GEOLOGY OF THE TOPLEY INTRUSIVES
IN THE ENDAKO AREA
BRITISH COLUMBIA

by

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ABSTRACT

Granitic rocks of the Topley intrusives underlying 100 square miles, centered around Endako, north central British Columbia, form part of a composite body which lies in a northwest trending belt of granitic plutons extending from Babine Lake to Quesnel, a distance of 180 miles.

Rocks of the Topley complex in the Endako area have intruded volcanic rocks of the Takla Group (Upper Triassic to Jurassic) and are unconformably overlain by flat-lying Tertiary volcanic flows. These intrusions are probably of Lower Jurassic to Lower Cretaceous age. The granitic rocks, ranging from diorite to alaskite form six large separately emplaced and sharply bounded intrusive bodies. The development of the Topley complex can be divided chronologically, from oldest to youngest, into five major stages: (I) the Simon Bay (diorite) complex; (II) the Endako quartz monzonite which is the host rock of the Endako molybdenum deposit, and the Francois granite; (III) the Glennanan complex; (IV) the Casey quartz monzonite-alaskite; and (V) the Stellako quartz monzonite.

The Glennanan complex, which is the best exposed and most intensely studied intrusive, consists of two large asymmetrically zoned bodies and a small stock of porphyritic quartz monzonite. The larger zoned body near the town of Endako has: (1) a western zone of porphyritic granite; (2) an intermediate zone of porphyritic quartz monzonite; and (3) an eastern zone of porphyritic granodiorite. A granodiorite zone is absent in the asymmetrically zoned Nithi Mountain intrusive body. All internal contact are gradational and all rock zones contain large rectangular perthite megacrysts which enclose oriented crystals of plagioclase and other minerals. The development of the rock zones can be accounted for by differentiation of a hornblende-biotite granodiorite magma at depth and successive intrusion of first granite, then quartz monzonite and finally granodiorite.

Topley stages II to V represent a continuous period of epizonal intrusion following the emplacement of the more deep seated (mesozonal?) Simon Bay complex. Northwesterly and northeasterly trending fracture zones controlled the structural evolution of the Topley complex in the map area.

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ILLUSTRATIONS

INTRODUCTION

SCOPE OF INVESTIGATION

This thesis is concerned with the geological history of the Topley batholith of British Columbia. The paper is a study of the distribution, petrology, mineralogy and structure of the various intrusive phases. A short account of the alteration and sulfide mineralization at the Endako mine is also included. The various phases of the Topley are shown on the accompanying geological map (in folder).

LOCATION AND ACCESSIBILITY

The map area lies 100 miles west of Prince George, British Columbia. The town of Endako, which is situated on Highway 16 and on a branch line of the C. N. R. is centrally located in the area. The Endako open-pit molybdenum mine is six miles southwest of the town.

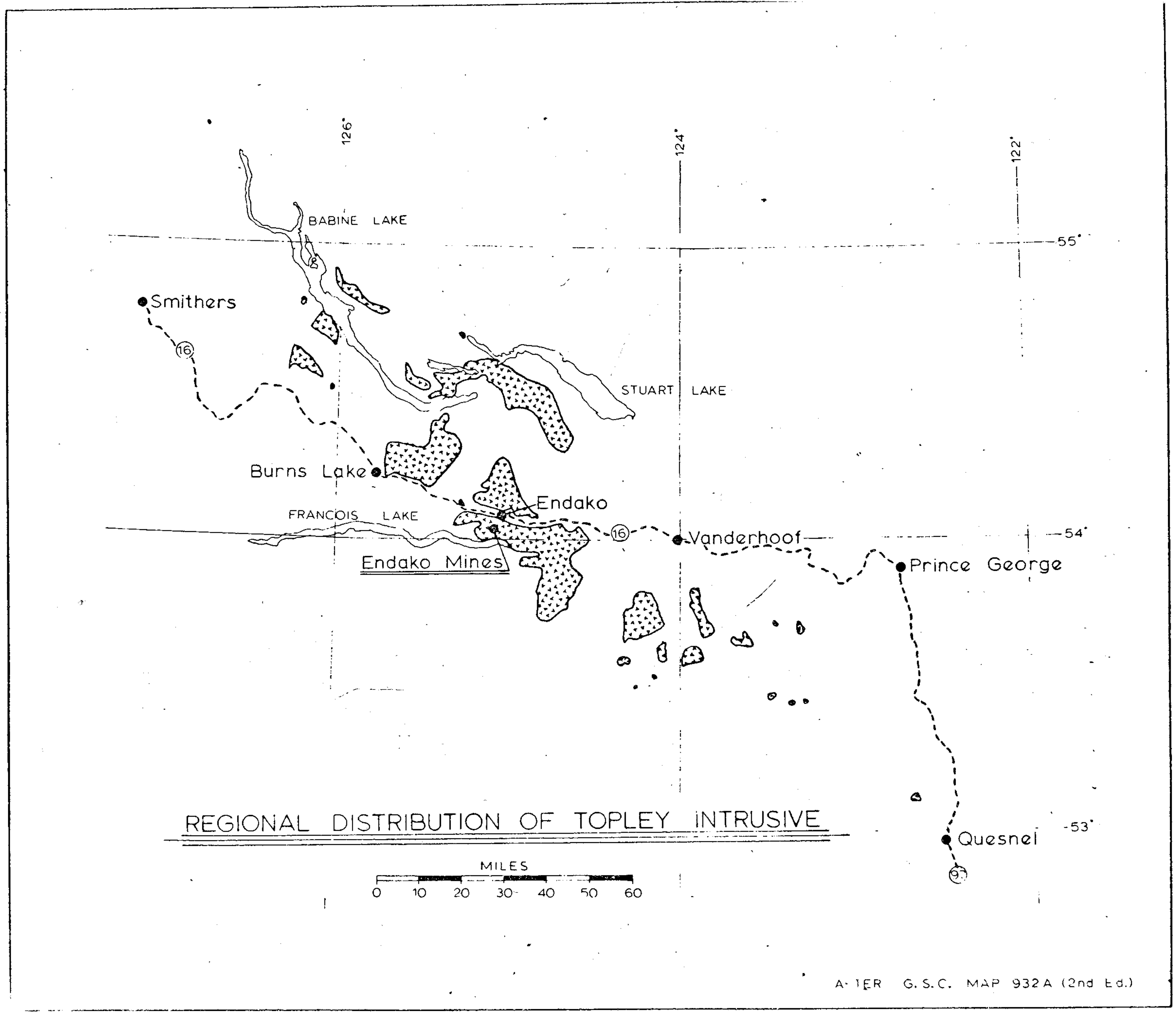
The area is readily accessible by three main gravel roads which connect Highway 16 with the mine and many resorts and private cottages along the north shore of Francois Lake. Numerous secondary roads which often require a four-wheel drive vehicle, traverse the area.

PHYSIOGRAPHY

The Francois Lake region lies on the southern edge of the Nechako Plateau physiographic unit, due east of the southern extent of the Nechako Plain. "In the plateau proper, the valleys are broad and the divides are rounded hills that rise 1500 to 2500 feet above the valley floors" (Armstrong, 1949). The 100 square mile map area has its least and greatest elevations at Francois Lake (2,197 feet) and Nithi Mountain (4,435 feet) respectively. The proportion of bedrock exposed in the area is estimated at about three percent. Glacial till and fluvio-glacial gravels reach thickness in excess of 20 feet on the higher ground and probably much greater thickness in the major valleys.

During the maximum development of the Cordilleran glacier, the mount-ice-fields flowed out onto the low-lying Nechako Plateau and Plain. Here the large valley glaciers coalesced and moved in a generally easterly and northeasterly direction. The last advance of the ice was followed by stagnation, decay of the ice-sheets and the development of glacial lakes. "Francois Lake was dammed by stagnant ice at the southern foot of Nithi Mountain and emptied into Fraser Lake through a rock-cut canyon in its present spillway, the Stellako River" (Carr, 1965).

Figure I



REGIONAL DISTRIBUTION OF TOPLEY INTRUSIVE

ACKNOWLEDGEMENTS

The author is indebted to Dr. K. C. McTaggart, of the University of British Columbia, who acted as supervisor for this thesis and offered advice and encouragement during the preparation of this manuscript.

Appreciation is also expressed to Drs. W. H. White and A. J. Sinclair of the University of British Columbia, for their help and guidance.

Special thanks are due to Dr. M. J. Carr of the British Columbia Department of Mines, who supervised the author in the course of the field work on which this thesis is based. He kindly allowed the author to use the government geological maps of the Endako area as well as a large collection of specimens and thin-sections.

GENERAL GEOLOGY

The Topley plutons of British Columbia are represented by a dozen or more phases of granitic rock that make up several composite bodies. On the Fort St. James map sheet (Armstrong J.E., 1949) 600 square miles of the southern part of the area are shown as underlain by Topley or similar intrusives (see distribution map, fig. I) The Topley rocks extend discontinuously from Babine Lake to Quesnel, a distance of about 180 miles along a northwesterly trend. They are shown intruding rocks of the Cache Creek Group (Lower Pennsylvanian to Upper Permian), the Takla Group (Upper Triassic to Jurassic) and as partly overlain by strata of the Hazelton (Jurassic to Lower Cretaceous) and younger groups. Armstrong (1949) was uncertain about the contact relation between the Topley plutonic rocks and the volcanic rocks of the Takla Group, but concluded "the Topley intrusions are probably of pre-Lower Cretaceous age and are possibly of post Middle Permian, pre-Upper Triassic age". Radiometric dates on biotites from the large Topley intrusives (except the Simon Bay Complex) in the Endako Area of British Columbia (White, W.H., 1966, 1967)* group around a date of 140 million years. (Middle Jurassic).

*White, W.H., 1966, personal communication

Six large plutons and two minor intrusive stocks comprise approximately 90 percent of the bedrock in the thesis area. A small area of metavolcanic rocks assigned to the Takla Group (Armstrong, 1949) occur on the south-western edge of the Topley complex. At the southwest margin of the map, the eastern edge of a large area of flat lying lava flows, of the Endako Group (Oligiocene or Eocene), unconformably overly the Topley rocks. Observation by the author of the unconformity near Dry William's Lake, east of the map area, disclosed a deeply (up to 10 feet) weathered granite surface. Isolated occurrences of the Endako Group are also to be found in the north-east and south-east corners of thearea.

The granitic rocks range from diorite to alaskite. Three quarters of the area, however, is underlain by quartz monzonite and granodiorite. The divisions between granodiorite, quartz monzonite and granite are made at the arbitrary boundary ratios of sodic oligioclase to total feldspar of, 1:3 and 2:3 respectively. The division between quartz diorite and granodiorite is based on the anorthite content of the plagioclase, An_{30} to An_{50}, and An_{10} to An_{29}, respectively.

Each pluton tends to be lithologically homogeneous except for the zoned Glennanan complex and the Simon Bay complex. Contacts between the Topley plutons are seldom observed but luckily most phases maintain distinct features of texture or composition on either side of the contact zone. Distinct cross-cutting relationships are shown only by the Casey and Stellako quartz monzonites (see geological map in folder at back).

The development of this batholithic complex in the Endako Area can be subdivided into five major stages of igneous activity. These stages are outlined chronologically from oldest to youngest as follows:

STAGE I

(1) Simon Bay complex

STAGE II

(1) Endako quartz monzonite

(2) Francois granite

STAGE III

(1) Glennanan porphyritic granite - quartz monzonite - granodiorite complex

STAGE IV

(1) Casey quartz monzonite-alaskite

STAGE V

(1) Stellako quartz monzonite

(2) Fraser and Pond quartz monzonite

The age of minor intrusions of aplite, dacite, andesite, diabase, quartz monzonite, and quartz diorite with respect to the various stages is unknown.

METHODS OF INVESTIGATION

Field work was done during the summer of 1965, when the author was employed by the British Columbia Department of Mines and Petroleum Resources. A detailed bedrock map of the area south of the Endako River (see map in pocket) was prepared on a scale, one inch to one mile. The author was provided with hand specimens and detailed information on the field relationships of the rocks north of the river, by M. J. Carr of the British Columbia Department of Mines. The area covered by this map is approximately 100 square miles.

Laboratory studies included the examination of 48 thin-sections chosen as representative of the Topley intrusives. For very porphyritic specimens, two or more thin sections were made. Their complementary hand specimens were checked for uniformity of texture and composition.

The approximate modal compositions of the Topley intrusives was calculated for 29 specimens. Because of the coarse-grained nature of some of these intrusives, particularly the Glennanan and Endako, a point-count thin-section analysis gave very erroneous results for the alkali feldspar and mafic mineral content. In such cases the modes of the major minerals, alkali feldspar, plagioclase and quartz were calculated from point-counts on polished hand specimens. The rock sections were stained with cobalti-nitrate prior to examination. The point-count was performed using grids of various sizes drawn on glass plates. The spacing of the grid lines was determined by the largest grain diameter within the hand specimen under investigation. When the hand-specimen contained unusually large phenocrysts (alakli feldspar), a grid spacing between the largest grain diameter in the groundmass and the phenocrysts was used. Perthitic integrowths are visible in the feldspars contained in the Endako, Francois and Glennanan intrusives. There was considerable difficulty in counting this mineral phase separately from the host potash feldspar during the point-count because: (1) their diameter was sometimes less than the diameter of the grid lines; and (2) strong staining of the alkali feldspar by cobalti-nitrate masked their presence.

The modes of alkali feldspar, plagioclase and quartz so obtained were then combined with the modes of the mafic minerals and accessories from thin-section point-counts in calculcating the final mode of the whole rock. It was necessary during this final calculation to include in the final mode of the plagioclase the approximate amount of exsolved plagioclase in the potash feldspar. The proportion of exsolved plagioclase in the microcline of the Endako or Glennanan intrusives varies from 2 to 10 percent within a single thin section. The presence of small irregular relict primary plagioclase grains in the perthite caused additional discrepancies in the modes. The error in calculating the mode of microcline could be as high as 10 percent in the coarse-grained rocks of the Glennanan complex which contain exceptionally large phenocrysts of perthite.

DETERMINATION OF THE ALKALI FELDSPAR COMPOSITION

The composition of cryptoperthites for the Topley intrusives (see Table I) was determined with a Phillips 1963 model X-ray diffractometer with a goniometer head. This method involves the measurement of the angle between a known standard peak [(101) reflection of $KBrO_3$] and the peak of the (201) reflection of alkali feldspar. The difference, $\Delta\ 2\theta = [\ 2\theta\ (201)\ Or - 2\theta\ (101)\ KBrO_3]$ is directly proportional to the orthoclase content. Parsons (1965) plotted the $\Delta\ 2\theta$ for 15 feldspars from feldspathic syenite intrusions in Scotland and found that they fell between the $\Delta\ 2\theta$ standard curves of the microcline-low albite series (Orville, 1960 and Smith, 1956) and the sanidine-high albite series (Orville, 1963). The $\Delta\ 2\theta$ for the alkali feldspars in this study were plotted between these two parallel plots somewhat closer to the microcline-low albite line which is characteristic of the plutonic rock environment (Sellmer, 1966).

Nine specimens of penthite (Table I), were purified first by magnetic separation with the Franz Isodynamic Separator and then each non-magnetic concentrate was passed through a solution of bromoform-methyl hydrate (specific gravity 2.57 gm/cc.). Alkali feldspar floats in this solution whereas plagioclase, quartz and the non-magnetic accessories sink. The purified alkali feldspar was heated in an electric furnace at 920$\pm$ 20 degrees centigrade for 24 hours to homogenize low albite-microcline cryptoperthite. The heated alkali feldspar was mixed with $KBr0_3$ (2:1 ratio) and mounted on a glass slide with nail polish. This mixture was then scanned over a range of 2θ = 19.60 degrees to 2θ = 22.20 degrees with the X-ray diffractometer. It was assumed that all albite was removed during the purification except the very fine cryptoperthific intergrowths of albite in the microcline.

The author followed Selmer's (1966) detailed outline of the original procedure put forward by Phair and Fisher (1962). Sellmar (1966) using the same equipment as the author in this study concluded that the accuracy of his results was in the order of $\pm$ 5 percent of Or.

TABLE I

COMPOSITION OF PURIFIED CRYPTOPERTHITES (VISIBLE ALBITE PART OF PERTHITE REMOVED) OF THE TOPLEY INTRUSIVE ROCK TYPES AS DETERMINED BY X-RAY ANALYSIS

Rock Type	Weight % of Or (by X - Ray)
Fine-grained Endako quartz monzonite	100
Coarse-grained Endako quartz monzonite	82
Fine-grained Francois granite	100
Glennanan granite	92
Glennanan glumero porphyritic facies on Nithi Mountain	95
Glennanan glomeroporphyritic facies at Dry Williams Lake	90
Glennanan quartz monzonite	88
Glennanan quartz monzonite	85
Casey alaskite	82
Aplite dike cutting Glennanan granite	85

CHEMICAL ANALYSIS OF THE TOPLEY INTRUSIVES CALCULATED FROM MODAL ANALYSIS

Dr. A. J. Sinclair of the Department of Geology, University of British Columbia has adapted for the U.B.C. computer a program that provides an approximately chemical composition of a rock from its modal analysis. The results obtained from thin-section and hand specimen point-counts (see page 8) were divided into the following components: orthoclase, albite, anorthite, quartz, biotite, hornblende, and the various accessory minerals. The proportion of albite to anorthite was calculated from the Or content of the cryptoperthitic microcline and the average Ab: An ratios of the plagioclase in the rock type. A composition most representative of the hornblende and biotite in the rock type under examination was chosen from standard chemical analyses which had been adapted into the computer program.

