thought to be Late Palaeozoic or Early Mesozoic. They are regionally metamorphosed to gneisses and schists. Sediments in the eastern half are unmetamorphosed and are of Late Jurassic and Early Cretaceous age. The plutonic rocks, which constitute almost half the exposed rock in the area, mainly diorite, quartz diorite, granodiorite, and quartz monzonite, and are regarded as post-Early Cretaceous in age. They commonly grade into the Palaeozoic gneiss complex. Major faults probably underlie some of the pronounced northwest-trending channels. Several old prospects of gold, copper, silver, zinc, iron, limestone, and salt occur within the area.

INTRODUCTION

Prince Rupert and Skeena map-areas comprise Terrace west half (103I W 1/2) (lat. 54° to 55°N, long. 129° to 130°W) and Prince Rupert east half (103 J E 1/2) (lat. 54° to 55°N, long. 130° to 131°W, and the Alaskan border). Mapping in this area was carried out in parts of the field seasons of 1962, 1963, 1964, and 1965.

In 1962 shoreline work and limited inland traversing of the mainland was carried out by Hutchison. The outer islands were mapped in 1963 as part of a larger coastal project in which the M.V. "Malecite" was used as a floating base. J.G. Souther, party leader, A.J. Baer and W.W. Hutchison, Survey staff geologists, were assisted by P.E. Fox and S.K. Nelson (who lost his life in an aircrash on this operation). The following summer, 1964, W.W. Hutchison and A.J. Baer, assisted by J. Dawson and J.Y. Buchingham, completed the mapping of Tsimpsean Peninsula and the southern half of the Terrace west-half area using helicopter support. In 1965, again as part of a large overall program, Prince Rupert-Skeena area was completed. During this final phase the helicopter-supported operation was based on the Fisheries Research Board barge "Velella" under the leadership of J.A. Roddick with A.J. Baer and W.W. Hutchison, assisted by R.R. Culbert and G. Woodsworth.

In the field, able assistance was rendered also by K. Bagnall, W. Born, M. Gidluck, B. McMahon, B. McHale, R. Won, P. Regher, M. Lasserre, E. Mortenson, A.B. Ellis, R. Woodsworth, R. Bruaset, and J. Simpson.

Prince Rupert (population 12,000 in 1961) is the only city within the map-area. Access to it is by rail, road, boat, or daily flight from Vancouver. The only road, Highway 16, follows the banks of the Skeena River and links Prince Rupert with the interior. Much of the western part of the map-area is accessible to small boats, but use of helicopter is the only efficient way of mapping most of the eastern half of the area.

PHYSICAL FEATURES

The area extends westwards from the rugged snow-capped peaks of the Kitimat Ranges of the Coast Mountains to the low-lying coastal mainland and islands that are part of the Hecate Depression (Holland, 1964).

The mountain ranges and valleys define a dominant northwest grain to the region that is interrupted by two major topographic features, Portland Inlet and Skeena River.

Physiographically the area can be subdivided into three main regions. The first comprises the islands and the greater part of Tsimpsean Peninsula where the metasedimentary and metavolcanic rocks have been greatly eroded. The less metamorphosed schists now form forested coastal lowland terrain on western Tsimpsean Peninsula and Digby Island. The more highly metamorphosed rocks form ridges up to 2,500 feet, which have resisted erosion so that in the eastern part of Tsimpsean Peninsula the relief is moderately rugged. Generally the slopes are densely forested and extensive outcrop is present only on ridge tops and along the shoreline.

On the outer islands of Dundas, Melville, Stephens, and Porcher the more easily eroded metamorphic rocks have been partly protected by the more resistant plutonic rocks, which now form rounded and in places dome-shaped hills less than 1,500 feet high. The islands are forested, but in many localities trees are stunted, especially near areas of open moorland.

The western and central physiographic regions are clearly separated by the western contacts of the Quottoon and Ecstall plutons, but only a broad transition zone extending from Mylor Peninsula southeast to Khatada Lake divides the central and eastern regions. In the central region the elevations of ridge-tops vary gradually from 3,500 feet in the west to more than 5,000 feet above sea-level in the east. The ridge-tops may represent part of an old erosion surface. The mountains underlain by plutonic rock have bare, broad summits and well rounded ridges and shoulders. Treeline is at approximately 2,500 feet. The valleys are U-shaped, commonly with impressive walls of smooth, near-vertical, joint-free rock that may exceed a thousand feet in height. A striking feature of this region is the scarcity of scree.

The transition between central and eastern regions is marked by increasing altitude and sharpening of the mountain ridges. Most ridge crests are above 5,000 feet and the highest peaks are just above 7,500 feet elevation. In this region the valley walls are less steep, scree is more common on the slopes and treeline is slightly higher, extending above 3,000 feet. Permanent snow and ice are common in cirques, where they form small valley glaciers. The longest glacier, at the head of the Exstew River, is about 5 miles long and its snout is below 2,500 feet elevation.

In the southern half of the map-area the streams are either part of the Skeena drainage system or flow directly into the sea. The Kitsumkalum and Ishkheenickh Rivers and their tributaries drain most of the northern part of the area. The Kitsumkalum flows eastward out of the map-area, but later flows south to join the Skeena near Terrace. The Ishkheenickh flows northwards into the Nass River, which enters Portland Inlet at the northern boundary of the area.

GLACIATION

Most of the region has probably been glaciated by alpine and valley glaciers and by at least one ice sheet. In spite of the obvious ice-sculpturing on the bold-featured landforms, glacial deposits are rare. Presumably the high precipitation and rugged relief have ensured that debris was flushed down into the valleys and part of it thence out to sea. Some of the larger valleys are floored by Pleistocene deposits, which have since been blanketed by alluvium. For example, drilling in Skeena River valley near the mouth of Kwinitsa Creek encountered 100 feet of clay underlain by 110 feet of salty mud (B.C. Minister of Mines Annual Report, 1913, p. 87).

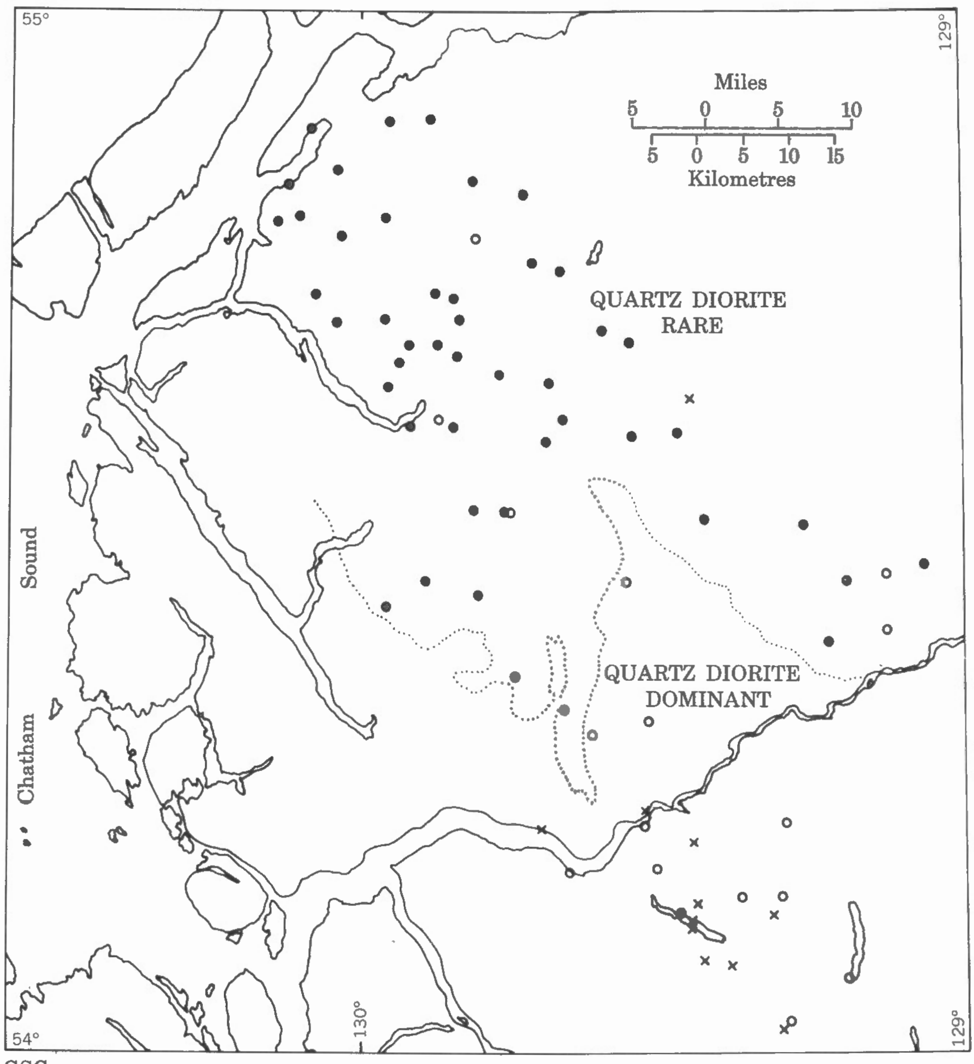
The distribution of glacial erratics and the orientation of striae indicate that the movement of the ice sheet on the mainland was from northeast to southwest. The direction of ice movement on the outer islands is not known.

GENERAL GEOLOGY

The core of the Coast Mountains in the project area is underlain by a northwest-trending zone of gneiss and migmatite that is flanked and penetrated by large bodies of plutonic rock. Regionally metamorphosed sedimentary and volcanic strata in the western half of the project area are of uncertain age, but are thought to be Late Palaeozoic and Early Mesozoic. The sediments to the east of the main body of plutonic rock are unmetamorphosed argillites belonging to the Bowser Group of Late Jurassic and Early Cretaceous age.

The major northwest trend is in many places deformed or obliterated by large bodies of plutonic rock. The plutonic rock commonly grades into the gneiss complex with which it appears to be intimately related. By contrast, the sedimentary rocks both to the west and east have been commonly deformed and forcefully intruded by the plutonic rock.

Major faults probably underlie some of the pronounced northwest-trending channels and also the northeast-trending channel of Portland Inlet.



LEGEND

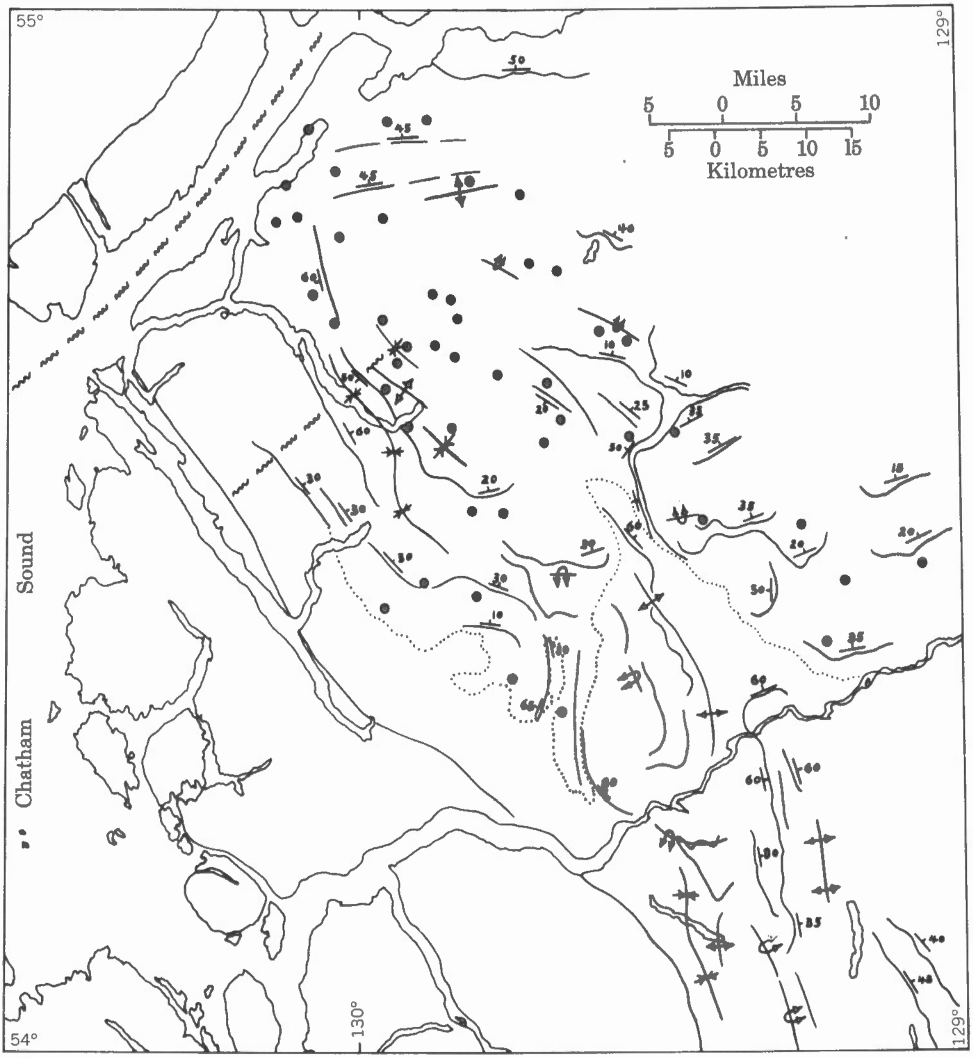
Approximate trace of 'Quartz diorite line' separating areas of granodiorite gneiss from areas of quartz diorite gneiss. . . . . . .