TAKLA GROUP

DISTRIBUTION AND PETROGRAPHY

Volcanic rocks assigned to the Takla group (Armstrong, 1949) are restricted to a single locality on the north shore of Francois Lake, 3 miles southwest of the Endako mine. They cover an area of approximately three-quarters of a square mile, on the southern edge of the Topley intrusions.

The rocks are porphyritic dacites and quartz latite flows, tuffs and breccias. Phenocrysts of quartz, biotite, white or pink plagioclase or occasionally pink potash feldspar occur in a grey-green to purple aphanitic matrix. The rocks are fractured and hydrothermally altered with the production of epidote, chlorite, pyrite, specularite and possibly tourmaline (Carr, 1965).

STRUCTURE AND AGE RELATIONSHIPS

The contact of the Takla rocks with the Francois granite was not observed. The attitude of the volcanic rocks is also unknown. They are fractured and hydrothermally altered, but contact metamorphic affects are absent. To the west, the Takla rocks are overlain by a thick sequence of relatively flat-lying tertiary volcanics of the Endako Group. On the Fort St. James Map Sheet (Armstrong, 1949) the Topley intrusives are shown intruding rocks of the Takla Group (Upper Triassic or Jurassic). In the thesis area, the Takla volcanics are cut by a 10 foot medium-grained pink quartz monzonite porphyryr dike and the Menard quartz laitite porphyry stock. The quartz monzonite dike is probably related to one of the Topley intrusives.

THE MENARD QUARTZ LATITE PORPHYRY STOCK

DISTRIBUTION AND PETROGRAPHY

A small stock or plug which intrudes the Takla volcanics, underlies an area of about 100 acres on the north shore of Francois Lake, near Menard's resort. The rock is a red or purple quartz latite porphyry. Pehnocrysts comprise up to 40 percent of this aphanitic rock. In order of abundance the phenocrysts are plagioclase, biotite, quartz, augite and hornblende (Carr, 1965). Subhedral plagioclase phenocrysts are white or flesh colored. Biotite forms chloritized plates or thick books 1/2 cm. long. Quartz phenocrysts are round or kidney shaped and augite and hornblende form long black prisms. In thin section the aphanitic matrix is composed of a granular mixture of about 35% quartz and 65% potash feldspar with minor patches of chlorite and epidote.

STRUCTURE

The intrusive seems to be a small stock emplaced in the Takla volcanics under near-surface conditions. The contact with the volcanics was not observed. The stock is cut by altered porphyritic rhyolite, quartz latite dikes and a medium grained quartz monzonite porphyry dike which also cuts the Takla volcanics. The northwesterly trend of these dikes is the same as that of minor intrusions in the older volcanics. The similarity of the medium-grained quartz monzonite porphyry dike with the rock types of the Topley intrusives suggests a pre-Topley age for this stock and hence for the Takla volcanic rocks as well.

TOPLEY STAGE I

THE SIMON BAY COMPLEX

FIELD RELATIONSHIPS

Regionally, the Simon Bay complex forms a wide belt of hybrid gneiss, amphibolite, foliated diorite and quartz diorite and minor lenses of gabbro, which extends from Stuart Lake (see fig. 1) southeasterly beyond Nithi Mountain. The northeastern and eastern margins of the Topley complex are bounded by this complex to the northwest beyond the map area. This trend is not too apparent in the map area itself because the Simon Bay complex is intruded by the Glennanan, Casey and Stellako plutons.

The Simon Bay complex enters the map area in the northeast near Fraser Lake, where it underlies an area of approximately eight square miles. The central part of this area is overlain by volcanic rocks of the Endako Group. Isolated exposures of diorite are to be found also on the flanks of Nithi Mountain south of the Endako River. The continuity of these exposures is interrupted by great expanses of drift and areas of younger intrusives.

PETROGRAPHY

The typical rock types of the Simon Bay complex, north of the Endako River, are green, fine to medium-grained foliated biotite-hornblende diorite with minor lenses of dark green gabbro and local areas of alternating diorite gneiss and amphibolite. The mode of these rocks is shown in table II, (Armstrong, 1949). The author did not map the area north of the Endako River but hand specimens of these rocks and information regarding their field relationships were provided by M. J. Carr (1965).

TABLE II

MODES OF THE SIMON BAY COMPLEX, NORTH OF THE ENDAKO RIVER (ARMSTRONG, 1949)

	Gabbro	Diorite	Diorite
Plagioclase	69.1	62.5	40.8
Augite	29.1	-	-
Biotite	-	33.3	6.1
Hornblende	-	2.2	49.7
Quartz	-	tr	1.0
Magnetite	1.8	1.5	2.5

The typical rock types of the Simon Bay complex, south of the Endako River are biotite - hornblende diorite and local areas of granodiorite near the contact with the younger Stellako quartz monzonite. A primary foliation is shown by a subparallel orientation of the biotite and hornblende. The trend and alignment of mafics within local areas of gneiss and amphibolite parallel the foliation of the diorite. Dark fine-grained angular or lenticular inclusions of amphibolite are common.

TABLE III

MODES OF THE SIMON BAY COMPLEX, SOUTH OF THE ENDAKO RIVER

	Hartman's Hill Diorite	Mouse Point Granodi-orite	Mudhole Lake Gran-odiorite
Alkali feldspar	trace	9.6	15.8
Plagioclase	59.5	63.4	54.8
Quartz	4.0	6.2	12.2
Biotite	2.1	3.1	9.5
Hornblende	31.1	15.0	5.2
Magnetite	2.2	3.0	2.5

In thin-section the diorite consists of abundant subhedral plagioclase, subhedral to anhedral dark brown biotite and green hornblende with minor interstitial quartz and occasionally small patches of interstitial microperthite. Most plagioclase is andesine (An_{30} to An_{38}) but it ranges from sodic oligioclase to labradorite. The plagioclase displays normal zoning but is faintly oscillatory zoned in the granodiorite at Mudhole Lake. Myrmekite occurs along some contacts between plagioclase and microperthite in the granodiorite. Interstitial microperthite porkilitically encloses inclusions of plagioclase, hornblende, biotite or occasionally quartz.

Green hornblende occurs as prismatic crystals or raggedly terminated grains containing inclusions of quartz, magnetite, apatite or occasionally plagioclase. Poikilitic brown-reddish brown biotite forms discrete crystals or aggregates and intergrowths with hornblende. Accessories include apatite, magnetite, sphene and pyrite.

The rocks of the Simon Bay complex, in general are strongly sheared and altered with the production of actinolite, chlorite, epidote, leucoxene, pyrite and iron oxides.

STRUCTURE

The contact of the Simon Bay complex with the older country rock lies beyond the map area and was not observed by the author. Foliation is visible in the Simon Bay diorite as parallel arrangement of biotite flakes, prismatic hornblende, mafic clots and inclusions. Its association with the interlocking texture of the feldspar and quartz

PLATE I

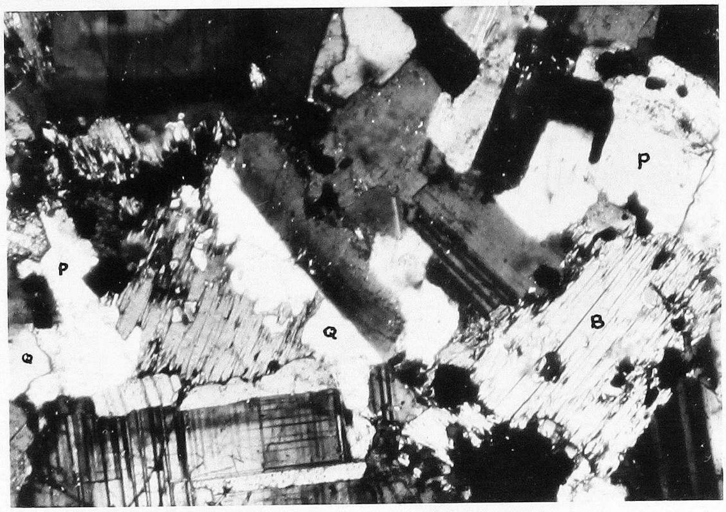


Figure 1: Texture of medium-grained Simon Bay diorite, (P) plagioclase, (Q) Quartz, (B) Biotite. (X35, crossed nicols)

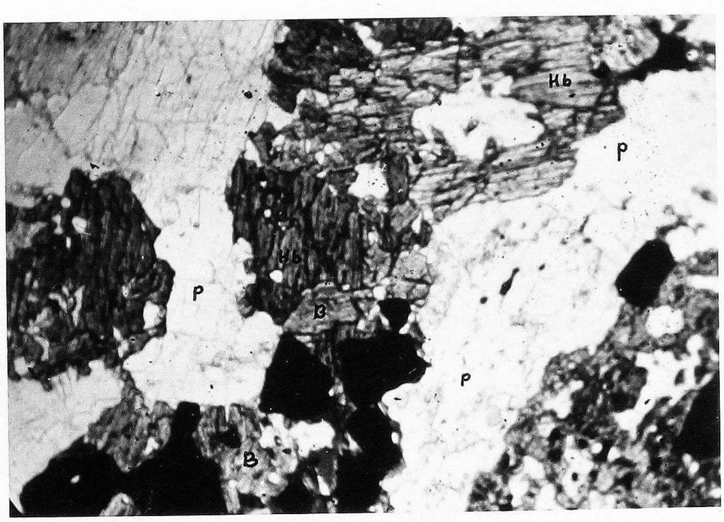


Figure 2: Anhedral poikilitic hornblende (Hb) and biotite (B) Interstitial to plagioclase (P) in Simon Bay diorite (X35, plain light).

suggests a primary origin in sheared and unsheared exposures. The local areas of gneiss, amphibolite and gabbro, particularly north of the Endako River, whose trend generally conforms to the foliation, suggests the possibility of an inherited foliation due to granitization of the country rock. Where the Simon Bay complex has been cut by the Stellako quartz monzonite, the wall rocks have been subjected to potash metasomatism.

The foliation of the Simon Bay complex in general conforms to the regional northwest trend of the belt of Topley intrusions (fig. 1). Near Alf Lake, Deserter Lake and Northward beyond the map boundary, the foliation is steeply inclined and strikes northwesterly, westerly and northeasterly. Three miles to the east of Alf Lake at Simon Bay, the foliation changes to an east-west direction but south of Fraser Lake, the trend swings back to the north-northeast. This trend is maintained in the isolated exposures of the complex as far south as Nithi Mountain, where it again swings to an easterly direction, southwest of Mary Lake. The variation of the foliation direction, south of the Endako River may possibly be the result of the shifting of large blocks of Simon Bay diorite during the emplacement of the intrusives of stage II to IV. This foliation does not appear to be the result of shearing in these areas.

ENVIRONMENT OF EMPLACEMENT

A mesozonal depth of emplacement is indicated by: (1) the primary foliation of the Simon Bay diorite; (2) alignment of screens of amphibolite, gneiss and gabbro; and (3) the general trend of the Simon Bay complex north of the Endako River which conforms to the regional trend of the Topley plutons. The evidence, however, is inconclusive and does not rule out a more deep seated environment of emplacement or possibly an origin by granitization in situ.

TOPLEY STAGE II

ENDAKO HORNBLENDE - BIOTITE QUARTZ MONZONITE

FIELD RELATIONSHIPS

The Endako quartz monzonite forms a regular belt averaging three miles wide, which extends from the Stellako River, west-north-westward for at least nine miles. This intrusive, which contains the Endako molybdenum deposit, is bounded on the south by the younger Francois granite and on the north by the younger Casey quartz monzonite and in part by the Glennanan granite. The southeastern extension of this belt may be truncated by the Stellako quartz monzonite, east of the Stellako River since it does not reappear in the map area. To the northwest, the Endako quartz monzonite is covered by sediments of the Endako River flood plain. Thecontact of the Endako quartz monzonite with most of the other plutons in the Endako area, was not seen butthe abruptness of the textural and mineralogical changes from one to the other, aids in determining its position.

Xenoliths of fine grained dark grey quartz diorite, rich in biotite, are abundant particularly along the Stellako River. They occur as rounded resorbed bodies and irregular mafic clots ranging in size from 1 to 4 c.m. or, less commonly, a slenticular fragments one foot or more in length near the Stellako River.

PETROGRAPHY

The typical rock of the Endako intrusive is a pinkish-grey medium-grained hypidiomorphic granular or occasionally subporphyritic hornblende- biotite quartz monzonite. Areas in the northeastern part of the intrusive where it is intruded by the Casey quartz monzonite-alaskite are granite. This very graditional variation is a function of increasing potash feldspar alone. Subhedral red perthitic feldspar crystals which may exceed lengths of 1 c.m. in the granite, impart a subporphyritic texture to the rock. With decreasing size and content of perthite, the Endako intrusive is an equigranular quartz monzonite in which a few phenocrysts of plagioclase, quartz and perthite can still be found. The lack of exposures prevented the drawing of boundaries between these variations. Perthite, quartz, biotite and hornblende are interstitial to plagioclase. Biotite forms hexagonal books, thin plates and irregular clusters. Hornblende occurs as anhedral to prismatic grains or aggregates with biotite. The modes of the rocks of the Endako intrusive are shown in Table IV.

In thin-section, the larger grains of microcline microperthite have a general enhedral form though their boundaries are irregular

TABLE IV

MODAL ANALYSES OF THE ENDAKO INTRUSIVE

	EGB-4	EGB-85	EGB-14	EN-174	EGB-11	EN-175	EN-STELLA	EN-5	EN-173
Microline	54.9	51.1	50.1	40.8	43.3	45.9	46.9	43.0	34.7
Plagioclase*	25.9	31.1	28.4	36.4	28.6	26.6	4.6	18.0	41.9
Quartz	14.5	14.3	14.7	16.6	21.6	17.7	40.3	32.0	15.4
Biotite	2.2	1.0	3.0	4.0	2.5	3.5	7.1	4.0	4.5
Hornblende	1.3	0.4	2.0	1.0	0.8	2.0	0.5	1.0	2.0
Magnetite	0.5	1.0	1.2	1.8	0.6	1.5	1.0	1.0	1.0
Sphene	0.8	tr.	tr.	1.3	0.5	1.2	tr.	tr.	0.5
Apatite	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.

* Composition of plagioclase is An_{18} to An_{24}

Composition of cryptoperthite microcline is Or_{85}

PLATE II

Figure 1: Patch perthitic intergrowths (P) in the microcline (N) of the Endako quartz monzonite. (x95, crossed nicols)

Figure 2: Relic plagioclase (P) grains in microperthite (M) Rock types is Endako quartz monzonite. (x45, crossed nicols)

and poikilitically enclose all the other minerals. More commonly, microcline forms anhedral poikiolitic grains interstitial to plagioclase (plate II, fig. 2). Microperthitic textures that range from fine films to irregular networks of stringers and veins (braid perthite) and coarse irregular patches (Emmons, 1953) may be observed within a single grain of microcline. Then plagioclase lamellae (plate III, fig. 1) the least abundant form of perthite are oriented parallel to the (010) cleavage direction in the microcline; orientations in the (001) cleavage direction are less common. Plagioclase in vein perthite (plate III, fig. 2) occurs as long narrow branching stringers which overlap in part but generally are elongated in the same direction as film perthite. The gradational nature of the regularly oriented film and braid perthitic intergrowths suggests an exsolution origin. Plagioclase in very coarse veins andirregular patches (plate II, fig. 1) is distributed equally throughout the host microcline and cross-cuts the oriented stringers and lamellae. These forms of perthite are locally controlled by the structure of the host. The patches and veins are coarse enough in places to show polysynthetic twinning, however, the individual twin lamellae can not be traced from one area to the immediately adjacent one. A replacement origin for the coarse vein and patch perthite is indicated, though they may have been controlled partly by early exsolution perthite.