Sillimanite garnet gneiss. . . . . ×

Plutonic phase of gneiss containing less than 5% K feldspar: quartz diorite gneiss. . . . . ○

Plutonic phase of gneiss containing between 5–30% K feldspar: granodiorite gneiss. . . . . . ●

Figure 1. Distribution of stained plutonic specimens from the gneiss complex. Granodiorite is dominant in the north, quartz diorite is dominant in the south.



GSC

LEGEND

Attitude of trend
Structural trend
Possible fault
Antiformal axis
Synformal axis
Plutonic phase of gneiss containing between 5–30% K feldspar: granodiorite gneiss
Approximate trace of 'Quartz diorite line' separating areas of granodiorite gneiss from areas of quartz diorite gneiss

Figure 2. Major structural features of the gneiss complex. 'Quartz diorite line' follows, in places, a zone of structural discontinuity, which suggests that this line may have some structural or stratigraphic significance.

STRATIFIED AND VOLCANIC ROCKS

Map-unit 1. Gneiss Complex

Map-unit 1 comprises high-grade gneiss, migmatite, and locally plutonic rock. The gneiss is characteristically granitoid and original sedimentary structures are rarely present. The gneissic layering varies from regular (each layer being less than 3 inches thick) to extremely discontinuous in which relics of original layers appear as streaks. Granitic layers in this type of gneiss commonly transgress layering that may represent original bedding. In many places the gneiss is veined by a stockwork of granitic material. Continuity of layering in gneiss is also disrupted by deformation. Folding is usually disharmonious and fluidal in character. Boudins are common in the amphibolitic layers and are in places not only dislocated but rotated in the gneissic matrix.

The gneiss commonly grades in various ways into relatively homogeneous plutonic rock. In places veins, both dilational and non-dilational, of granitic material in the gneiss increase in abundance until the rock is dominantly granitic. Elsewhere the gneiss is transformed to a granitic rock by a persuasive crystal growth with little disturbance of the layering. The end product is a massive granitoid rock in which ghostly relics of the layering are delicately preserved. Consequently in many places no definable 'contact' between plutonic rock and gneiss exists.

Sufficiently distinctive and continuous marker horizons are rare. Where present they are commonly rusty-weathering layers in the gneiss, which can be followed only for short distances. Structural trends placed on the map mainly represent the trace of these layers where they could be followed.

Data from staining for K-feldspar of granitic layers within the gneiss (Figs. 1 and 2) indicate that the northern part of the gneiss complex differs from the southern part. In the north the integral granitic layers commonly contain K-feldspar, that is, they are granodioritic in composition, whereas in the south the granitic layers normally lack K-feldspar and are quartz dioritic. The dotted boundary on Figures 1 and 2 separating these two areas can therefore be regarded as the approximate trace of the "quartz diorite line" through the gneiss complex. The occurrence of sillimanite-garnet-gneiss to the south (Fig. 1) suggests that the dissimilarities to the north and south of this line may then reflect original lithological differences and/or differences in metamorphic grade.

The age of the rocks in this gneiss complex and the age of metamorphism are not known. Probably the gneiss is made up of a number of stratigraphic units. A tentative pre-Permian age has been assigned for two reasons. The gneiss complex extends southeast of the map-area (see Roddick, Baer, and Hutchison, 1966) through the Douglas Channel area to the Whitesail map-area, where it appears to underlie metamorphic rocks, which according to E.W. Bamber of the Geological Survey, contain fossils of probable Permian age. Also the Permian limestone and greenstone that extend westward along the Skeena River from the town of Terrace and appear to die out at the east boundary of the present map-area (Duffell and Souther, 1964) are relatively unmetamorphosed. The lack of apparent metamorphic equivalents of the combination of limestone and greenstone in the gneiss complex to the west is interpreted as indicating that Permian strata do not form part of the complex.

Map-units 2 and 3

Map-units 2 and 3 are made up chiefly of thinly bedded metasedimentary rocks with individual beds typically ranging from 2 to 6 inches in thickness. Hornblende biotite (± garnet), biotite garnet, and amphibolite schist and gneiss, and layered quartz feldspar schists and impure quartzites are the dominant types in the higher grade (almandine amphibolite facies) rocks. In the lower grade (greenschist facies) rocks the most common types are chlorite, sericite, biotite, biotite hornblende garnet, graphitic schists, and phyllite and slate. Locally conglomerates are common. Usually they are intraformational but one, on Genn Islands (northeast of Porcher Island) contains granitic clasts. A minor part of the exposed strata is formed of crystalline limestone, which occurs thickly bedded in zones ranging in width from 10 to more than 100 feet. Most of the schist and gneiss is not calcareous, but calc-silicate minerals are locally common. Sills and/or flows, although not common on Tsimpsean Peninsula, form a large, but not dominant, part of the succession on Porcher Island. The rocks of map-units 2 and 3 are so strongly folded that no meaningful estimate of thickness can be given.

On Tsimpsean Peninsula the grade of metamorphism gradually increases from greenschist facies in the west to almandine amphibolite facies in the east. Also, south of Khutzeymateen Inlet, the metamorphic grade in the metasedimentary inlier apparently decreases inward away from the contacts with the gneiss.

On Pearse Island the high-grade gneisses of map-unit 3 are not easily distinguished from those of unit 1. Consequently some gneiss mapped as unit 3 may belong to map-unit 1.

Flat-lying schist and limestone cap mountains southwest of Amoth Lake in the northern region of the gneiss complex. The contact between gneiss complex and the capping schists is there sharply defined.

Elsewhere the contact between map-units 1 and 3 may vary from gradational to sharply defined. The highly folded nature of unit 3 and plastic flowage effects in unit 1 obscure any definite evidence of unconformity, if such exists between the two units.

No diagnostic fossils have been found in units 2 and 3. Richardson (1876), Dawson (1880), McConnell (1914), and Dolmage (1923), on the basis of lithology suggested a Triassic and/or Upper Palaeozoic age for these rocks. Dawson, who was familiar with some of the stratigraphy of Vancouver Island and Queen Charlotte Islands, was impressed by the similarity of Triassic strata there to the schists found at various localities on Tsimpsean Peninsula. Sutherland Brown (personal communication) also suggests that some of the thin-bedded, impure quartzite and amphibolitic schist between Prince Rupert and Port Edward are similar to the Sinemurian part of the Kunga Formation (Upper Triassic-Lower Jurassic) of the Queen Charlotte Islands.