PLATE III

Figure 1: Microcline containing oriented lamellae of exsolved albite. Note the strong undulatory anhedral quartz of Endako quartz monzonite (x35, crossed nicols)

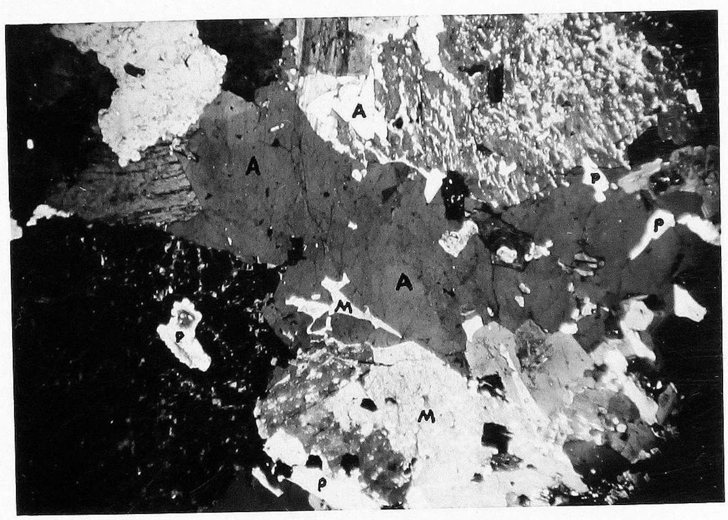


Figure 2: Subgraphic habit of quartz (A) and microcline (M) in the fine-grained Endako quartz monzonite. Note plagioclase (P) inclusions in quartz. (x90, crossed nicols)

Euhedral to subhedral normally zoned plagioclase ranges in composition from An_{18} to An_{24}. Some large grains show oscillatory zoning in the core areas but revert to a normal trend near the rims. Corroded plagioclase borders and myrmekite are abundant along the contacts between microcline and plagioclase (plate IV, fig. 2). Clusters of small very irregular grains of plagioclase in microcline (plate II, fig. 2) are the result of their advanced replacement by the host. In the coarse-grained Endako quartz monzonite, quartz occurs as irregular, interstitial grains with strong undulatory extinction (plate III, fig. 1). Quartz in the finer-grained rocks bordering on the chilled zone of the Francois granite occurs as interstitial grains which in places are graphically intergrown with microcline microperthite (plate III, fig. 2). Quartz enclose plagioclase, biotite, hornblende and accessory minerals. Finely granular quartz and feldspar have been introduced along fractures and grain boundaries of the primary minerals, in specimens examined near the Endako ore body. Poikiolitic ragged laths or subhedral grains of biotite enclose grains of sphere, apatite magnetite and brown hornblende. Biotite forms rims around and intergrowths with hornblende and has the following pleochroic scheme: X, pale green; Y greenish brown; Z, medium brown. Clusters of straw yellow to pale green biotite, calcite and epidote are secondary after hornblende.

PLATE IV

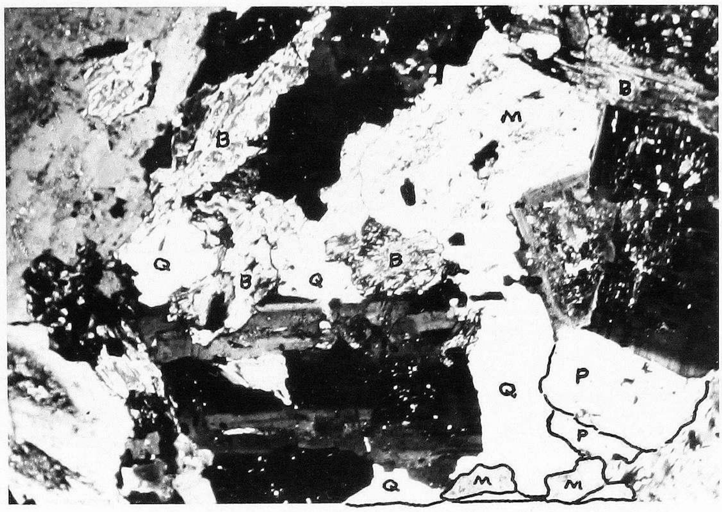


Figure 1: Interlocking relation of anhedral biotite (B) quartz (Q) plagioclase (P) and microcline (M) in the coarse-grained Endako quartz monzonite (x35, crossed nicols)

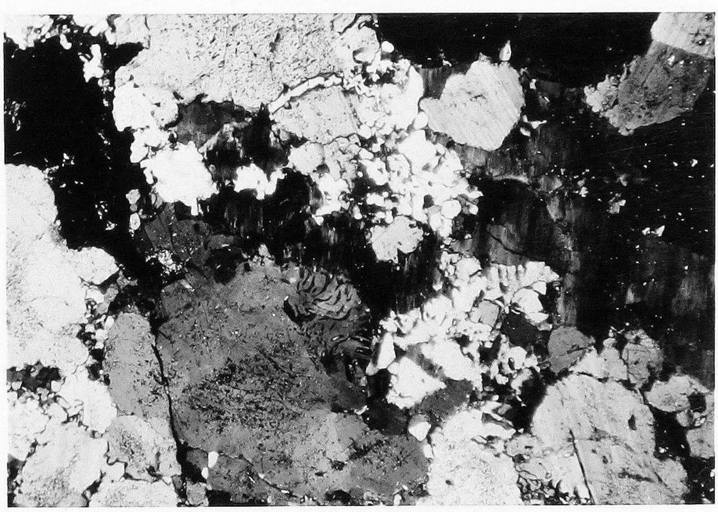


Figure 2: Texture of the fine grained Endako intrusive near the contact with the Francois granite. (x100, crossed nicols)

Sphene, magnetite and apatite are the most abundant accessories in this rock. Sphene forms rhombic crystals and aggregates with magnetite, apatite and biotite. Illmenite occurs as inclusions in sphene, intergrowths with magnetite or as dark reddish brown skeletal crystals. Apatite forms euhedral crystals and clusters of small crystals of rutile and pyrite are present. Pyrite is most likely the result of deuteric or hydrothermal alteration.

Outside of the immediate Endako mine area, the alteration for the most part is restricted to the mafic minerals of the Endako quartz monzonite. In strongly sheared and fractured exposures: (1) hornblende is chloritized; (2) sphene is altered to finer granular leucoxene; and (3) intergrowths of chlorite, sericite, calcite and iron ore form psuedomorphs after biotite. Plagioclase is strongly saussuritized and microcline is charged with kaolinite (?).

STRUCTURE

Evidence of widespread faulting which did not produce recognizable offsets is seen in the sheared, fractured and altered nature of many outcrops, particularly near the Endako mine. Known faults, shears, dikes and contacts coincide closely with west-northwest and northeast lineaments (see map in folder). From air photographs, a network of closely spaced major linears can be discerned (fig. 2) in the immediate mine area. Since some of these linears do correspond to faults, shears and dikes, many of the others may also mark such features. The northeasterly lineaments appear to offset the west-northwesterly set which parallel the contacts of the Endako intrusive. Geological mapping within the Endako ore body (Kimura, 1966) discloses the same structural pattern in places, but not of the same order of magnitude. These major structural elements are easily traceable on air photographs over large distances within the Endako and Francois intrusives but are often vague or undetectable when sought in the younger intrusions. Discordant plutons and dikes do however mark their presence in the younger plutons.

The contacts of the Endako quartz monzonite with the older Simon Bay complex or most of the younger intrusives were not observed by the author. The chilled margin of the Casey quartz monzonite was observed adjacent to uncontaminated sheared Endako quartz monzonite immediately south of highway 16. The Endako intrusive progressively decreases in grain size towards the chilled contact of the younger Francois granite, southwest of the Endako mine. A weak northerly planar orientation of the xenoliths was observed along parts of the Stellako River. The extension of the Endako intrusive to the southeast may cut the east-west foliation of the Simon Bay complex on Nithi Mountain.

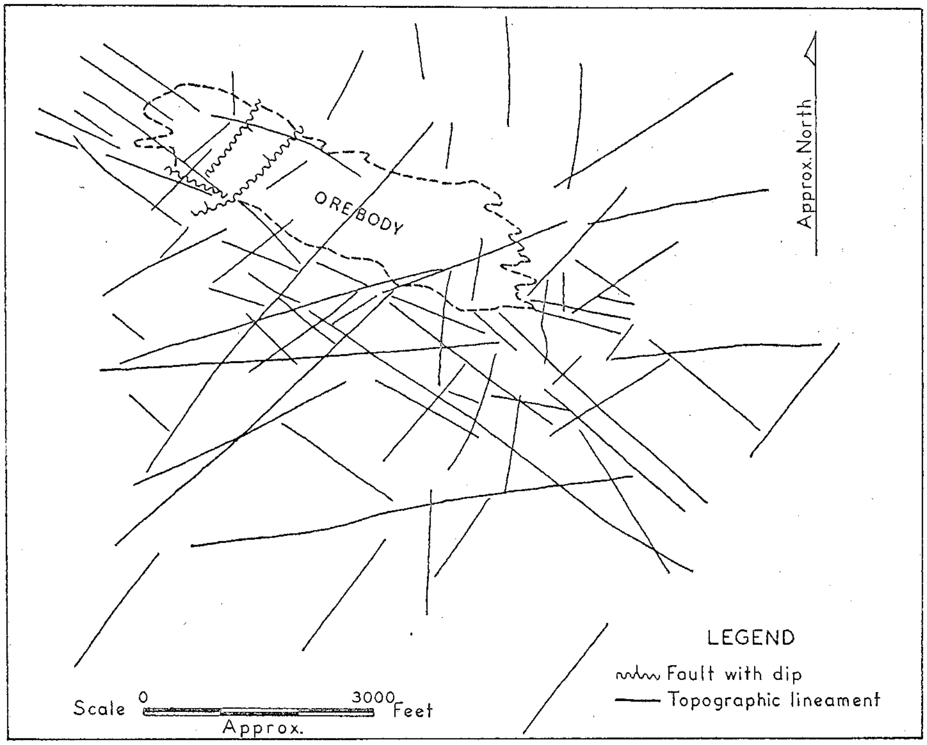


Figure 2. Sketch map of lineaments near the Endako orebody from an air photograph (Carr, 1965).

ENDAKO MOLYBDENUM DEPOSIT

STRUCTURE AND METALLIC MINERALS

The Endako ore deposit occurs wholly within the Endako intrusive near the junction of a close network of west-northwesterly and northeasterly trending faults and lineaments. This area has been particularly susceptible to intense and continuous fracturing and local block faulting. In the mine area the Endako quartz monzonite has been intruded by pre-mineral aplite, porphyritic granite dikes and brown to pink quartz feldspar prophyry dikes as well as post-mineral lamprophyre and diabase dikes. The brown porphyry dikes are not found elsewhere in the map area.

The orebody strikes S 60°E, dips 20° to 50° south, and measures 5, 500 feet long by 1, 200 feet wide (Kimura, 1966). Margins are arbitrarily determined by assay cutoffs. Molybdenite and pyrite are the major metallic minerals with minor amounts of hematite and magnetite and trace amounts of chalcopyrite. Mineralization is of two types. The most prominent mineralization is a series of quartz-molybdenite veins, continuous over several hundred feet and ranging in widths from a few inches to as much as five feet. These parallel veins mostly strike east and north of east and dip southward at 45 degrees. The second type of mineralization consists of a stockwork of narrow quartz-molybdenite veins and fracture fillings adjacent to and surrounding the main vein network. A pyrite halo containing narrow barren quartz fracture fillings is reported on the south side of the orebody.

ROCK ALTERATION

The mine geologists (Kimura, 1966) have determined three distinct phases of hydrothermal alteration in the ore zone:

(a) the development of potash feldspar and secondary biotite envelope adjacent to the veins and fractures.

(b) a second, less common mixture of fine quartz, sericite and pyrite adjacent to veins and fractures.

(c) a pervasive kaolinization of the host rock in several degrees of intensity. In the most intense phase, potash feldspar starts to break down to kaolinite, biotite is chloritized and plagioclase is completely broken down to a greasy greenish mixture of clay minerals. Some secondary black biotite is also produced at this stage.

FRANCOIS HORNBLENDE-BIOTITE GRANITE

FIELD RELATIONSHIPS

The Francois granite occurs as a regular body which trends northwesterly and has a length in the map area of 6 1/2 miles and a width of 1 3/4 miles. Flat lying volcanics of the Endako Group overlie the Francois intrusive along its southwestern margin.

PETROGRAPHY

The typical rock type of the Francois intrusive is a red, medium-grained hypidiomorphic granular hornblende-biotite granite with a porphyritic chilled border facies at the contact with the Endako intrusive. In places the rock is a quartz monzonite. A granophyric texture occurs in the chilled margins and fine-grained rocks. In the medium-grained central regions, perthite and quartz are interstitial to plagioclase. Plagioclase phenocrysts reach lengths of 7 m. m. in the chilled margins.

All minerals of the Francois granite show various stages of deuteric or hydrothermal alteration. Near the borders of the intrusive, plagioclase is thoroughly saussuritized, perthite is charged with a drusy grey mineral (kaolinite?) and minor sericite, and biotite is

PLATE V

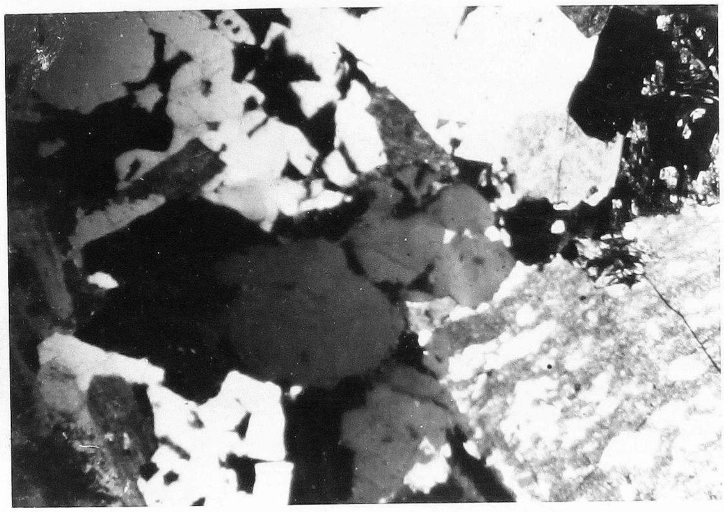


Figure 1: Texture of the Francois granite near chilled contact (x100, crossed nicols)

Figure 2: Texture of the Francois granite in central regions of the intrusive. Note the interlocking grains of microcline (m), plagioclase (p) and quartz (a) (x35, crossed nicols)

TABLE V

MODAL ANALYSES OF THE FRANCOIS INTRUSIVE

	Granite		Quartz Monzonite		
	EN-190	EM-193	EN-191	EN-194	EN-192
Microcline	48.0	39.4	46.0	35.7	33.7
Plagioclase *	9.8	18.8	16.0	31.0	28.8
Quartz	29.8	32.0	32.0	25.3	29.9
Biotite	8.7	2.5	5.0	6.2	5.4
Hornblende	2.4	1.0	tr.	1.5	0.7
Magnetite	1.2	0.5	1.0	1.0	1.2
Sphene	tr.	tr.	tr.	tr.	tr.

*Composition of plagioclase averages An_{24}

completely chloritized and stained by limonite. Aggregates of bleached biotite are secondary after long needle-shaped hornblende crystals. Small amounts of relatively fresh hornblende can be found in the central areas of the intrusion. Small miarolitic cavities containing euhedral quartz and potash are scarce. The modal compositions of the Francois intrusive are shown in Table V.

In thin-section, microcline microperthite is graphically intergrown with quartz in the chilled margins and fine-grained rocks of the Francois granite. In the medium-grained interior of the intrusive microperthite and quartz are interstitial to plagioclase (plate V. fig. 2) A granophyric texture occurs locally. Microperthite poikiolitically encloses all minerals in the coarse-grained rocks and plagioclase forms oriented lamellae, stringers, veins and irregular patches throughout the host microcline. Microperthite, if present in the chilled border facies of the Francois granite, occurs largely as sparse oriented lamellae and stringers in the microcline. Replacement of plagioclase by microcline is less abundant in the border zones than in the interior regions of the intrusive.

Subhedral plagioclase, the earliest forming mineral, occurs as phenocrysts in and near the chilled margins. Elsewhere it is nearly equidimensional with microperthite and quartz. The composition ranges from An_{24} to An_{29}; zoning is normal and less commonly oscillatory.

Strongly deformed twin lamellae associated with marked undulatory quartz and bent and broken biotite can be observed in sections taken along the borders of the pluton. The core regions of most plagioclase crystals are crowded with saussuritic and sericitic inclusions. With intense alteration the sodic rims are sericitized; epidote, calcite and granular iron ore are easily identifiable in the plagioclase cores and microcline is charged with sericite and kaolinite (?).

The mafic minerals of the Francois granite consist of pale brown intergranular biotite and subordinate anhedral pale green hornblende. Ragged laths of poikilitic biotite contain inclusions of all the minerals except microcline. Biotite has the following pleochroic scheme; X, pale brown; Y, light green; Z, dark green. In the medium grained interior of the intrusive, brown biotite is partly altered to chlorite and fine granular sphene and secondary straw yellow to pale green biotite is intergrown with hornblende. In the border areas of the intrusive, brown biotite is completely altered to a mixture of chlorite and limonite and all hornblende has been replaced by a mixture of chloritized secondary biotite, calcite and epidote.

Accessories include rhombic sphene, euheral apatite, magnetite, and pyrite. Irregular masses of leucoxene and limonite are alteration products of sphene and pyrite respectively.

STRUCTURE

The Francois granite is intrusive into the finer-grained south-western edge of the coarse-grained Endako quartz monzonite. A sharp contact can be drawn between them. A chilled contact was observed in the core of a drill-hole located one mile due west of the Endako mine. Two hundred feet north of Francois Lake, the porphyritic chilled marginal zone in which the groundmass minerals average 1 1/2 m.m. in size is exposed. This texture was observed over a width of approximately 70 feet. The Francois seems to have an intrusive relationship with the Takla volcanics. Towards this contact, the medium-grained granite decreases in grain size and in places assumes a porphyitic character. There is no evidence that these volcanics were affected by contact metamorphism.