Map-units 1, 2, and 3 are the southerly extension of the Wrangell-Revillagigedo belt of metamorphic rocks in Alaska. On the basis of lithology and some palaeontological evidence, Buddington and Chapin (1929) suggested that this belt comprises chiefly Carboniferous and Triassic strata.

Lithologic similarities indicate that the metasediments of the Prince Rupert area (map-units 2 and 3) include mainly Triassic-Lower Jurassic strata and minor Upper Palaeozoic strata.

Map-unit 4

The metavolcanic rocks (map-unit 4) of the outer islands include non-porphyritic greenstones, tuffs, breccias, and minor porphyritic rhyolite. In places parts of the volcanic assemblage (4b) have acquired a complex dioritic character owing to metamorphism and possibly to local metasomatism. Similar dioritic phases are found in metavolcanic rocks northeast of Alastair Lake. Mount Morse, north of Prince Rupert, is believed to be part of a recrystallized mass of acid volcanic rock, which typically lacks any evidence of bedding.

Map-unit 5

The metavolcanic rocks on Porcher Island may not be all of the same age. Volcanic rocks on Porcher Island (5) thought to be younger than those of map-unit 4 are similar in lithology, but seem to be less metamorphosed and less schistose. Also, they are only gently folded and, in places, vesicular.

The age of neither of these metavolcanic map-units is known, nor is the relationship between the metavolcanic rocks and the metasediments (2, 3). Previously the writer (Hutchison, 1965b) attributed a Middle Jurassic age to the metavolcanic rocks northeast of Alastair Lake on the basis of their continuity with volcanic rocks of supposed Hazelton-type in the adjacent Terrace area (Duffell and Souther, 1964). On re-examination of these volcanic rocks, however, he now feels the evidence is insufficient to support this postulated age.

Map-unit 6

In the northeast corner of the map-area are dark grey and, in places, rusty-weathering unmetamorphosed argillites and greywackes (unit 6), which form the western extension of the Bowser Group. This group, which underlies much of the northern half of the Terrace map-area, has yielded both fossil shells and plant remains (Duffell and Souther, 1964). Based on these fossils the age of this group is Late Jurassic and probably Early Cretaceous. Fossil collections made from the group in Prince Rupert-Skeena map-area have not yet been described.

At contacts with the granitic rocks of Ponder pluton the argillites and greywackes are strongly deformed, but show only slight evidence of contact metamorphism.

Map-unit 13

Intrusive volcanic breccias (13) on islands near Port Simpson possibly represent young (Tertiary?) volcanic necks and may be related to the northeast-trending dyke swarms that are common along Portland Inlet.

STRUCTURE AND METAMORPHISM OF ROCKS IN UNITS 1 TO 6

The structure on the mainland is complex. One or more regional deformations and metamorphisms, the variation in structural styles, and the superimposed effects of plutonism have combined to form a complicated structural pattern.

Gneiss Complex (Map-unit 1)

Although folding is commonly disharmonious with no apparent consistent attitudes or trends, some parts of the gneiss complex do display two or more locally persistent trends. Two trends are particularly evident between the head of Quottoon Inlet to the west and Exstew River to the east.

There the gneiss is formed of many sheets or plates, which strike roughly east and dip gently north. These sheets are locally deformed or disrupted by north to northwest trends in the gneiss and gneissic plutonic rock. In the northern region of the gneiss complex the dominant attitude is also east-striking and north-dipping. At four places recumbent with approximately east-west axes (see Fig. 2) can be traced laterally for only short distances before they are deformed or obliterated by north to northwest trends. In the few places where relationships can be interpreted with confidence the east-west trends appear to be older.

The evidence therefore points to a possible early phase of deformation during which some of the large recumbent folds (see Hutchison, 1965a) were formed. Because some of these trends are cut or partly obliterated by plutonic rock this deformation took place apparently before or in the early stages of emplacement in this region.

The problem also arises whether some of the gneiss complex represents an older basement; that is, strata folded, metamorphosed, and eroded prior to deposition of the younger (now metamorphosed) sediments. The subsequent upwelling of parts of the migmatite complex, the accompanying deformation, metamorphism, and partial migmatization of the mantling sediments would in many places obliterate, perhaps completely, the unconformity between basement and the metasediments. In the Prince Rupert area some evidence, however, suggests that it exists. For example, the complex structure of the gneiss on either side of the metasediments on Khutzeymateen Inlet consists partly of east-northeast attitudes and fold axes plunging at shallow angles to the east-northeast; comparable structures have not been observed in the neighbouring metasediments. The actual contact between metasediments and gneiss complex appears in many places to represent a marked discontinuity in metamorphic character; the gneiss complex is typically granitoid in appearance whereas metasedimentary strata commonly comprise flaggy schists with marked sedimentary layering. Contradicting this evidence for an old basement is the apparent conformity found between flat-lying metasediments and gneiss on the mountain 5 miles southwest of Amoth Lake. Nevertheless, the marked change at the contact from granitoid character of the gneiss to the dark finer-grained character of the schist indicates a possible disconformity.

The development of the dominant north to northwest trend probably represents the culmination of the major period of metamorphism and folding. In places, west of Alastair Lake and between Quottoon pluton and the metasediments of Khutzeymateen Inlet, the layers of the gneiss complex (1) display shallow dips to the east and northeast. Recumbent folds are present (Fig. 2) in a few places indicating tectonic transport to the southwest.

Elsewhere the north to northwest trends in the gneiss are accompanied by steep dips (for example, at Khatada Lake). Although small folds in the gneiss and migmatite are commonly disharmonic, many fold axes plunge at shallow angles to the north suggesting a regional tectonic event.

The metamorphic rocks of the gneiss complex belong to the almandine-amphibolite facies of metamorphism. On and south of Skeena River sillimanite is commonly present (but not kyanite, which has been found only in one locality, about 8 miles southeast of Amoth Lake). The restriction of sillimanite to the area south of Skeena River may reflect higher metamorphic temperatures there.

Meta-sediments of Khutzeymateen Inlet (Map-unit 3b)

In Khutzeymateen Inlet the sediments are isoclinally folded and appear to form an asymmetrical northwest-plunging synformal structure. The eastern zone of this structure is characterized by steep dips to the west and the western zone by steep to moderate dips to the east. Most of the sediments immediately overlying the gneiss complex belong to the almandine-amphibolite facies but farther from the contact most belong to the greenschist facies.