The intrusion itself is not foliated and contains small partly assimilated inclusions of a type more often seen in the Endako quartz monzonite. Two dominant attitudes of shears and dikes are N40 W to N60 W and N20 E to N60 E with steep dips to the west, southwest and northeast.

RELATIONSHIP BETWEEN THE ENDAKO AND FRANCOIS INTRUSIVES:

The Endako quartz monzonite which is intruded by the Francois granite shows similarities in texture and constituents to the latter when examined in thin-section. The subgraphic relation of quartz and microperthite in the fine-grained Endako quartz monzonite is comparable to the graphic habit of quartz and microperthite in the Francois granite. Quartz is interstitial in most of the Endako intrusive and the central regions of the Francois granite. Their plagioclases have normal zoning but the composition in the Francois is more calcic. Brown biotite and secondary straw yellow biotite after hornblende are present in both intrusives and their xenoliths are of the same type. These similarities suggest a common source and environment of emplacement for the Endako quartz monzonite and the Francois granite. Figure 3 shows the plot of the modal compositions of these two intrusives on the Ab-SiO_2-Or ternary diagram. In general they plot in two separate areas but two plots of the Endako quartz monzonite do overlap the Francois granite field.

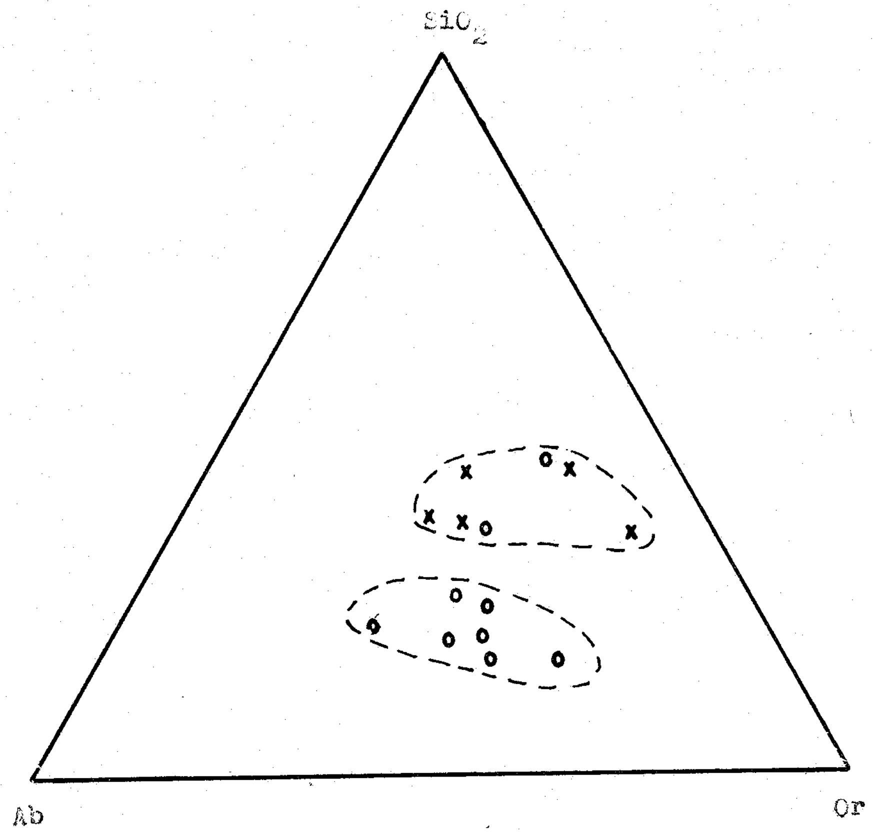


Figure 3. The modal Q:Ab:Or ratios of the Endako quartz monzonite (o) and the Francois granite (x), calculated from Tables IV and V.

MODE AND ENVIRONMENT OF EMPLACEMENT OF THE INTRUSIVES OF TOPLEY STAGE II:

The absence of foliation in the Francois granite and the Endako quartz monzonite except for a weak alignment of inclusions in the Endako intrusive along the Stellako River suggests that these magmas were largely liquid when emplaced. The random orientation of plagioclase phenocrysts in the chilled margins of the Francois granite supports this assumption. The Francois intrusive may represent a second generation of magma from the same source as the Endako or possible a later injection of more alkali-rich material from a single differentiating magma at depth.

An epizonal depth of emplacement for the Endako quartz monzonite and the Francois granite is indicated by: (1) the absence of foliation in both intrusives; (2) the porphyritic chilled margin and the presence of mariolitic cavities in the Francois granite; (3) the granophyric texture in the Francois granite and a weaker developed similar texture in the fine-grained rocks of the Endako quartz monzonite, and (4) the conformity of their contacts to each other and to the regional northwest trend of the Simon Bay compled near and beyond the northern margins of the map area. This is more commonly a characteristic of mesozonal plutons (Buddington, 1959).

TOPLEY STAGE III

THE GLENNANAN COMPLEX

GENERAL DESCRIPTION

The Glennanan complex underlies about 30 square miles of the map area (see map in folder). This is only a small part of a large composite body which extends eight miles or more northwest beyond the boundaries of the thesis area. Regional mapping of this area by the British Columbia Department of Mines (Carr, 1965) disclosed large areas of Glennanan (designated Tatin, Litan, Rex and Triangle Lake intrusives, Figure 22, page 144A, Lode Metals in British Columbia, 1965) porphyritic quartz monzonite and granodiorite with little or no granite. In contrast, the rocks of the Glennanan complex in the map area are predominantly porphyritic granite and quartz monzonite.

The Glennanan intrusive forms three separate bodies in the map area. The largest body, centered around the town of Endako, is the asymmetrically zoned southeastern part of the main Glennanan pluton which trends north-northwest far beyond the map area. The east-west trending Endako River flood plain divides this body into two segments. Immediately south of the river, coarse-grained porphyritic granite forms the marginal zone around the western and southwestern borders of the intrusive. A porphyritic chilled zone was observed 1/4 mile east of Casey Lake. The granite zone grades into a coarse-grained porphyritic hornblende-biotite quartz monzonite. Immediately north of the Endako River, medium grained porphyritic quartz monzonite forms a narrow segment around the exposed western edge of the Glennanan complex. This segment, which seems to be gradational with the quartz monzonite south of the river, grades eastward into a broad zone of porphyritic granodiorite. A body of aplite lies along the western exposed edge of the porphyritic quartz monzonite to the west. The porphyritic granodiorite is bordered on the east in the map area and the northeast beyond it, by the older Simon Bay (diorite) complex.

The second Glennanan intrusive body occurs eight miles southeast of the town of Endako. It forms an asymmetrically zoned crescent shaped body, five miles long and one mile wide along the west flank of Nithi Mountain. A band of porphyritic granite lies along the western margin of this intrusive. Gradationally bounded bodies of glomeroporphyritic granite, up to 50 feet in length, are exposed along the chilled borders of the Glennanan granite on Nithi Mountain. Similar zones are found at Alf Lake and near Dry William's Lake just beyond the eastern margin of the map area. In all three places, the adjacent country rock is the Simon Bay. diorite. J It is probable that similar irregular lenses of glomeroporphyritic granite occur intermittently along other parts of the chilled margins of the granite. The granite zone grades into a porphyritic quartz monzonite. A small exposure of porphyritic quartz monzonite, covering an area of about 1/2 square mile, occurs on the eastern flank of Nithi Mountain, south of the Foster Lakes. This was possibly part of the larger body on the west flank of Nithi Mountain but has been isolated from it by the intrusion of the younger Casey quartz monzonite-alaskite.

Porphyritic quartz monzonite forms a third intrusive body one mile long and 1/2 mile wide near Alf Lake north of the Endako River.

Modes of each rock type are shown in Table VI. The average densities of the porphyritic granodiorite, quartz monzonite and granite are 2.73, 2.68 and 2.64 gm/cc respectively.

Minor intrusions include aplites, porphyritic dacite, latite and rhyolite dikes as well as fine grained quartz monzonite, quartz diorite and diabase dikes. Their dominant trends are northwest and north to northeast.

TABLE VI

MODAL ANALYSES OF THE GLENNANAN COMPLEX

GRANITE

	EGB-1*	EGB-2	EGB-169	EN-171	EN-168
Microcline[1]	70.1	55.0	55.5	55.8	51.9
Plagioclase[2]	11.2	25.0	14.3	25.3	25.0
Quartz	17.1	20.0	27.7	17.2	17.7
Biotite	1.0	2.0	2.3	1.6	2.8
Hornblende	0.3	1.0	0.5	0.7	1.3
Magnetite	0.4	0.5	0.6	1.5	1.0
Sphene	0.5	tr.	tr.	0.4	0.8
Apatite	tr.	tr.	tr.	tr.	0.3

* - chilled margin

(2) plagioclase ranges from An_{22} to An_{28}

	QUARTZ MONZONITE			GRANODIORITE	
	EGB-8	EN-170	EGB-12	EGB-16	EGB-17
Microcline[1]	41.4	46.5	42.0	23.9	21.1
Plagioclase[2]	35.5	32.6	30.0	42.9	47.7
Quartz	14.7	16.3	26.0	21.0	17.5
Biotite	3.5	3.0	2.0	4.5	5.6
Hornblende	1.8	1.2	1.0	2.2	5.5
Magnetite	1.2	1.0	tr.	2.2	3.4
Sphene	1.4	0.5	tr.	1.6	1.2
Apatite	0.3	tr.	tr.	tr.	tr.

(1) The composition of the alkali feldspar ranged from Or_{90} to Or_{95} in the granite and Or_{85} to Or_{88} in the quartz monzonite and granodiorite (see Table I)

(2) Plagioclase ranges from An_{22} to An_{34} in quartz monzonite and granodiorite.

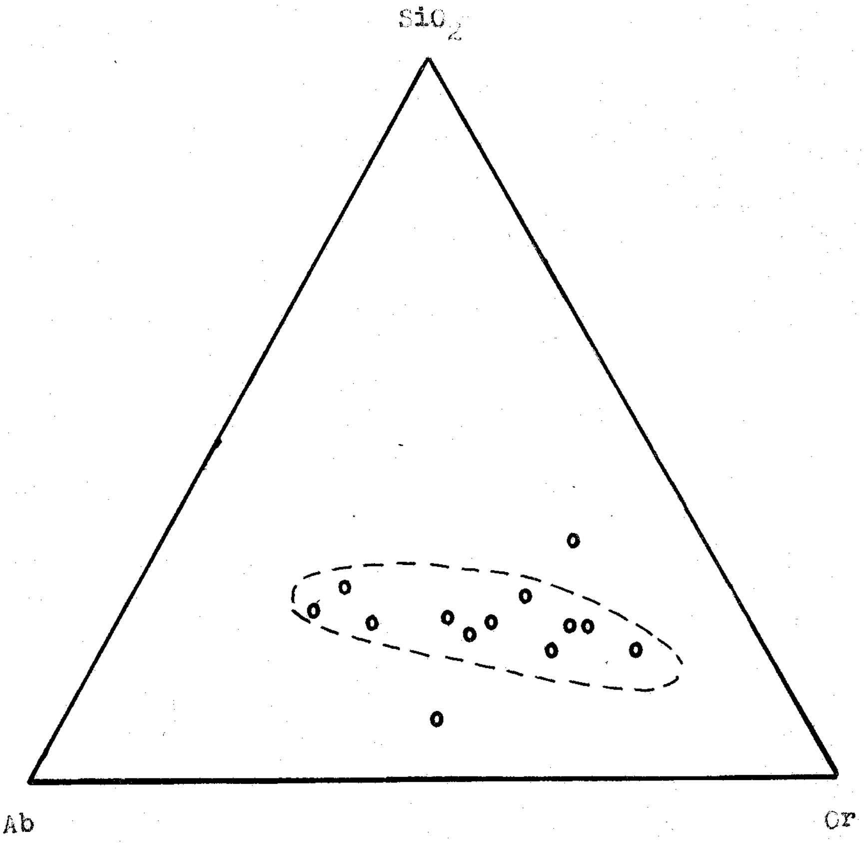


Figure 4. The modal Q:Ab:Or ratios of the Glennanan complex, calculated from Table VI.

PETROGRAPHY

Porphyritic Hornblende-Biotite Granite

Pink to grey, very coarse-grained porphyritic hornblende-biotite granite forms a crescentic marginal zoning ranging from 2,500 feet to 5,000 feet wide around the western and southwestern side of the main intrusive body. Porphyritic granite forms a border zone, ranging from 1000 to 4000 feet wide along the western side of the Nithi Mountain intrusive body. The granite grades into coarse-grained prophyritic hornblende-biotite quartz monzonite. Pink to pale orange perthitic microcline forms rectangular crystals, ranging in length from 1 to 4 cm., in the chilled borders and interior regions of the granite zone. A rough zonal arrangement of quartz, biotite, hornblende, sphene, magnetite and tabular plagioclase is displayed, particularly in the larger phenocrysts (megacrysts). Plagioclase forms subhedral white crystals, generally subordinate in size to perthite, but occasionally occurs as phenocrysts 1 cm. long. Crystal faces can be seen on quartz grains throughout the groundmass. Quartz in discrete grains or clusters is interstitial to plagioclase and perthite megacrysts. Biotite forms thick hexagonal books or platy aggregates. Subordinate hornblende is inconspicuous in the chilled border facies of the granite.

Perthite megacrysts are concentrated in local areas of glomeroporphyritic granite along the borders of the granite zone. The relative coarse-grain size of subhedral perthite, in the coarse-grained groundmass, give the rock a porphyritic texture even where perthite megacrysts are scarce or absent.

A weak planar orientation of the megacrysts is perceptible near the margin of the granite and in the glomeroporphyritic facies. Inclusions are absent in the observed chilled marginal zones but small, irregular inclusions of quartz monzonite or quartz diorite and irregular mafic clots were observed in the coarse-grained rocks.

In thin section, microcline microperthite in the coarse-grained groundmass occurs in two forms: (1) subhedral grains whose margins poikiolitically enclose all minerals in the rock; and (2) small equant or anhedral interstitial grains (plate VII, fig. 2.) Perthite megacrysts have a general euhedral form but their boundaries are very irregular and partly or wholly enclose minerals of the matrix (plate VII, fig. 1.). The megacrysts display carlsbad or diffuse to sharp grid twinning. Microperthitic textures, that range from fine films to veins or networks of veins and irregular patches, display cross-cutting relationships. in the host microcline. Plagioclase in fine stringers and lamellae which are oriented parallel to the cleavage directions of the megacrysts probably had an exsolution origin. The megacrysts contain abundant inclusions of mainly plagioclase but biotite, hornblende, quartz, magnetite and sphene are also present. The tabular shaped crystals are oriented with their longest direction parallel to the (010), (001) and (110) planes of the microcline (fig. 5) Their striking structural orientation and zonal arrangement in the megacrysts is more fully described later in the discussion of the glomeroporphyritic facies of the granite.

Subhedral plagioclase displays oscillatory zoning and combination twinning. Plagioclase is strongly replaced by microcline (plate VI, fig. 1.) and myrmekite occurs along most contacts between them In the chilled margin, plagioclase forms mantles along parts of the larger anhedral microcline which extinguish similtaneously grains (plate VI, fig. 2) Plagioclase ranges in composition from An_{28} to An_{24} in the cores to An_{26} to An_{22} at the edges. Quartz occurs in three forms: (1) irregular large aggregates composed of anhedral and subhedral crystals, in the chilled margins; (2) euhedral, unstrained crystals that are included in groundmass microcline, the margins of perthite megacrysts (plates VI, VII, figs 1, 1 respectively); and (3) irregular, interstitial fractured grains, with undulatory extinction which commonly form overgrowths on the earlier euhedral form. Mafic minerals are biotite and minor hornblende. Biotite poikiolitically encloses apatite, sphene, magnetite and hornblende and has the following pleochroic scheme: X, yellowish brown; Y, dark brown;

PLATE VI

Figure 1: Microperthite replacing plagioclase (P) in the Glennanan granite. Note euhedral quartz (Q) in micropherthite (M). (x100, crossed nicols)

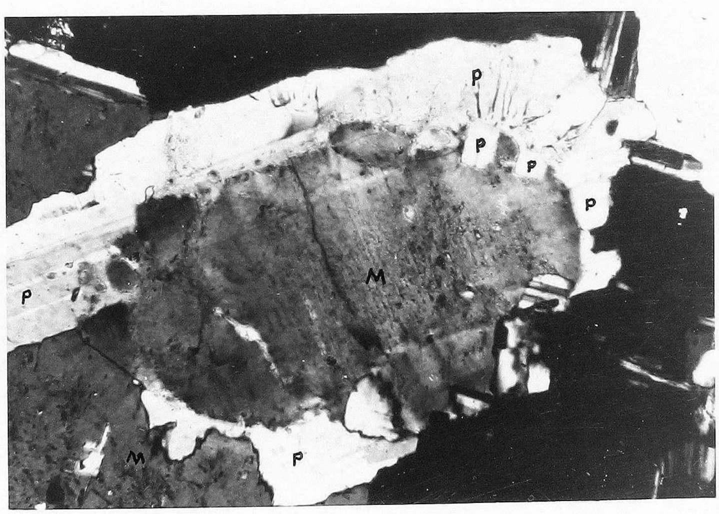


Figure 2: Texture of Glennanan granite near chilled margins. Microperthite (M) is partly mantled by plagioclase (P) (x95, crossed nicols)

PLATE VII

Figure 1: Poikilitic microperthite (M) containing subhedral plagioclase (P) and euhedral quartz (Q) crystals. (x35, crossed nicols) in the Glennanan granite.

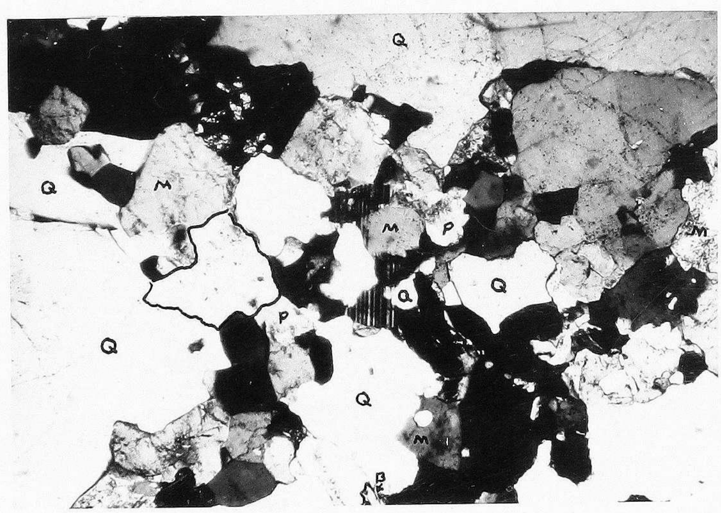


Figure 2: Finely granular quartz (Q), microcline (M), plagioclase (P) and biotite (B) in coarse-grained groundmass of Glenanan granite. (x100, crossed nicols)

Z, greenish brown. It forms hexagonal plates, ragged laths intergrown with green hornblende and irregular clusters with hornblende in the groundmass.

Finely granular microcline, quartz, plagioclase and mafic minerals ranging in size from 1 m.m. to 0.3 m.m. form irregular pockets in the coarser grained groundmass (plate VII, fig. 2) and narrow zones along the grain boundaries of the megacrysts throughout the granite. At the most, this feature constitutes between 1 and 2 percent of the rock and indicates a late stage of rapid cooling after most of the magma had crystallized. This feature was not observed in the porphyritic quartz monzonite or granodiorite. Rhombic sphene, euhedral apatite and magnetite are very common accessory minerals in the granite. Allanite is present in small quantities.

Glomeroporphyritic Facies of Granite

Local areas of hornblende-biotite granite composed of 25 to 75 percent perthite megacrysts occur along the chilled margins of the granite. The crude alignment of perthite crystals, the largest of which measured 4 cm. long and 1.5 cm. wide, give the rock a weak foliation. In the fine-to medium-grained groundmass, perthite, quartz, plagioclase, biotite and hornblende are interstitial to the perthite megacrysts and a few large aggregates of quartz.

In thin-section, the margins of the microcline megacrysts extend irregularly into the allotriomorphic granular groundmass. Euhedral to subhedral plagioclase, biotite, hornblende and sphene are oriented on the (010), (001) and (110) planes of the microcline (fig. 5. and plate VIII, fig. 1). The (100) face of plagioclase has a strong preference for orientation on the (100) face of microcline. The orientation of quartz, magnetite or the occasional crystal of apatite does not appear to have been controlled by the structure of the microcline. Quartz occurs in two forms: (1) rounded or anhedral grains or irregular mantles partially rimming plagioclase, biotite, hornblende, or sphene in the central areas of the megacrysts; and (2) euhedral to subhedral grains along the margins of the megacrysts (plate VIII fig. 2).

The inclusions also display a zonal arrangement in the megacrysts. With the exception of biotite all minerals are found in or near the core regions. Biotite occurs in the outermost zones of the megacrysts (fig. 5) where the highest concentration of inclusions are found. Inclusions in the cores are not as strongly oriented as those in the perispheral zones of the megacrysts. Here, plagioclase forms euhedral to subhedral grains ranging in size from 0.6 m.m. to 0.1 m.m., whereas the larger grains in the outer zones are embayed by the microcline. Plagioclase inclusions have broad calcic cores with thin sodic margins. Most grains display normal zoning and polysynthetic

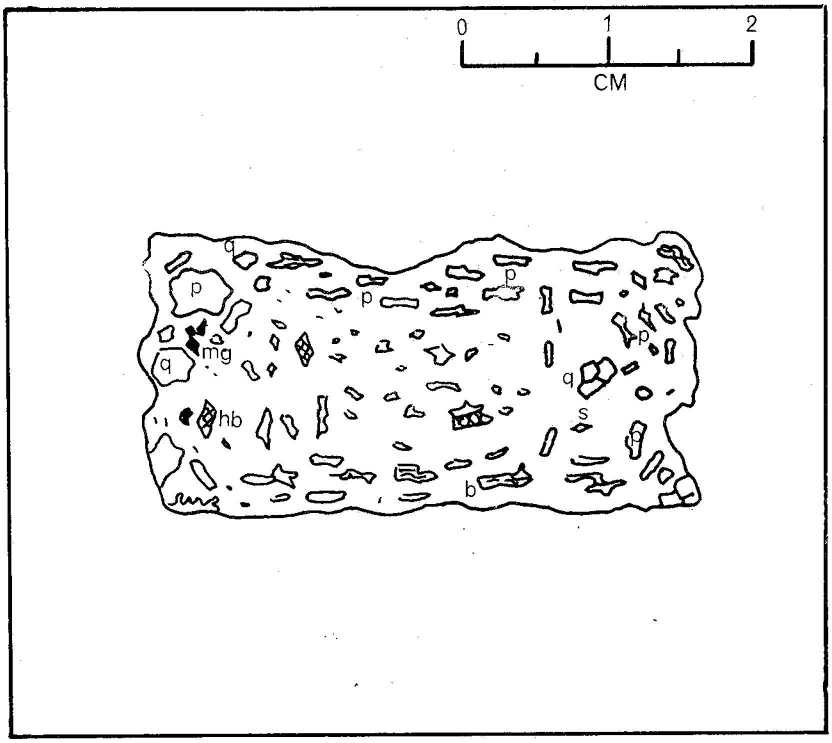


Figure 5. Structural orientation and zonal arrangement of plagioclase (p), biotite (b), hornblende (hb) and sphene (s), and unoriented quartz (q) and magnetite (mg) in a perthite megacryst from the glomeroporphyritic facies of the Glennanan granite.

PLATE VIII

Figure 1: Oriented inclusions of plagioclase (P), sphene (S) and unoriented euhedral quartz (Q) in perthite megacryst of Glennanan glomeroporphyritic granite (x45, crossed nicols)

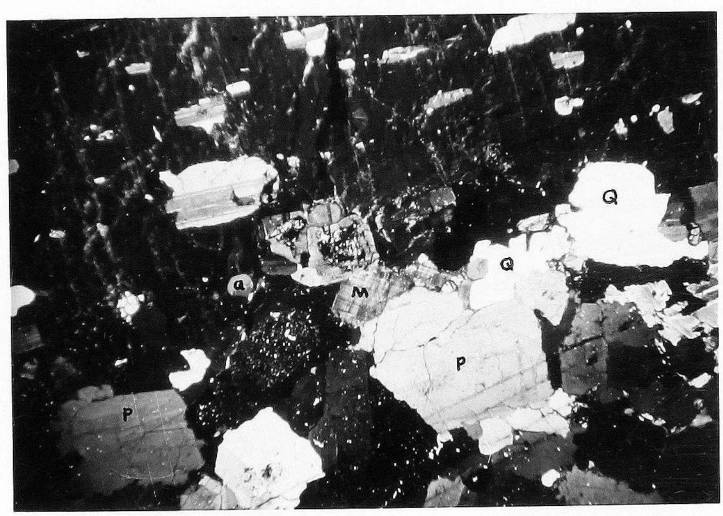


Figure 2: Contact zone between perthite megacryst and groundmass in glomerophyritic granite. Note anhedral microcline (M) and round quartz (Q) grains near edge of perthite megacryst (x45, crossed nicols)

twinning. The composition of nine oriented plagioclase grains from a single perthite megacryst was determined using the a-normal method and appropriate curves from Deer, Howie and Zussman (1963). The compositions showed a progressive change from the interior to the margins of the microcline megacryst (fig. 5) of An_{38}, An_{34} to An_{29} respectively.

At the margins of the megacrysts, very coarse-grained myrmekite occurs along the contacts with plagioclase. Interspersed with zones of myrmekite are areas of micropegmatite. In the groundmass proper, myrmekite is abundant but micropegmatite is scarce. The composition of the groundmass plagioclase averages An_{28} but may range as high as An_{32} or as low as An_{25}. Oscillatory zoning with a strong normal trend near the edges if common. Poikilitic microperthitic microcline comprises about 20 percent of the groundmass. It forms interstitial grains or, less commonly, small equant grains (plate VIII, fig. 2). Quartz forms euhedral or, more commonly, irregular interstitial grains. The mafic minerals occur in the same manner as in the porphyritic granite.

Porphyritic Hornblende-Biotite Quartz Monzonite

Coarse-grained porphyritic hornblende-biotite quartz monzonite forms: (1) a plug near Alf Lake; (2) the eastern zone of the Nithi

Mountain intrusive body; and (3) the intermediate zone between porphyritic granite and granodiorite along the Endako River flood plain. The boundary between each rock zone is arbitrarily based on their plagioclase to total feldspar ratio. Perthite megacrysts, containing inclusions of plagioclase, biotite and hornblende, comprise less than 10 percent, but usually more than 5 percent, of the quartz monzonite and are much smaller than those of the granite zone. Dark green tabular or prismatic hornblende comprises between 3 and 4 percent of the rock, but reaches a maximum of about 8 percent in the Alf Lake stock. There is a crude alignment of perthite megacrysts and prismatic hornblende near Alf Lake. Xenoliths are more abundant in the medium-grained quartz monzonite, north of the town of Endako, than in the coasre-grained quartz monzonite or granite south of the Endako River and on Nithi Mountain.

In thin-section, relatively large grains of poikiolitic microcline microperthite are largely interstitial to plagioclase but some small, equant, sharply twinned grains of microcline were observed in some specimens. They occur as discrete grains in microperthite with euhedral quartz crystal or interlocking grains with plagioclase and anhedral quartz. Corrosion of plagioclase by microcline and myrmekite are not as prominent in the quartz monzonite as in the granite zone. Euhedral to subhedral oscillatory zoned plagioclase (plate X, fig. 1) varies in composition from An_{34} to An_{22}. The cores of some grains

PLATE IX

Figure 1: Zonal pattern of anhedral quartz overgrowths on euhedral quartz crystals in the microperthite of the Glennanan quartz monzonite. (x35, crossed nicols)

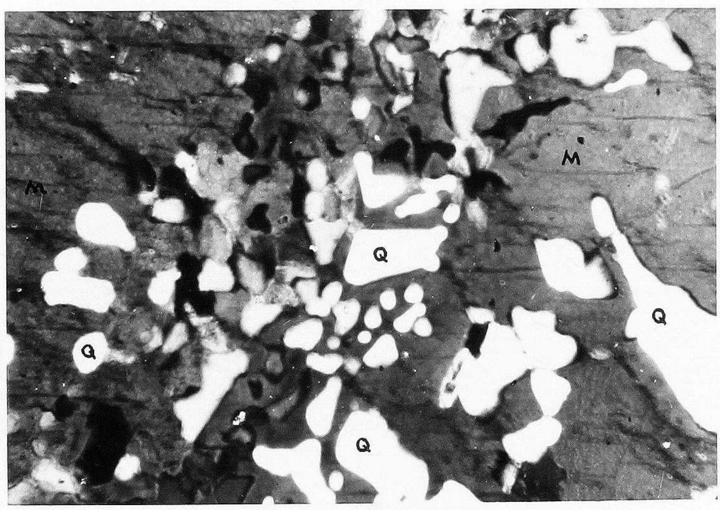


Figure 2: Euhedral quartz (Q) crystals with anhedral overgrowths, in the microcline (M) of the Glennanan quartz monzonite. (x450, crossed nicols)

PLATE X

Figure 1: Euhedral quartz crystals in microperthite and zoned plagioclase in the Glennanan quartz monzonite, (x35, crossed nicols)

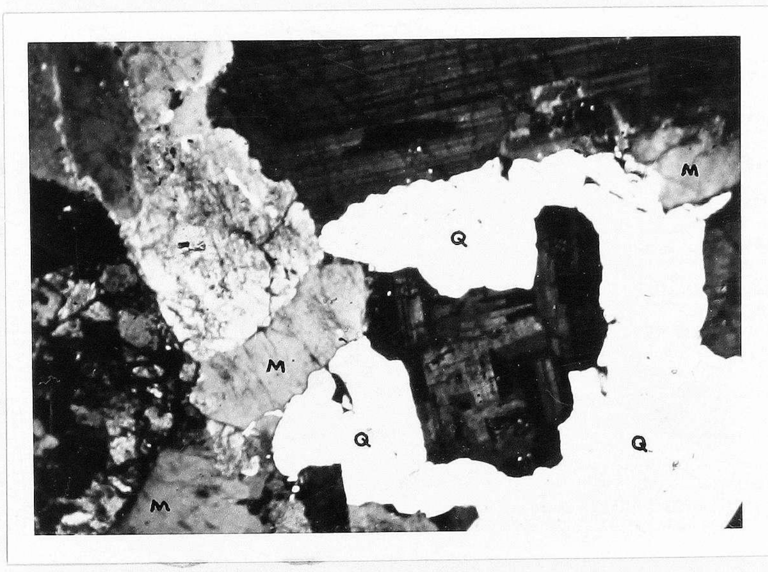


Figure 2: Interstitial habit of quartz (Q) and microcline (M) in the Glennanan granodiorite, (x100, crossed nicols)

are saussuritized and contain inclusions of prismotic hornblende, anhedral to rounded quartz and tabular biotite.

Quartz, like in the granite zone occurs in three forms: (1) euhedral crystals enclosed in microcline microperthite (plate X, fig. 1) or interlocking grains in the groundmass; (2) irregular, interstitial grains which commonly form overgrowths on the euhedral form; and (3) an association of euhedral quartz grains and graphic quartz in microcline (plate IX, fig. 1). A close examination of these quartz intergrowths disclosed that they are euhedral quartz crystals, 0.05 m.m. and less in size which have been overgrown with anhedral quartz. The optical orientation of these intergrowths is determined by the enclosed euhedral crystal or crystals. Some quartz intergrowths do not contain euhedral quartz nuclei and their optical orientation appears to have been controlled by the host microcline. The euhedral form of the quartz and the equant grains of microcline in the microperthite suggests to the author that they formed in a magma with little interference from adjacent crystals.

Interstitial brown biotite and green hornblende comprise as much as 10 percent of the rock. Sphene and magnetite are more abundant than in the granite zone.

Porphyritic Hornblende-Biotite Granodiorite

Pinkish-grey medium-grained porphyritic hornblende-biotite granodiorite occurs only north of the Endako River but continues eight miles or more northwest beyond the map area. It covers an area of approximately five square miles and is gradational to a narrow zone of medium-grained quartz monzonite along the western edge. The granodiorite seems to be gradational with the quartz monzonite immediately south of the Endako River. The granodiorite contains in places between 1 and 5 percent perthite megacrysts which are mostly 1 or 2 cm. long. Phenocrysts of plagioclase and hornblende or occasionally large quartz aggregates may be found associated with megacrysts in local pods and clusters near the eastern edge of the granodiorite. An indistinct foliation marked by the preferred alignment of inclusions and elongated aggregates of hornblende and biotite becomes more apparent near the contact with the Simon Bay diorite. In the easternmost exposure of the granodiorite in the map area and to the north beyond its boundaries, local pods and clusters of perthite phenocrysts together with swarms of quartz diorite inclusions, give the rock a weak foliation.

In thin-section, subhedral plagioclase displays strong oscillatory zoning with saussuritized cores in which epidote, calcite and sericite are easily identifiable. The average size is 4 m.m. by 2 m. m, but

PLATE XI

Figure 1: Euhedral sphene associated with mafic minerals in Glennanan granodiorite (x35, plain light)

Figure 2: Subhedral hornblende (Hb) and biotite (B) in Glennanan granodiorite, (x35, plain light)

occasionally phenocrysts 1 cm. long are found. The composition ranges from An_{34} to An_{28} in the core to An_{24} or more sodic on the rims. Inclusions of hornblende biotite and anhedral quartz are present. Microcline microperthite and quartz are interstitial to plagioclase (plate X, fig. 2). A few small euhedral crystals of quartz are present in the transition zone between quartz monzonite and granodiorite. Myrmekite is scarce along the contacts between plagioclase and microcline and poikiolitic brown biotite and green hornblende are interstitial to plagioclase. Hornblende forms prismatic or anhedral grains or aggregates, intergrown with biotite (plate XI, fig. 2). Hornblende has the following pleochroic scheme: X, pale green; Y, dark green; Z, greenish brown. Chlorite and sericite are the common alteration products of biotite but hornblende is relatively fresh-looking.