Tsimpsean Peninsula and the Outer Islands (Map-units 2, 2a, 3a, 3c, 3d, 4, 4a, 4b, 4c, 4d, 4e and 5)

Tsimpsean Peninsula displays a variety of structural styles and metamorphism. The grade of metamorphism generally increases from west to east resulting in three main zones: greenschist facies of map-unit 2; almandine-amphibolite facies of map-unit 3d; schist, gneiss, and minor migmatite of the kyanite-muscovite-quartz subfacies of map-unit 3a. The structure is most complex in the low grade metamorphic rocks where several phases of deformation can be distinguished at some localities. There the rocks, typical of low grade schists and phyllites, have well developed, axial-plane foliation with generally shallow attitudes but with refolding and crinkling of the schistosity. In the almandine-amphibolite facies the rocks are tightly or isoclinally folded. The general dip is to the east and varies gradually from moderate in the west to steep in the east. In the kyanite-muscovite-quartz subfacies the dips are commonly steep and plastic flow-folding is evident.

Metamorphism, including the formation of kyanite, occurred during or late in the main phase of major deformation and was followed by partial recrystallization during which some minerals, especially biotite, grew randomly across the schistosity.

The structural picture in the southern part of Tsimpsean Peninsula is further complicated by superimposed deformation associated with the forceful emplacement of the Ecstall pluton. The sediments were buckled by the upward and northward movement of this body, disrupting the northwest trends.

Sedimentary strata on the islands are tightly or isoclinally folded. East of Salt Lagoon on Porcher Island the dominant feature seems to be a northwest-trending synformal structure. Younger volcanic strata (map-unit 5) that apparently overlie the structure are gently folded about north-south axes.

Generally the intense folding and metamorphism obscure the precise relationships between rock of map-units 1 to 5. Some exceptions have already been referred to. The problem of relationships is further compounded by the uncertainty that each map-unit comprises everywhere the same stratigraphic units.

FAULTS

Some of the channels that parallel the regional northwesterly trend represent eroded fault zones. Portland Inlet, which crosses the regional trend, is possibly a major fault but the rough continuity of some map-units across it indicates that the lateral offset is less than 5 miles.

PLUTONIC ROCKS

General Statement

Almost half the exposed rock in the map-area is of plutonic origin. Intermediate (map-units 8, 9, and 10) and acidic (11 and 12) plutonic rocks are dominant and form large parts of the major plutons; basic rock (7) is of relatively minor extent.

Detailed petrographic examinations of thin sections from the rocks are currently being carried out and the results will be published later. Consequently some of the data reported in the following paragraphs and tables are preliminary and generalized.

Most of the plutonic rocks are grey, while more acidic varieties, such as granodiorite and quartz monzonite, may be buff grey. Because it is not commonly possible to make estimates of the relative proportions of the felsic minerals in a hand specimen owing to difficulty in distinguishing plagioclase, quartz, and K-feldspar, many of the rock samples were stained in the field (Roddick, Baer, and Hutchison, 1966). This greatly assisted in the classification of the plutonic rocks.

Some of the petrographic and textural features of the major plutonic rocks are summarized in Table I. The mineralogy is similar to that reported for other major areas of granodiorite and quartz diorite. Unusual or abnormal plutonic rock types were not found in this region.

Each of the four common plutonic rock types (diorite, quartz diorite, granodiorite, and quartz monzonite) can be subdivided into four groups depending on their relative proportions of biotite and hornblende; this gives a total of 16 subdivisions. The average modal estimate and specific gravity are listed in Table II for each of the 16 subdivisions. These figures provide data on the mineralogical composition of the dominant rock types in this region. In Table III the specific gravity for each subdivision indicates a general although not uniform decrease in specific gravity from hornblende-biotite diorite to biotite quartz monzonite.

The habits of minerals vary widely. As a result the following comments refer to the most common habits noted for minerals in the major plutonic rock types. Hornblende crystals vary in habit from granular intergrown aggregates to isolated stumpy prisms. Biotite typically occurs as small flakes, coarse hexagonal books, or coarse, ragged poikiloblastic crystals. Plagioclase varies in form from coarse granular to subhedral tabular crystals. In composition it normally lies in the oligoclase-andesine range. Quartz forms coarse anhedral crystals, which may be isolated or in aggregates. Although normally glassy and transparent, it may also be translucent and of a smoky hue. Potash feldspar, if present in small amounts (less than 3% approximately), usually occurs in the interstices of the rock associated with myrmekite, but if present in larger amounts it forms coarse poikiloblastic crystals. At a few localities the potash feldspar forms coarse euhedral megacrysts in the plutonic rock. In parts of some plutons (e.g. Quottoon) sphene is prominent as coarse, dark honey-coloured, lozenge-shaped crystals. Coarse granular epidote is a common accessory mineral in the Ecstall pluton.

Parts of some plutons are foliated or gneissic in character. Foliation is here defined as a parallel alignment of mafic minerals and to a lesser extent of tabular plagioclase crystals and aggregates of quartz. The degree of foliation was assessed as faint, moderate, or well developed. Gneissic structure refers here to the layering or banding produced by the apparent segregation of dark and light minerals. Normally the gneissic character of a rock can be assessed only on an outcrop whereas foliation

TABLE I

Summary of some petrographic and textural features of the major plutonic rock types

Map Unit	Average Grain Size	Average Foliation	Major Minerals	Minor Minerals (those less commonly present in brackets)	Common Accessory Minerals
Diorite-Gabbro (7)	Medium grained	None to faint	Labradorite - Andesine, H.B., Pyx., Bi	Qtz., Kp.	Mag., Il., Ap.
Gneissic Diorite (8) and Diorite (9)	Coarse grained	Mod. to well developed	Andesine, Hb., Bi	Qtz., Kp., Chl.	Mag., Il., Epid., Sphene, Ser., Zr.
Qtz. Diorite (10)	Coarse grained	None to well developed	Andesine, Qtz., Hb., Bi.	Chl. (Sphene, Epid.)	Sphene, Epid., Mag., Ser., Ap., Zr., Prehnite
Granodiorite (11)	Medium to coarse grained	None to well developed	Oligoclase-andesine, Qtz., Kp., Hb., Bi.	Chl. (epid.)	Epid., Sphene, Mag., Ap., Zr.
Qtz. Monzonite	Medium to very coarse grained	None to faint	Oligoclase-andesine, Qtz., Kp., Hb., Bi.	Chl. (Muscovite)	Epid., Sphene, Mag., Ap., Zr., Prehnite.

Abbreviations:

Hb. - Hornblende	Kp. - K feldspar	Mag. - Magnetite
Pyx. - Pyroxene	Chl. - Chlorite	Ap. - Apatite
Bi. - Biotite	Epid. - Epidote	Il. - Ilmenite
Qtz. - Quartz	Ser. - Sericite	Zr. - Zircon

TABLE II

Averages of modal estimates and specific gravities of 211 samples from the Prince Rupert-Skeena area.