Sphene is relatively abundant but apatite is less so than in the other rock types of the intrusive. Sphene forms very large rhombic crystals (plate XI, fig. 1) up to 2. m. m. long. Magnetite, besides forming interlocking grains with the other accessories in the groundmass, commonly forms inclusions in or intergrowths with sphene.

TABLE VII

RECALCULATED MODAL ANALYSES OF THE GLENNANAN COMPLEX

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Microcline	62.8	50.5	46.6	45.2	36.1	50.5	23.9	20.8	17.9	42.7	32.7	38.3
Albite*	14.4	19.3	15.6	18.2	29.5	19.3	33.9	35.9	37.7	38.0	29.9	28.1
Anorthite*	2.7	5.0	3.8	5.2	9.6	5.0	10.7	10.8	11.1	10.7	9.3	9.1
Quartz	17.2	18.9	30.3	17.6	14.4	18.9	15.5	21.5	16.9	7.0	19.3	12.7
Biotite	1.1	2.4	2.3	7.2	3.9	2.4	6.2	4.5	5.6	0.7	2.9	7.3
Hornblende	0.2	1.8	0.2	3.4	2.1	1.8	4.4	2.2	5.5	0.5	2.3	0.8
Magnetite	0.8	1.3	0.8	1.9	2.8	1.3	3.6	2.2	3.4	0.4	2.4	0.7
Sphene	0.4	0.5	0.4	1.0	1.8	0.5	1.4	1.6	1.3	---	0.9	---

* Average values of An_{24} and Or_{90} for the plagioclase and alkali feldspars respectively, were used to recalculate the albite and anorthite separately, for the calculation of the chemical analysis of these rocks.

TABLE VIII

CALCULATED CHEMICAL ANALYSIS OF THE GLENNANAN COMPLEX FROM MODAL ANALYSES (TABLE VII)

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2
(1) EGB-1	69.6	15.5	0.59	0.48	0.17	0.82	1.70	10.7	0.20
(2) EN-171	68.6	16.1	1.16	0.83	0.31	1.48	2.75	8.44	0.21
(3) EGB-18	73.8	13.3	0.64	0.70	0.27	0.98	1.85	8.07	0.23
(4) EGB-3	66.1	15.1	1.71	2.21	1.48	1.92	2.19	8.25	0.65
(5) EGB-8	65.1	16.6	1.81	1.61	0.87	2.91	3.50	6.42	0.86
(6) EGB-172	68.9	15.3	1.12	1.02	0.66	1.39	2.30	8.75	0.29
(7) EGB-15	63.6	16.2	2.90	2.64	1.64	3.23	4.04	4.57	0.78
(8) EGB-16	67.6	15.6	1.78	1.74	0.95	3.05	4.27	3.90	0.81
(9) EGB-17	64.2	15.9	2.80	2.54	1.84	3.52	4.48	3.49	0.71
(10) EGB-5*	65.9	19.2	0.31	0.28	0.18	2.21	4.49	7.28	--
(11) EGB-6*	67.3	15.8	1.83	1.46	0.82	2.60	3.54	5.77	0.47
(12) EGB-9*	65.0	17.2	0.94	1.85	1.34	2.41	3.59	7.13	0.52

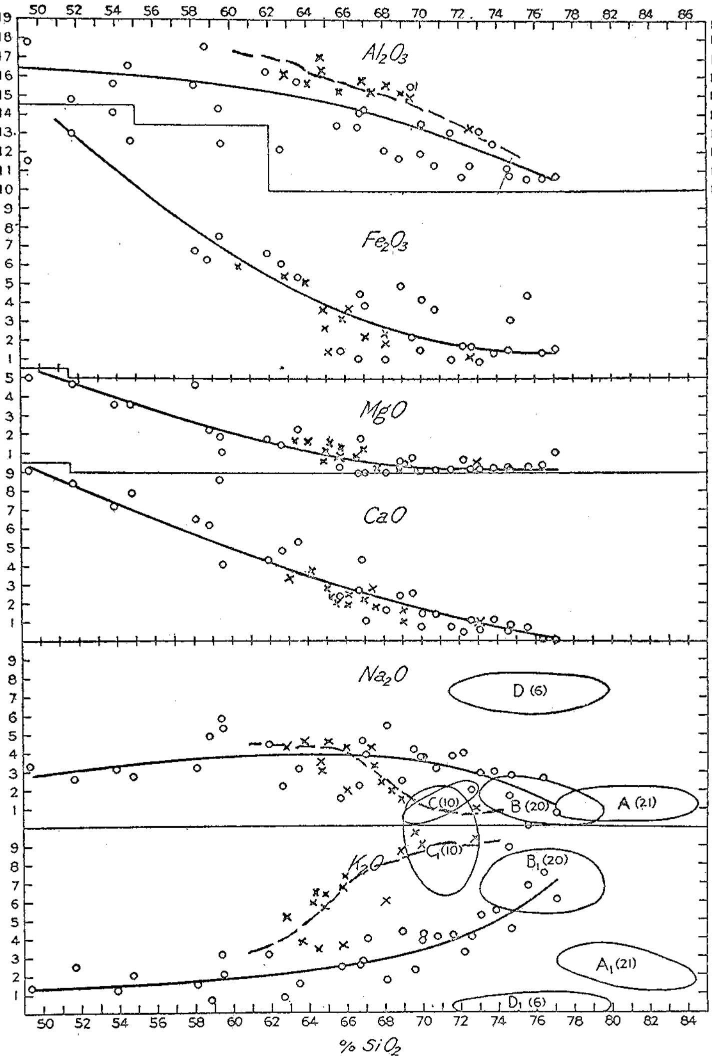


Figure 6. Variation diagram comparing the curves of the principle oxides of the Glennanan rock types (X) calculated from Table VIII, with those of 27 pitchstones and perlites and 4 trachylites (O) (Bowen, 1928, fig. 38, p. 127).

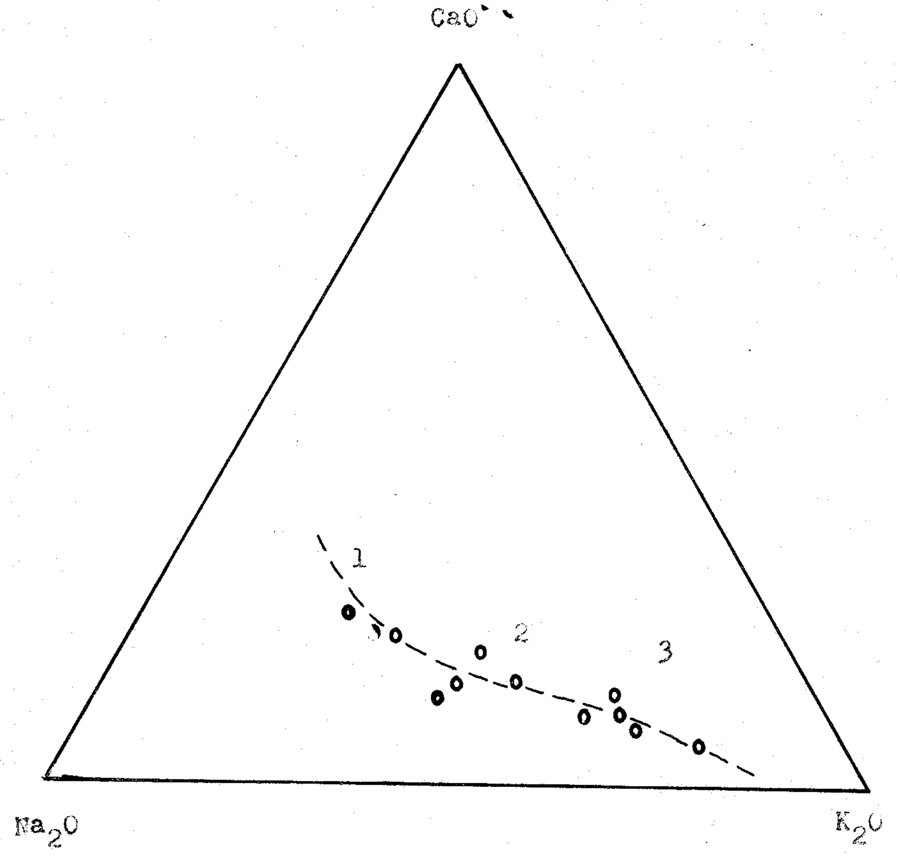


Figure 7. Variation diagram for the Glennanan complex from (1) granodiorite, (2) quartz monzonite to (3) granite (calculated from Table VIII).

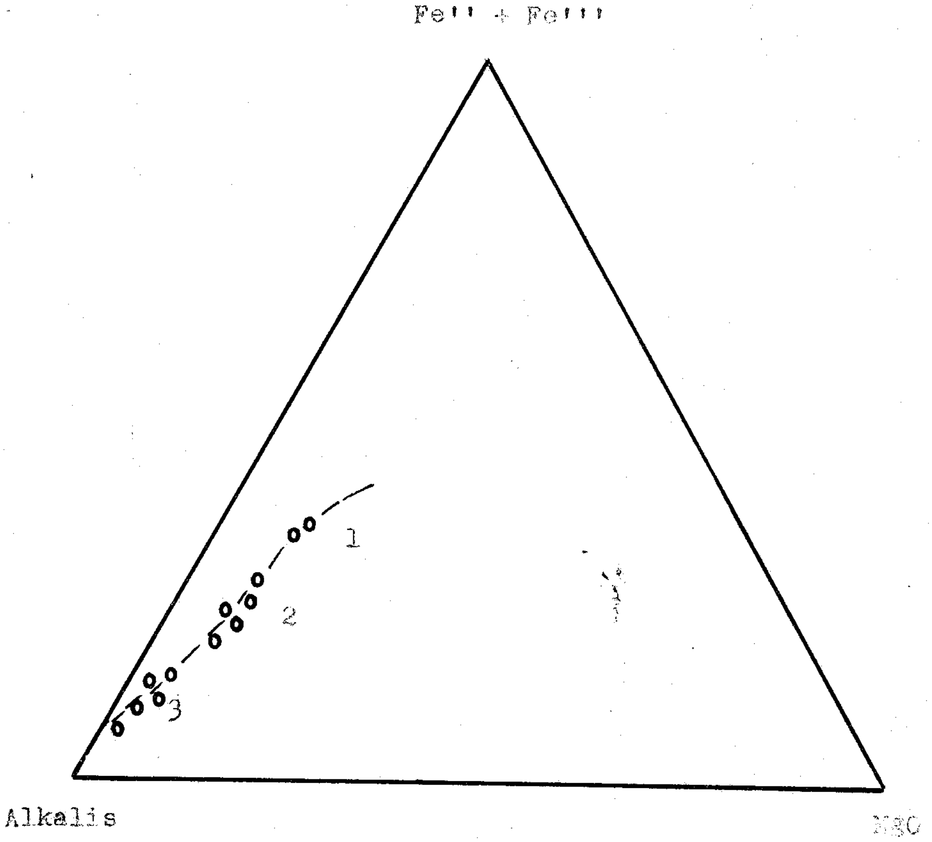


Figure 8. Variation diagram for the Glennanan complex from (1) granodiorite, (2) quartz monzonite to (3) granite, (calculated from Table VIII).

DISCUSSION OF THE VARIATION DIAGRAMS FOR THE GLENNANAN COMPLEX:

The percentage of the principle oxides of the Glennanan rocks from Table VIII have been plotted with the variation diagrams of pitchstones and perlites, (fig. 38) Bowen, 1928, page 127 in figure 6, These standard curves represent an unquestionable magmatic variation. The areas designated A and A_1 represent a large group of granites, high in SiO_2 and rather low in both alkalis; B and B_1 are granites high in K_2O and very low in Na_2O; C and C_1 are granites with extremely high K_2O and but little Na_2O; and D and D_1 are a group of siliceous granites very high in soda with potash nearly lacking (Bowen, 1928). There are no corresponding rocks among pitchstones and perlites in these designated areas except in the case of B and B_1. Rhyolitic obsidians whose compositions are analogous to the crystalline igneous rocks do not plot in these circled areas (Bowen, 1928). The fact that crystalline rocks include compositions unmatched in glassy rocks suggest an origin of rocks in these circled areas by crystal accumulation (Bowen, 1928) or some other secondary process of differentiation.

The striking feature of the variation in the Glennanan rocks is the high value of the K_2O and the low value of Na_2O. The Al_2O_3. Fe_2O_3+FeO, MgO and CaO of the Glennanan complex parallel the compositional variation in the glassy rocks, Fig. 6 but the trend of the alkalis departs at a SiO_2 content of 65 percent and moves into the field (C and C_1) of potash rich granites. Over a SiO_2 range of 65 to 71 percent, the K_2O value varies from 3.5 to 8.8 and Na_2O varies from 3.5 to 1.7 percent. A K_2O value of 10.1 was obtained from the chilled zone of the granite. Ryolitic obsidians, the aphanitic equivalents of granitic rocks cluster around a K_2O value of 4.5 percent and a Na_2O content of about 4 percent.

An error of 10 percent was assumed possible (Page 10) in the modal analysis of the potash feldspar in the coarse grained porphyritic granite. From the calculated chemical analysis of the Glennanan specimens EGB-18a and En-171 (Tables VII, VIII) whose biotite content is 1.8 and 1.6 respectively the variation in the K_2O value of the rock in response to the changing mode of microcline can be approximated. A 10 percent error in the mode of microcline for EGB-18, would result in a 7 percent error in the K_2O value or a decrease from a K_2O value of 8.04 to 7.48 percent. The average K_2O value in the Glennanan granite is 8.4 percent. If the correct value of the potash content in the chilled zone of the granite is near this average value rather than the calculated value of 10.1 (sp. EGB-1) percent, an error of approximately 40 percent in the modal analysis of microcline would have had to be made. This does not seem very likely.

The author concludes that a variation (fig. 6) in the K_20 value of the Glennanan complex over a $Si0_2$ content of 64 to 73 percent, from 3.5 to 8 percent is a close approximation and the variation is toward area C_1 or possibly B_1, representative of granites rich in potash and low in soda.

The smooth variation cruves of certain oxides of the rock zones in the Glennanan complex, figs. 7 and 8 are compatable with their formation by differentiation of a parent granodiorite magma.

STRUCTURE

The Glennanan intrusive complex occurs as three separate bodies in the map area: (1) an asymmetrically zoned body of porphyritic granite - quartz monzonite - and granodiorite bordering on the Endako River; (2) an asymmetrically zoned body of porphyritic granite-and quartz monzonite on Nithi Mountain; and (3) a small stock of porphyritic quartz monzonite around Alf Lake. Perthite megacrysts are present in all rock zones but are larger and more abundant in the granite zone. The larger intrusive body, spanning the Endako River, is the south-eastern extension of the main Glennanan pluton which extends in a north-northwest direction, 8 miles or more beyond the map area. All contacts between the rock zones of the complex are gradational over wide areas. The trend of the rock zones of the larger body conforms to the general north-northwest trend of the main pluton, whereas the rock zones on Nithi Mountain trend in a more northerly direction.

A weak foliation, characteristic of epizonal intrusives (Buddington, 1959) is marked by: (1) the preferred orientation of perthite megacrysts along the chilled margins of the granite zone; and (2) preferred alignment of mafic minerals, clusters of perthite megacrysts and xenoliths near the contact of the granodiorite, particularly north of the map area (Carr, 1965), with the Simon Bay diorite. The conformity of these features with the wall rock suggests that the foliation is a primary flow structure. The foliation dips steeply and strikes between west and northwest in the granite zone and north and northwesterly in the granodiorite. Foliation in the quartz monzonite and throughout most of the granite and granodiorite zones is indistinct or absent.

The lack of exposures prevented direct observation of the contacts of the Glennanan intrusive bodies with the country rock and the order of emplacement of the Glennanan rock zones is not known. The porphyritic chilled margin of the granite zone, diagnostic feature of the epizone (Buddington, 1959) is exposed 1/4 mile due east of Casey Lake. Here, the chilled zone of the granite is exposed over a width of approximately 50 feet and is separated from the chilled margin of the Casey intrusive to the west by about 60 feet of overburden.

North of Casey Lake, the contact between the Glennanan granite and the Endako quartz monzonite is hidden but seems to have been controlled by a north-northwest fracture zone through Casey Lake. A 30 to 50 foot wide dark grey porphyritic latite dike, which cuts the Endako, Casey and the Glennanan intrusives, has been intruded along this zone (see map in folder). On the west flank of Nithi Mountain the uncontaminated porphyritic chilled margin of the granite and medium-grained foliated Simon Bay diorite are exposed about 100 feet from each other. The nature of the contact of the Glennanan quartz monzonite zones, north of the Endako River and on Nithi Mountain, with the older plutons is not known. The eastern most exposure of the porphyritic granodiorite is foliated and contaminated by inclusion of the Simon Bay diorite complex.

ENVIRONMENT OF EMPLACEMENT

That the intrusive bodies of the Glennanan Complex were emplaced in the epizone (Buddington, 1959) is suggested by: (1) weakly developed flow structures along the margins of the granite and granodiorite adjacent to the older Simon Bay Complex; (2) sharply bounded porphyritic chilled margins of the granite which are gradational inward to coarse-grained porphyritic granite-quartz monzonite-and granodiorite; and (3) granophyric texture in the glomeroporphyritic facies of the granite and in the porphyritic quartz monzonite.

ORIGIN OF THE PARENT MAGMA

The uncontaminated porphyritic chilled margins of the Glennanan granite disqualifies granitization as a mode of origin for the complex. The variation trends of the principle oxides of the Glennanan rock types (fig. 6) lend support to a magmatic origin for these rocks. The composition of the main rock zones varies systematically from the chilled margin of the granite zone to the granodiorite zone (Table VI). The compositional trends established in the ternary diagrams, Fig. 7 and 8, are compatable with the formation of the pluton by differentiation of a parent granodiorite magma.

A magmatic origin of the perthite megacrysts of the glomero-porphyritic facies of the granite is strongly indicated from the following evidence:

(1) zonal distribution of euhedral and anhedral inclusions

(2) systematic increase in albite content of plagioclase inclusions with increasing distance from the centre of the perthite megacrysts

(3) the structural and optical orientations of the inclusions, particularly the plagioclase with the host perthite (Hibbard M. J., 1965)

The presence of perthite megacrysts and large aggregates of quartz in the chilled borders as well as interior zones of the Glennanan complex indicates a very early stage of crystallization for these constituents. Since there are plagioclase crystals in the core of the perthite megacrysts, plagioclase with a composition about An_{38+2} must have been the first feldspar phase to crystallize. The amount of plagioclase that formed before the appearance of alkali feldspar must have been small. In general, 75 percent or more of the inclusions of plagioclase are concentrated in the outer regions of the megacrysts. The quartz, hornblende, sphene and magnetite inclusions in the core areas indicate that they also joined plagioclase at a very early stage of crystallization. Biotite formed later than hornblende.

Hibbard (pg. 254, 1965) states "the orientation of the plagioclase crystals parallel to rational crystallographic planes of the phenocrysts is explained most logically as a continuous process of attachment and incorporation of small plagioclase crystals on the euhedral surfaces of growing alkali feldspar crystals. This means that crystals of plagioclase and alkali feldspar were suspended in a melt and that the melt was sufficiently mobile to allow these growing crystals to come into contact. Turbulence related to magmatic flow is probably responsible for the motion required by this hypothesis."

Perthite megacrysts which contain oriented and non-oriented inclusions in the other rock zones of the Glennanan complex probably developed in the same manner as the megacrysts in the glomeroporphyritic facies of the granite zone. The euhedral form of quartz and the equant grains of microcline in the interstitial microperthite of the Glennanan porphyritic granite and quartz monzonite suggests that they formed in a magma with little interference from adjacent crystals. These features, together with the general lack of flow structures in all rock zones, suggests that the magma was emplaced in a highly fluid state.

DIFFERENTIATION

Although the asymmetrical pattern of the Glennanan intrusives suggests intrusion of three independent magmas, the universality of the perthite megacrysts and the gradational contacts between the rock zones disqualifies this hypothesis. Differentiation of a single magma in situ to form a porphyritic granite zone along the western side, an intermediate zone of porphyritic quartz monzonite, and an eastern zone of porphyritic granodiorite, north of the Endako River is not very likely because of the relative immobility of crystals in viscous granite melts. Differentiation in place may have arisen as a result of contamination of a granitic magma by more basic wall rock material. The granite zone if emplaced along the eastern contact of the pluton may have been modified to a granodiorite by assimilation of the Simon Bay diorite north of the Endako River. The granite zone on the southwest side of this body is uncontaminated but this might be expected since the country rock, the Endako quartz monzonite is chemically similar to the intruding phase. However, the uncontaminated porphyritic granite contact with the Simon Bay diorite on Nithi Mountain indicates a minor role of wall rock assimilation in the formation of the Glennanan complex in the map area.

The author concludes that the compositional variation is the result of differentiation of a single magma at depth. A homogeneous magma of intermediate composition through some mechanism of differentiation at depth, might yield a heterogeneous body of magma more alkali-rich in the upper regions. The concentration of perthite megacrysts in the granite zone suggests the possibility that this fractionation might have occurred in response to the gravitational rising of these crystals in a denser liquid. The effectiveness of such a process in the differentiation of viscous granitic melts is less widely accepted than is the downward concentration of heavy minerals in basic magmas (Turner and Verhoogen, 1960, pg. 84). A mechanism whereby alkalis may be concentrated in the upper regions of the magma has been suggested by Kennedy, 1955, "Water will diffuse and distribute itself in a magma so that the chemical potential of water is the same throughout the magma chamber. By this mechanism water tends to be concentrated in the magma chamber in the regions of lowest pressures and temperatures. Alkalis and certain metals will co-ordinate with water and, similarly be concentrated in the regions of lowest pressure and temperature."

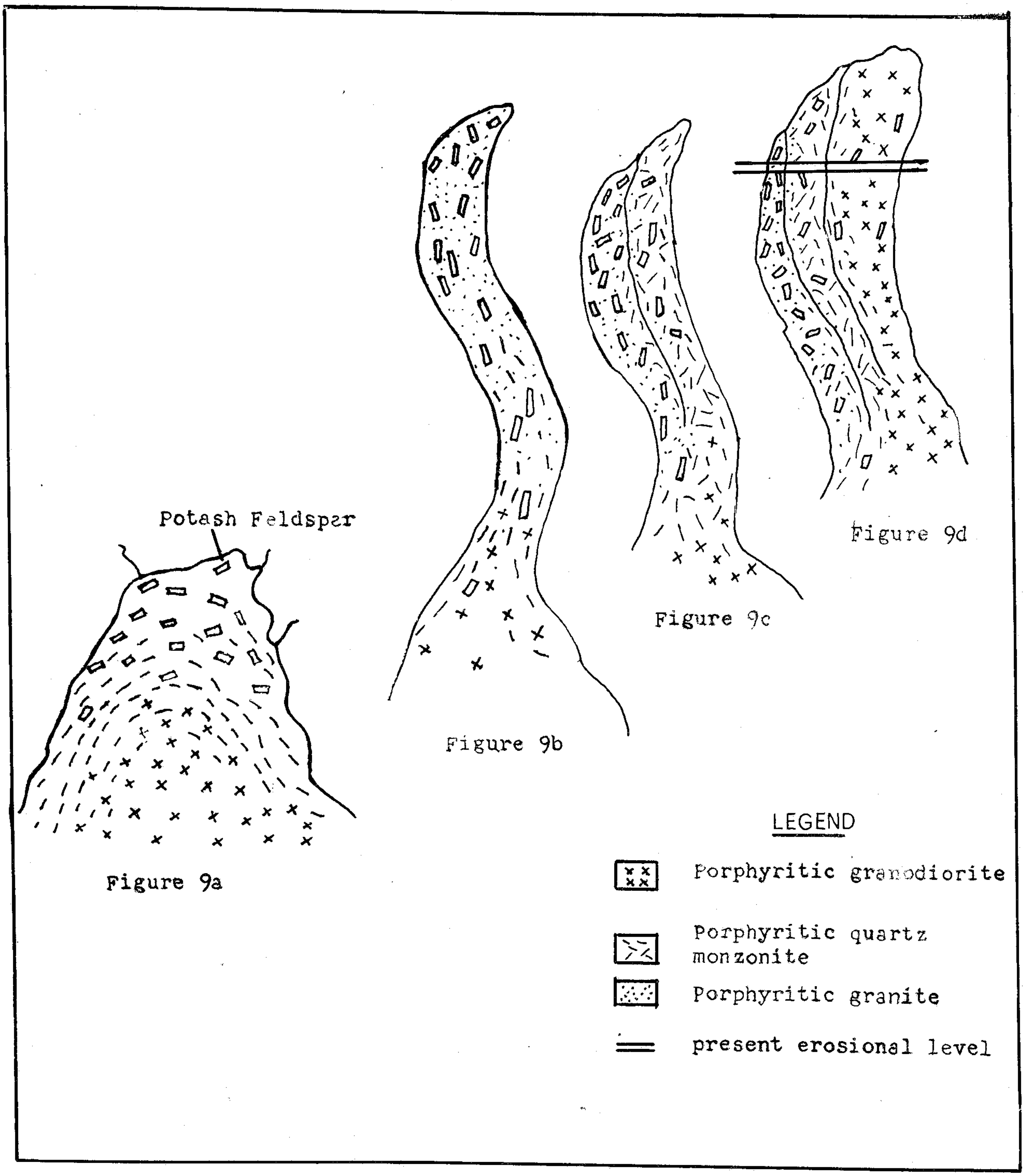


Figure 9. Diagrammatic sketch showing a hypothetical development of rock zones of the Glennanan Complex.

An hypothetical sequence of events that is proposed to explain the development of the asymmetrical rock zones in the Glennanan intrusive bodies is illustrated diagramatically in Figure 9.

In figure 9a, large potash feldspars crystallized from the alkali-rich magma formed at the top of the magma chamber. The continuous removal and incorporation in the growing potash feldspars of other crystal phases forming in the magma, contributed to the process effecting differentiation, that is, diffusion of volatiles and alkalis. During the first stage of intrusion (fig. 9b) the upper part of the magma, charged with these potash feldspar megacrysts, was drawn off to form the outer coarse-grained porphyritic hornblende-biotite granite. The steep dipping attitude of the observed flow structures along the borders of the intrusive indicates that vertical movement was prominent and that the pluton is probably not domed at the present erosional level. In places along the rapidly cooling margins of the granite zone, potash feldspar megacrysts were aligned parallel to the steep flow direction by the upward and outward force of the intruding magma. At other loci, pockets of magma saturated with megacrysts were swept off and carried up as units to produce the glomeroporphyritic granite along the chilled margins. The very coarse-grained texture of the porphyritic granite zone over most of its width indicates that except for along the margins, the magma cooled very slowly. Crystallization inwards, possibly towards a quartz monzonite composition, was probably still taking place when the quartz monzonite fraction of the magma was drawn off and intruded into the eastern edge of the granite zone (fig. 9c). This newly intruded magma mixed completely with the granite along their contacts to form the coarse-grained porphyritic hornblende-biotite quartz monzonite intermediate zone. Some potash feldspar megacrysts were probably still available in the magma chamber to be drawn off during this stage.

In the same manner as the preceding stages, the remainder of the differentiated magma was drawn off and intruded into the eastern edge of the porphyritic quartz monzonite (fig. 9d) to produce the medium-grained porphyritic hornblende-biotite granodiorite zone, north of the Endako River. If at this stage, the magma had been completely depleated of megacrysts, it may have been possible for the granodiorite to capture some megacrysts from the crystallizing porphyritic quartz monzonite zone. Wall rock contamination is a minor effect along the eastern contact of the granodiorite zone and does not appear to have had an effect on the overall development of the rock zones in the map area.

TOPLEY STAGE IV

CASEY BIOTITE QUARTZ MONZONITE-ALASKITE

FIELD RELATIONSHIPS

The major center of intrusion of the Casey quartz monzonite is north of Savory Lake, just beyond the northwestern margins of the map area (see Carr, 1965). Radiating from this main intrusive body are a series of very large fine-to-medium-grained dikes which extend for miles across the regional trend of the older intrusives of the Topley complex. Isolated stocks and dikes, considerable distances from this center, are possibly related to other centers of intrusion which did not breach the present erosional surface of the thesis area.

Such a satellite dike, averaging one mile in width, enters the map area south of Savory Lake and continues east-southeast a distance of 11 miles to the Stellako River. A sharply bounded stock of Casey quartz monzonite-alaskite underlies an area of approximately 12 square miles on the east flank of Nithi Mountain. Small isolated exposures occur along the northern edge of the map area and probably represent the southern extension of larger satellite dikes of the main pluton.

Subsiduary dikes and aplites occupy fractures ranging in width from one inch to 500 feet, along the main contacts.

PETROGRAPHY

Specimens taken from the main Casey intrusion north of the map area, are pink coarse-grained, equigranular to sub-porphyritic biotite quartz monzonites. Hornblende is not present. The average grain size is 8 m.m. but perthite and quartz may reach diameters of 1.5 cm. in places. A porphyritic texture is generally inconspicuous because of the irregularity of the grain margins. Biotite comprises between 2 and 4 percent of the rock. Miarolitic cavities and pods of pegmatite are more abundant than in the satellitic intrusions in the thesis area. A porphyritic chilled facies was observed near Owl Lake, 5 miles north of Savory Lake.

The Casey intrusions in the map area have very broad border zones, composed of fine-grained (averaging 2 m.m. in size) porphyritic leucocratic granite and quartz monzonite (collectively referred to as alaskite). This marginal facies is gradational into a central region consisting of medium-grained (averaging 5 m.m. in diameter) porphyritic biotite quartz monzonite. In the fine-to medium-grained rocks, biotite may exceed 1 percent and quartz or occasionally potash feldspar may form phenocrysts. A sharply bounded chilled zone ranging in width from one foot to 50 feet was observed near Savory Lake south of highway 16, and due east of Casey Lake respectively. Quartz phenocrysts, 1 to 2 m.m. in diameter are conspicuous in the very fine granular groundmass. The rocks in and near the margins carry only traces of biotite and tend to be rich in potash feldspar. Miarolitic cavities, lenses of pegmatite and pods of biotite are found in the Nithi Mountain stock. The modes of these rocks is shown in Table IX

TABLE IX

Modal Analyses of the Casey Intrusive

	Granite		Quartz Monzonite	
	EN-184	EN-202	EN-185	EN-186
Microcline[1]	52.0	45.3	40.0	30.0
Plagioclase[2]	11.0	20.1	25.0	30.0
Quartz	37.0	33.1	33.0	36.0
Biotite	tr.	1.5	1.0	3.0
Muscovite	tr.	-	tr.	-
Magnetite	tr.	tr.	tr.	1.0

[1] - Microcline composition is Or_{92} Ab_{18}

[2] - Plagioclase composition is An_{22}

In thin section, the main textural difference between the fine and coarse-grained rocks of the Casey intrusive, is the habit of quartz. In the fine-grain and chilled margins of the intrusive, euhedral six sided crystals or rounded subhedral grains form inclusions in plagioclase and microcline (plate XII, fig. 1) as well as interlocking crystals in the groundmass. Quartz also occurs as anhedral interstitial grains which embay plagioclase and microcline in the fine-grained rocks. With increasing grain size, the Casey intrusive shows a less granular, more interstitial texture with respect to quartz and feldspar. Euhedral to subhedral quartz crystals are present in some of the coarse-grained rocks of the central zone of the Casey quartz monzonite.

Poikilitic perthitic microcline forms interstitial grains or occasionally phenocrysts with very irregular margins. Exsolved plagioclase comprises about 1 per cent of the microcline in the fine-grained rocks and 3 to 4 percent in the coarse-grained quartz monzonite. Embayment of plagioclase by microperthite and segregation of exsolved albite towards the grain margins of the host are more prevalent in the coarse-grained rocks.

Plagioclase forms subhedral crystals with broad saussuritic and sericitic cores and thin unaltered margins. The average composition is oligioclase (An_{22}). Oscillatory zoning is absent in the fine-grained

PLATE XII

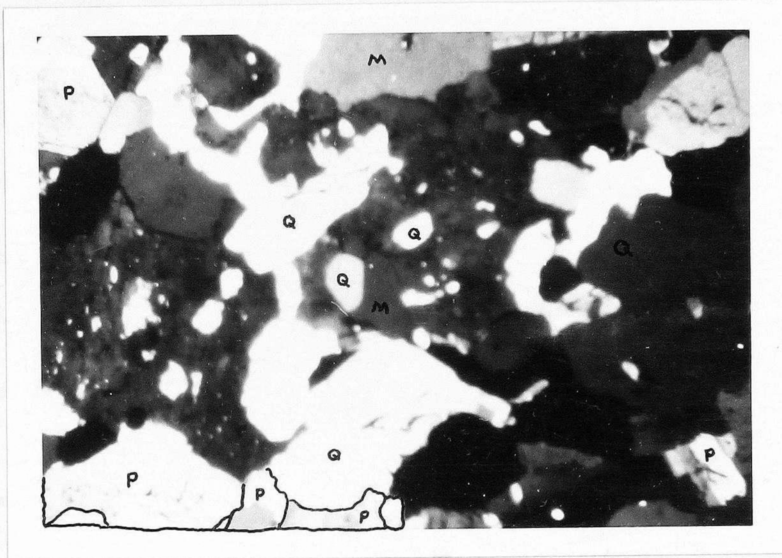


Figure 1: Anhedral and euhedral quartz (Q) crystals in microcline (M) which is interstitial to the plagioclase (P) in the chilled zone of the Casey alaskite (x100, crossed nicols)

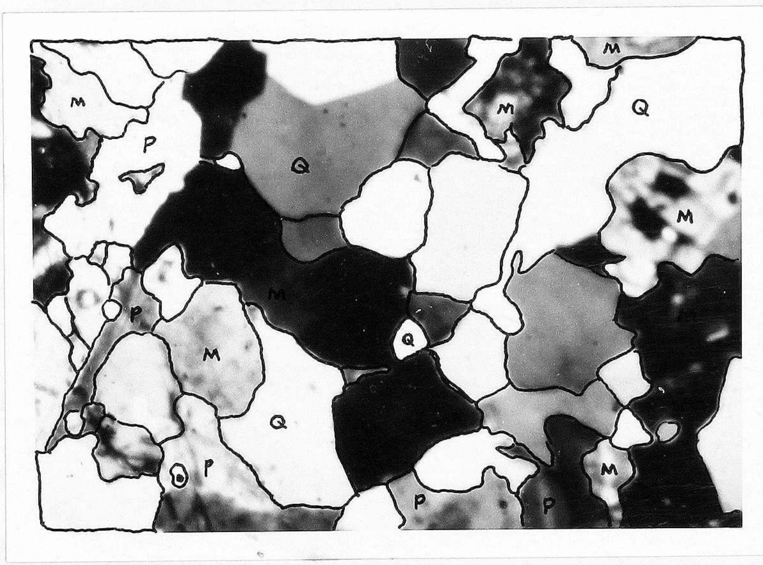


Figure 2: Microcline (M) interstitial to plagioclase (P) and subhedral to anhedral quartz (Q) in the control zone of the Casey quartz monzonite-alaskite (x35, crossed nicols)

rocks and weakly developed in the coarse-grained.