Rock Type	No. of Samples	Total Mafic Minerals	Potash Feldspar	Quartz	Plagioclase Feldspar	Average Density	Standard Deviation
Hornblende Diorite	1	40	0	3	56	2.94	n.d.
Hornblende-Biotite Diorite	6	25	1	3	71	2.80	0.05
Biotite-Hornblende Diorite	3	20	1	3	76	2.72	0.05
Biotite Diorite	-	-	-	-	-	-	-
Hornblende Quartz Diorite	-	-	-	-	-	-	-
Hornblende-Biotite Qtz. Diorite	24	21	1	11	67	2.74	0.03
Biotite-Hornblende Qtz. Diorite	25	21	1	17	61	2.75	0.04
Biotite-Quartz Diorite	13	17	1	18	63	2.71	0.05
Hornblende Granodiorite	-	-	-	-	-	-	-
Hornblende-Biotite, Granodiorite	16	12	11	21	56	2.70	0.04
Biotite-Hornblende Granodiorite	39	14	10	19	54	2.70	0.04
Biotite Granodiorite	29	10	11	21	58	2.66	0.03
Hornblende-Quartz Monzonite	-	-	-	-	-	-	-
Hornblende-Biotite-Qtz. Monzonite	3	10	20	17	53	2.66	0.03
Biotite-Hornblende-Qtz. Monzonite	15	8	24	27	41	2.65	0.03
Biotite-Quartz Monzonite	37	7	25	28	40	2.64	0.03

(Modal estimates made in field on stained surface of a rock sample)

TABLE III

Average specific gravities for major plutonic rock types (from 211 stained specimens).

BIOTITE / HORNBLENDE Ratio \ ROCK TYPE	DIORITE	QUARTZ DIORITE	GRANO-DIORITE	QUARTZ MONZONITE
BIOTITE		2.71 (13)	2.66 (29)	2.64 (37)
BIOTITE > HORN.	2.72 (3)	2.75 (25)	2.70 (39)	2.65 (15)
HORN. > BIOTITE	2.80 (6)	2.74 (24)	2.70 (16)	2.66 (3)
HORNBLENDE	2.94 (1)			

Standard deviation ranges from 0.03 to 0.05 (see Table II).
Number in parentheses refers to number of specimens.

Abbreviations: Biotite > Horn. - Biotite more abundant than hornblende.
Horn. > Biotite - Hornblende more abundant than biotite.

can be assessed on a single hand specimen. Gneissic plutonic rock is dominantly foliated in character, yet in places exhibits gneissic structure that commonly grades into foliated plutonic rock along strike. In a few localities gneiss can be traced along strike into foliated plutonic rock and ultimately into massive homogeneous plutonic rock. The layers in a gneissic plutonic rock may not themselves be foliated. Also, whereas the gneissic layering is commonly not equally developed over one outcrop, foliation commonly is. In some places foliation clearly transects the gneissic structure in the plutonic rock.

The degree of foliation commonly decreases inward from the contacts of plutons. For example, in the Ecstall pluton, the northern part of Quottoon pluton, and near the eastern margin of Ponder pluton it decreases gradually inward from well developed or moderate to poor or non-existent. The central areas of most plutons are underlain by massive plutonic rock.

Gneissic plutonic rock is most common in the southern part of Quottoon pluton, in the diorite body between Kwinitsa, on Skeena River, and Exchamsiks River and in many places along the southwest margin of the Ponder pluton, as well as at other places indicated on the map. A faint but discernable regular gneissic structure forms gross layers or sheets in Alastair Lake pluton near the east margin of the project area. This produces a sheeting effect that can be seen from a distance of a mile or more dipping gently to the northeast.

Map-unit 7

Gabbro, norite, and pyroxene diorite (7) occur as small isolated bodies. The norite of Smith Island grades outward into diorite and quartz diorite and thus appears to form the core of a zoned plutonic body. Northeast of Alastair Lake the small basic masses are thought to be younger than the neighbouring plutonic and metamorphic rocks, but the relationships have not been definitely established.

Map-units 8 to 12

Map-unit 8 is dominantly a gneissic diorite that is heterogeneous and commonly contains amphibolite and augen gneiss. Much of this unit probably represents recrystallized metavolcanic rocks and sedimentary derivatives. By contrast the diorite of map-unit 9 is comparatively massive and homogeneous on the islands near the northeast margin of the Ecstall pluton and in the small body near the east margin of the map-area south of Skeena River. The diorite body north of Skeena River between Kasiks and Exchamsiks Rivers, however, is commonly foliated, gneissic, and gradational into the gneiss complex (1). Quartz diorite (10) forms the greater part of Quottoon pluton and underlies large areas of Ecstall and Alastair Lake plutons and other bodies on the outer islands. Gneissic quartz diorite is dominant in the southern part of the Quottoon pluton. Quartz diorite also forms part of the irregularly shaped and, in places, flat-lying masses west of Alastair Lake. Granodiorite (11) forms most of Ponder pluton, large parts of Ecstall and Alastair Lake plutons, and underlies scattered areas on the mainland and on some of the islands. Parts of the Ecstall and Ponder composite plutons and those on Melville and Porcher Island are formed of homogeneous, massive and generally inclusion-free quartz monzonite (12).

Contacts between plutonic rocks of units 8 to 12 are in many places gradational so that relative ages of the rock are not always apparent. Commonly one plutonic rock type may be foliated whereas the adjacent plutonic rock type may not be; these relationships are interpreted to indicate that the less well foliated rock type is younger. On this basis it can be shown that the more acidic plutonic rocks are dominantly younger than the intermediate plutonic rocks.

Inclusions

The plutonic rocks contain two principal types of inclusions: inclusions of nearby wall-rock, and rounded or lensoid masses of amphibolite, which commonly are of uncertain origin.

Inclusions of Wall-Rock

Inclusions of wall-rock are normally restricted to certain regions along the contact of a pluton and range between two extreme types that are probably representative of two different processes. One end member occurs as angular blocks, which appear to have been broken from larger blocks or wall-rock. At the other extreme are inclusions of partly transformed country rock. Good examples of the first mentioned variety are found near the east contact of Ponder pluton, where large angular blocks of Bowser Group in plutonic rock are part of a locally developed agmatite. Some of these large blocks can be seen to have been separated from the wall-rock by dilational veining and at a few localities the blocks have been apparently rotated. Good examples of blocks representing relics of a passive transformation of wall-rock are not common in this map-area. The main reason for this appears to be that transformation is commonly accompanied by movement in this region. One good example, however, is found on the ridge to the south of the glacier at the headwaters of the Exchamsiks River where quartz diorite that is commonly foliated or gneissic has been passively transformed to a finer-grained quartz monzonite or granodiorite.

Amphibolite Inclusions of Uncertain Origin

Almost ubiquitous in some plutons and in parts of others are dark lensoid inclusions ranging in size from 5 to 30 inches. They are composed chiefly of hornblende (± biotite) and plagioclase. These inclusions commonly have the shape of flattened ellipsoids, with the greater axes lying in the plane of foliation in the plutonic rock. The degree of flattening is normally proportional to the degree of foliation. In massive plutonic rock most inclusions lack the lensoid character and are spherical.

Inclusions of similar composition but of greater size (in places up to 30 feet or more in length) are found locally in plutonic rock containing the more normal-sized inclusions. For example, on the north shore of Somerville Island, the quartz diorite contains dark elongate lensoid inclusions ranging from 6 feet long and 1 foot across up to 30 feet long and 5 feet across, which resulted in this phase of quartz diorite being termed 'porpoise rock'. Adjacent quartz diorite contains the normal football-size inclusions.

These amphibolitic inclusions generally form less than 5 per cent of the exposed rock, but locally they comprise over 50 per cent. They are most common in diorite and quartz diorite and less common in granodiorite. Quartz monzonite rarely contains such inclusions.

The origin of these inclusions is not completely understood. Many appear to be partly transformed metavolcanic rocks (such as on northern Porcher Island, northern Dundas Island, and western Dunira Island) or untransformed amphibolitic relics in mobilized gneissic plutonic rock (such as on Wales Island, and between Leverson Lake and the mouth of the Khyex River). A few appear to have a different origin. At two localities synplutonic dykes (Roddick, 1965) were traced into a zone where the dykes were partly replaced leaving rounded inclusions. Farther along the expected continuation of the dyke only scattered, rounded inclusions remain. Presumably only a small number of inclusions originated in this way.

Synplutonic Dykes

The principal characteristics of synplutonic dykes are illustrated and described in detail in Roddick and Armstrong (1959) and Roddick (1965). In the Prince Rupert-Skeena map-area these dykes were encountered much less frequently than in map-areas to the south and southeast. In spite of their rarity they are none the less of great importance in providing vital data on the processes of plutonism (see Roddick, 1965). These dykes were observed on the northwest shore of Nasoga Gulf. There two sets of dykes intersect one another; the older clearly cuts the banded gneiss component of a migmatite, but is itself partly replaced and also highly deformed by shearing parallel to the foliation in the plutonic phase of the migmatite. The younger dyke cuts the older and is also partly transformed and dislocated, but it has not been deformed by the shear foliation.

Although most of these dykes appear to be synplutonic in the sense described by Roddick some may be 'interplutonic'. Insufficient work has been done to assess their origin and relative time of emplacement.

PLUTONISM AND EMPLACEMENT OF PLUTONIC ROCKS

Plutonic rocks occur in different environments ranging from that in large discrete bodies to that in the integral parts of migmatites. The relationships of these rocks to the prevailing country rock reveal in places the manner of emplacement and also some of the stages followed in their evolution.

Ponder pluton along its western contact grades into the gneiss complex north of Amoth Lake, but in places shows a complex interfingering with the gneiss. South of Mt. Leighton a tongue of massive, homogeneous plutonic rock extends for at least 6 miles over almost flat-lying gneiss. The actual contact appears to be gradational, but has not been examined in sufficient detail to establish whether this mass of plutonic rock actually overrode the gneiss or formed in situ. Similarly sheets and tongues of gneissic plutonic rock in the gneiss complex west of Alastair Lake do not appear to have intruded the gneiss but rather appear to have moved upward with the gneiss.

In contrast to the intimate relationship of gneiss and plutonic rock along its western contact, the eastern part of the Ponder pluton evidently forcefully intruded strata of the Bowser Group. There the strata have not been regionally metamorphosed but show the characteristic "spotting" and hornfelsing normally associated with contact metamorphism.

The present topography seems to expose different "levels" of Ponder pluton; a deep-seated level on the west, and a shallow level on the east. This could result from a number of causes, such as the centre of uplift or the greatest superincumbent load lying near the western edge of Ponder pluton.

The northern and western contacts of the Ecstall pluton give the impression that it intruded and partly overrode the metasediments as an essentially solid but plastic mass. The evidence for solidity is the smooth form of the contact, the lack of inclusions of country rock near the contacts, the lack of veins or dykes of plutonic rock in the metasediments, crinkling and drag-folding of early foliation in the plutonic rock by younger shear folding at a few places close to the contact, and the lack of any pronounced thermal aureole in the adjacent metasediments.

By contrast the plutons on Melville, Stephens, and western Porcher Islands, and on Toon River have apparently been emplaced in part by forceful intrusion and stoping of wall-rock accompanied by local contact metamorphism.

Attention has already been drawn (Hutchison, 1965b) to the grossly 'tadpole' shape in plan of Quottoon, Ecstall, and Captain Cove plutons (Captain Cove pluton is located on Macaulay and Pitt Islands in the Douglas Channel map-area to the southwest of the Prince Rupert map-area). The three, which are aligned in a northwest direction have 'heads' that appear to have moved bodily to the northwest intruding the surrounding country rock. This may represent a northward movement away from the deeper axial zone of the Skeena Arch towards higher zones of lower pressure on the flanks of the arch.

The apparent movement of the head of Quottoon pluton away from high-grade migmatite gneisses to the south, the almost consistent plunge to the north of small fold axes in the gneiss, and the apparent increase in grade of metamorphism in the gneisses south of Skeena River combine to suggest that exposures to the south represent successively deeper levels of this pluton. Rather than regard the Quottoon pluton as part of a large underlying batholith, the writer postulates that it is a partly homogenized and partly mobilized stratigraphic unit that underlies and also intrudes the gneiss complex.

TIME OF EMPLACEMENT OF THE PLUTONIC ROCKS

Little is known about the ages of emplacement of the plutonic rocks. Parts of Ponder pluton clearly intrude the Bowser Group in the northeast corner of the area and are therefore presumed to be post-Early Cretaceous in age. Potassium argon dates on biotite give 46 m.y. and 44 m.y. for samples collected from Ponder and Alastair Lake plutons respectively. A sample from Ecstall pluton is dated at 64 m.y. and a diorite on the Skeena River just west of the mouth of Kasiks River gives a younger age of 43 m.y.

These ages do not contradict field evidence for time of emplacement. None the less it should be emphasized that some corroborative evidence is required before these results can be accepted. Instead of the time of emplacement the indicated ages may represent a distinct post-emplacement thermal event or alternatively the time at which radiogenic argon ceased to diffuse during gradual unroofing and uplift.

GEOLOGICAL HISTORY

In the Prince Rupert-Terrace map-areas there are at least three periods of tectonism (Table IV). The earliest seems to be the folding and metamorphism that produced the gneiss complex. Next is the local pre-Upper Jurassic folding and possible local intrusion, which may have been associated with the development of the Skeena Arch. The climax of metamorphism and folding probably took place in the late Lower Cretaceous, based mainly on evidence (Buddington and Chapin, 1929) in southeastern Alaska.

Little evidence for dating the emplacement of plutonic rocks in the northern Coast Mountains is presently available. Most of it concerns the presence of granitic clasts in conglomerates, which merely dates the unroofing of a pluton but not its emplacement. Only for Ponder pluton, which cuts Upper Jurassic and Lower Cretaceous strata, can a maximum age be set on the time of emplacement. Until we know what the K/Ar dates represent, we cannot use them with confidence in the interpretation of the history of this region.

ECONOMIC GEOLOGY

A few old prospects of gold, copper, silver, zinc, iron, limestone and salt lie within the map-area. Gold, silver, and some copper were mined at Surf Point and Edye Pass, Porcher Island, mainly in the 1930s. Surf Point produced over 20,000 ounces of gold, 7,000 ounces of silver and 9,000 pounds of copper whereas Edye Pass produced less than 300 ounces of gold and less than 100 ounces of silver. Coarse crystalline limestone was quarried on the north side of Tsum Tsadai Inlet, Smith Island, in 1950-51, for use in the pulp digesters at the nearby Columbia Cellulose plant at Port Edward. Less than 2,000 tons were produced and operations ceased because the limestone was not sufficiently pure.

Although the geological setting of most of the map-area does not provide encouragement for intensive base-metal exploration the most likely targets would seem to be the low grade metamorphic rocks of Porcher, Dunira, and Dundas Islands. In those areas particular attention should be paid to the greenstones and greenschists, and the plutonic rocks that intrude them.

The following are the principal references to the main mineral prospects in this area. The index letter corresponds to the letter at the location of the prospect on the map.

	Location	Reference
A Gold	Edye Pass Mine Porcher Island	Ann. Repts. Minister of Mines, B.C., 1934-39. Smith, A.: Surf Point and Edye Pass Mines; in Structural geology of Canadian ore deposits; Can. Inst. Mining Met., pp. 94-99, 1948
B Gold	Surf Point Mine Porcher Island	Ann. Repts. Minister of Mines, B.C., 1934-39. Smith, A.; Control of ore by primary igneous structures, Porcher Island, B.C.; Bull. Geol. Soc. Am., vol. 58, pp. 245-262, 1947. Smith, A.: (see 1948 reference above).
C Iron	Star Group Porcher Island	Ann. Rept. Minister of Mines, B.C., 1956. Young, G.A. and Uglow, W.L.: The iron ores of Canada, Volume I, British Columbia and Yukon; Geol. Surv. Can., Econ. Geol. Series No. 3, 1926.
D Copper	Bald Mountain Group Porcher Island	Ann. Rept. Minister of Mines, B.C., 1916.
E Zinc	Scotia Group Porcher Island	Ann. Rept. Minister of Mines, B.C., 1960.
F Limestone	Smith Island	Ann. Rept. Minister of Mines, B.C., 1950.
G Salt	Kwinitsa	Ann. Rept. Minister of Mines, B.C., 1913.

Explanatory notes for Table IV

PRE-JURASSIC (underlined)	-	Probable	Degree of certainty
PRE-JURASSIC	-	Possible	of data listed
Pre-Jurassic	-	Speculative	in Table

(1) K-Ar dates on biotites. (Roddick, Baer, and Hutchison, 1966)

(2) K-Ar dates on biotites. (Roddick, Baer, and Hutchison, 1966)

(3) Contains plant remains reported by W. A. Bell to indicate an Upper Cretaceous age. This is from a small area underlain by Upper Cretaceous (?) strata 5 miles east of Bella Bella, in Laredo Sound area.

(4) Granitic clasts in conglomerate at (3).

(5) Ponder pluton intrudes Bowser Group (Upper Jurassic-Lower Cretaceous (?)).

(6) Two biotites from Anger Island pluton (south of Prince Rupert – Skeena area) gave ages of 103 and 111 m.y. This pluton intrudes metamorphic rocks. Assuming the K-Ar dates are minima, then the regional metamorphism must have taken place during or before emplacement of this pluton.

(7) Duffell and Souther (1964).

(8) Part of Bowser Group lies with angular unconformity on folded middle Jurassic strata (Duffell and Souther, 1964).

(9) The Skeena Arch or 'high' appeared in post-Middle Jurassic and pre-Upper Jurassic time. It is postulated in this report that some structural features of the Prince Rupert area may be related to tilting of strata forming the northern flank of this arch.

(10) Basal conglomerate of Bowser Group contains granitic boulders (Duffell and Souther, 1964).

(11) Baer (1965).

(12) Fossils in greywacke overlying conglomerate (with green granodiorite boulders) suggest a Lower or Middle Jurassic age (Baer, 1965).

(13) Conglomerates containing granitic boulders occur within the metasedimentary belt extending from Prince Rupert to Bella Coola (Roddick, Baer, and Hutchison, 1966). These conglomerates are probably Jurassic or Triassic in age.

	DEPOSITION	TECTONISM AND METAMORPHISM	EMPLACEMENT OF PLUTONIC ROCK
EOCENE, PALEOCENE			Eocene, Paleocene (1)
UPPER CRETACEOUS	UPPER CRETACEOUS CONGLOMERATE WITH GRANITIC CLASTS IN LAREDO SOUND (3)		Upper Cretaceous (2)
LATE LOWER CRETACEOUS		Climax of Metamorphism and Deformation (6)	PRE-UPPER CRETACEOUS (4) AND POST LOWER CRETACEOUS (5)
LOWER CRETACEOUS UPPER JURASSIC	BOWSER GROUP (7)		
LATE MIDDLE JURASSIC		Local (?) PRE-UPPER JURASSIC FOLDING (8) (Tilting associated with development of Skeena Arch (9))	PRE-UPPER JURASSIC (10)
MIDDLE JURASSIC	HAZELTON GROUP (VOLCANICS AND MINOR SEDIMENTS IN BELLA COOLA (11))		
LOWER JURASSIC, TRIASSIC ± PERMIAN	SEDIMENTS WITH LOCALLY GRANITIC CLASTS (13) (in part equivalent to KUNGA FORMATION in Queen Charlotte Islands); PRE-HAZELTON VOLCANIC ROCKS IN BELLA COOLA		PRE-LOWER MIDDLE JURASSIC (12)
PRE-PERMIAN	Sedimentation of part of gneiss in gneiss complex ?	Folding and metamorphism of part of gneiss complex ?	

Table IV. Summary of Geological History of Northern Coast Mountains

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