Green biotite ranges from trace amounts in the alaskite, 1-2 percent in the fine-medium-grained areas of the dike and stock, to 3 to 5 percent in the main body, north of Savory Lake. The pleochroic scheme of biotite is as follows: x, medium green; Y, dark green; Z, pale apple green. The texture varies from interstitial wisps and ragged laths to tabular interlocking grains.

Muscovite occurs in alaskitic areas of the Casey intrusive. In places along the margins, it comprises as much of the rocks as does biotite. It forms intergranular laths and wisps with biotite, intergrowths with and occasionally wide rims on biotite grains. The contact between the rim muscovite and core biotite is very sharp and the muscovite reproduces the shape of the enclosed biotite grain. The muscovite is fresh-looking compared to the chloritized biotite. Accessory minerals, apatite, sphene, magnetite and allanite form interlocking grains in the groundmass and inclusions in biotite and microperthite.

Along the margins of the Casey intrusive, some effects of strain and crushing are shown by strongly undulose quartz, bent and broken plagioclase twin lamellae and deformed micas. Similar features were observed in some specimens taken from the central areas of the intrusive.

STRUCTURE

The emplacement of the Casey intrusions in the map area has been strongly controlled by a set of west-northwesterly and north-easterly trending fracture zones. This discordant intrusive is sharply bounded against the older intrusives of the Topley complex. West of Casey Lake, the intrusive is confined to the Endako quartz monzonite but to the east it was emplaced along the contact between the Glennanan complex and the Endako pluton. On Nithi Mountain, it has intruded the central area of what was probably once one continuous body of the Glennanan complex.

Contacts with the older units of the batholith are chilled and show no evidence of the exchange of material with the wall rocks. Xenoliths are absent and the rock lacks a directional fabric. Along the Stellako River the Casey intrusive is sharply truncated by the younger Stellako quartz monzonite.

ENVIRONMENT OF EMPLACEMENT

An epizonal depth of emplacement for the Casey intrusives is strongly indicated by the following:

(1) the sharply bounded pophyritic chilled margins

(2) the lack of a foliation and xenoliths

(3) the absence of brecciation along the contacts

(4) the presence of microlitic cavities and pods of coarse grained potash feldspar, quartz and hexagonal biotite books.

The Casey quartz monzonite-alaskite was probably emplaced along wide fracture zones by forceful injection of a highly fluid magma.

TOPLEY STAGE V

STELLAKO HORNBLENDE-BIOTITE QUARTZ MONZONITE

FIELD RELATIONSHIPS

Rocks of the Stellako intrusive are restricted to the eastern part of the map area between the Stellako River and the west flank of Nithi Mountain. These exposures, generally covering less than 1 square mile, are separated by wide areas of recent sediments. Smaller exposures occur on an island and the west side of a peninsula in Fraser Lake. Fresh-looking porphyritic hornblende quartz diorite dikes, striking northeasterly, cut the Endako quartz monzonite near the junction of the Glennanan and Mine roads and along the river north of Pond Lake. Similar dikes cut the Glennanan granite west of the small lake on the Glennanan road, the quartz monzonite near Alf Lake and the Simon Bay diorite at Mouse Point on Fraser Lake. On the peninsula in Fraser Lake, the Simon Bay complex is also cut by fine-grained porphyritic quartz diorite and quartz monzonite dikes which are offshoots of the Stellako quartz monzonite intrusive immediately to the south.

PETROGRAPHY

The rock is a fine-to medium-grained grey-pink hornblende biotite quartz monzonite. Granodiorite occurs in places near the contacts with the older intrusives. The approximate modal composition of several representative types is given in Table X.

TABLE X

Modal Analyses of the rocks of the Stellako Intrusive

	Quartz Monzonite			Granodiorite
	Mudhole Lake	Shotgun Creek	Lower Stellako River*	Upper Stellako River
Alkali feldspar	38.0	20.0	25.0	14.0
Plagioclase[1]	20.0	37.0	45.0	55.0
Quartz	32.0	35.0	20.0	23.0
Biotite	5.0	6.0	8.0	4.0
Hornblende	3.0	2.0	--	2.0

[1] - plagioclase composition ranges An_{24} to An_{34}

*Carr, 1965

PLATE XIII

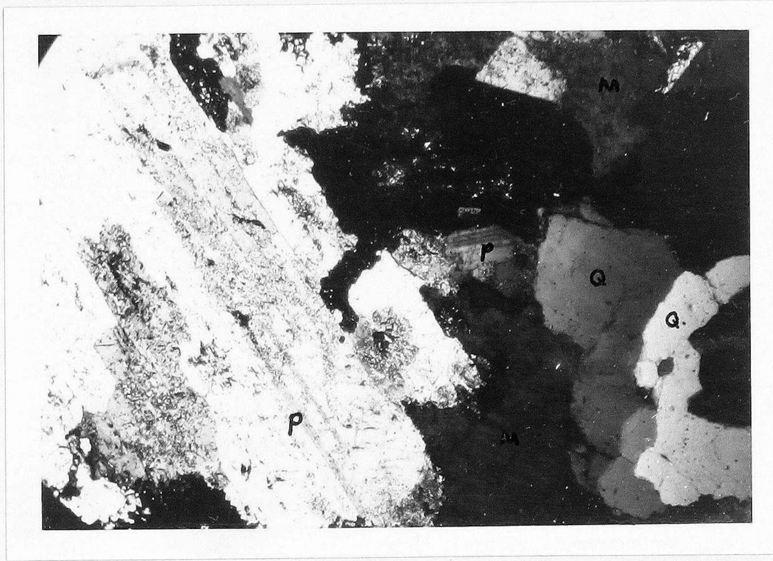


Figure 1: Saussuritized subhedral plagioclase (P) with interstitial quartz (Q), and microperthite (M) in the Stellako quartz monzonite. (x100, crossed nicols)

Figure 2: Texture of Stellako quartz monzonite. Note anhedral biotite (B), and subhedral plagioclase (P) in microperthite (M) (x35, crossed nicols)

The texture of the Stellako intrusive is equigranular along the Stellako River and west of Seas Lake but porphyritic at Mudhole Lake and on the west flank of Nithi Mountain. Here, potash feldspar phenocrysts range in size from 1/2 to 1 cm. long. Quartz and potash feldspar in the groundmass are interstitial to plagioclase. Biotite exceeds hornblende and together they comprise between 4 and 8 percent of the rock. Prismatic hornblende or streaks and elongated mafic clots in the matrix give the rock a weak linear element. Near the contacts of the Stellako intrusive the generally indistinct foliation is accentuated in places by mafic rich lenses and bands which give the rock a gneissic texture.

In thin-section, euhedral to subhedral plagioclase is normally zoned near the Stellako River but zoning is faint or absent at Mudhole Lake. The cores have a composition of An_{30} to An_{34} and the peripheral zone varies between An_{24} to An_{20}. Myrmekite is not common. Interstitial microperthite, poikiolitically encloses quartz, biotite, hornblende and plagioclase, and locally embays these minerals. Undulatory, interstitial quartz contains inclusions of apatite, magnetite or occasionally biotite and hornblende. Biotite of the brown variety occurs as subhedral grains, ragged laths or intergrowths and clusters with hornblende. Green hornblende commonly forms prismatic grains. The accessory minerals magnetite, sphene, apatite and pyrite form interstitial grains in the groundmass or inclusions in biotite, hornblende, microperthite or occasionally plagioclase.

STRUCTURE

The Stellako intrusive cuts the Endako quartz monzonite and sharply truncates the Casey quartz monzonite-alaskite along the Stellako River. Here, fine-grained Stellako granodiorite gneiss with minor lenses of amphibolite, forms a 40 foot wide marginal zone against the Casey intrusive. Bands of gneiss, lenses of amphibolite and the mafic minerals are aligned parallel to the northeasterly contact with the Casey intrusive and appear to dip steeply to the west. At a distance of 20 to 30 feet east of the river, the foliation of the Stellako granodiorite is indistinct and the rock is medium-grain. The total width of the fine-grained chilled zone is approximately 75 feet. The contact of the Stellako intrusive with the Endako quartz monzonite is hidden. On the large peninsula at the west end of Fraser Lake, the contact with the Simon Bay diorite is crowded with angular to subrounded fragments of amphibolite and quartz diorite (Carr, 1965) On the west side of Hartman's Hill, Simon Bay diorite has been potash metasomatized by the intruding Stellako quartz monzonite. This has resulted in a transition zone approximately 200 feet wide composed of Stellako granodiorite and Simon Bay syenodiorite between the typical rock types of these two intrusives. Aplite dikes and segregations of hornblende and potash feldspar are common in this transition zone. Potash metasomatism was observed in the Simon Bay diorite adjacent to the Stellako intrusive near Mary and Mudhole Lakes. The foliation of the Stellako intrusive in these transition zones, parallels that observed in the older diorite.

ENVIRONMENT OF EMPLACEMENT

An upper mesozonal to lower epizonal depth of emplacement is indicated by: (1) chilled and unchilled contacts; (2) foliated margins and local zones of gneiss near the borders which conform to the trend of the wall rock; (3) the sharp truncation of the Casey quartz monzonite along the Stellako River; and (4) brecciated contacts and feldspathization of the Simon Bay wall rocks. Emplacement was probably accomplished by forceful intrusion with local stoping, wall rock assimilation and metasomatism.

POND QUARTZ MONZONITE PLUG

This rock is exposed in a single outcrop near the tailings-pond dam north of the Endako mine. It is a pinkish-grey, fresh looking, medium-grained equigranular hornblende-biotite quartz monzonite.

In thin section the texture is largely hypidiomorphic granular with an average grain size of 2.5 m.m. Minor amounts of inter-granular fine-grained quartz and feldspar are present, but in insufficient quantity to give the rock a porphyritic texture. Sub-poikilitic, interstitial microperthite includes all minerals. Sericitic microperthite locally embays plagioclase and quartz. Myrmekitic borders are not common on plagioclase which has strong normal zoning with a weak oscillatory trend in the core regions. The composition ranges from An_{16} to An_{25}. Variations within individual zoned crystals could not be determined because of the weakly developed twin lamellae.

Anhedral quartz together with biotite and hornblende have an intergranular habit. Accessories include sphene and magnetite. The estimated modal composition is perthite, 20%; plagioclase, 50%; quartz, 35%; biotite, 3%; hornblende, 2%; and accessories, 1%.

The Pond quartz monzonite probably intrudes the Endako quartz monzonite. It is not known whether this plug is younger or older than the Fraser quartz monzonite stock.

FRASER QUARTZ MONZONITE STOCK

Exposures of this medium grained subporphyritic pink biotite-hornblende quartz monzonite are confined to two outcrops on Highway 16, near the west end of Fraser Lake.

In the hand specimen, subhedral grey-green plagioclase and prismatic dark green hornblende form phenocryst up to 8 m. m. long, in a pink groundmass averaging between 1 and 3 m. m. in grain size. In thin section poikilitic microperthite includes plagioclase, biotite and hornblende and is graphically intergrown with quartz. Subhedral plagioclase has a composition about An_{18} and exhibits oscillatory-normal zoning. Poikilitic reddish brown biotite and prismatic or anhedral green hornblende are interstitial. Biotite forms rims on or intergrowths with hornblende. Accessory minerals are apatite, magnetite and sphene. The estimated modal composition is perthite, 32%; plagioclase, 43%; quartz, 18%; biotite 2%; hornblende, 5% and accessories 1-2%.

The outcrops of the Fraser porphyritic quartz monzonite occupy a position in an area of contrasting low magnetic susceptability (aeromagnetic Maps 1589-G, Hallet Lake and 1590-G Fraser Lake,

1963) with the surrounding Stellako quartz monzonite. Contacts were not observed and foliation is absent. The eastern outcrop is finer-grained than the other and possibly lies close to the edge of the stock. Using these guides, the Fraser stock would then seem to form an east-west trending elliptical body approximately 1/2 mile wide and 1 mile long.

The intrusive probably intrudes the Stellako quartz monzonite and its granophyric texture indicates an epizonal environment of emplacement (Buddington, 1959).

ENDAKO GROUP

The Endako intermediate to basic volcanic flows unconformably overly 8 square miles of the Topley intrusive complex on the north shore of Francois Lake, 6 square miles on the northwest shore of Fraser Lake and small areas southeast of Nithi Mountain.

The volcanic rocks are dark green or brown andesitic or basaltic flows showing amygdaloidal, vesicular, scoriaceous or porphyritic textures. Chalcedonic quartz, pink to cream-colored calcite, chlorite anx zeolites form the amygdules. Phenocrysts of plagioclase and pyroxene are prominent along the north shore of Francois Lake.

These flat-lying flows are assigned to the Endako Group of Oligiocene or Eocene age.

SUMMARY AND CONCLUSIONS

The Topley intrusives in the Endako area make up part of a composite body which occurs in a northwest trending belt of granite plutons which extends discontinuously from Babine Lake to Quesnel, a distance of 180 miles (see Fig. 1). The Francois intrusive phase of the complex intrudes volcanic rocks of the Takla Group of Upper Triassic to Jurassic age. Flat lying volcanics of the Endako Group (Eocene or Oligiocene) unconformably overly the Topley intrusives in parts of the map area.

Sheared and altered diorite with minor lenses of amphibolite, gneiss and gabbro of the Simon Bay complex is the oldest plutonic rock exposed in the map area. The Simon Bay complex, which is cut by intrusives of stages III, IV and V in the map area, is the southeastern extension of a discontinuous belt of foliated diorite and amphibolite, trending northwesterly along the periphery of the Topley intrusions particularly north of the map area (Armstrong, 1949). The foliation of the Simon Bay complex in general conforms to the regional northwest trend of the belt of Topley intrusions. The lenses or screens of gneiss, amphibolite and gabbro which accentuate the foliation of the Simon Bay complex possibly represent country rock in various stages of metamorphism and metasomatism. The foliated diorite could be a more extreme product of this same period of granitization. The character of the foliation in exposures of unsheared diorite however, suggests a primary origin produced during emplacement of a magma. Although the structural evidence is inconclusive, the author concludes that the Simon Bay complex represents a mesozonal pluton which was intruded along northwest zones of weakness in the country rock. Stoping, metasomatism and assimilation of wall rock material were probably operating along the periphery of the intruded magma.

The intrusives of stage II represent a relatively shallow level of igneous activity superimposed upon the earlier more deep-seated period which formed the Simon Bay complex. The coarse-grained subporphyritic Endako quartz monzonite and medium-grained Francois granite, which has a porphyritic chilled border zone against the fine-to-medium-grained Endako intrusive, are epizonal intrusions. They were emplaced along the southwestern edge of the growing Topley complex under the influence of a second period of northwest faulting and fracture. These major fracture systems, together with a later northeasterly set, have controlled the structural development of the batholithic complex in the thesis area. The contacts of the Endako and Francois intrusives are conformable to each other and the regional northwest trend of the Simon Bay complex near and beyond the northern margins of the map area. The southeastern extension of the Endako quartz monzonite, however, may cut across the foliation of the older diorite on Nithi Mountain. The absence of foliation in the Francois granite and Endako quartz monzonite suggests a largely liquid mode of transfer from depth. The Francois intrusive may represent a second generation of magma from the same source as the Endako intrusive or possibly a later injection of more alkali-rich material from a single differentiating magma at depth.

The intrusions of stage II were nearly completely consolidated when a newly formed upsurge of magma, the Glennanan complex, was intruded as : (1) a large asymmetrically zoned body of porphyritic granite-quartz monzonite-and granodiorite along a regional zone of weakness between the Endako quartz monzonite and the Simon Bay complex; (2) a smaller, asymmetrically zoned body of porphyritic granite-and quartz monzonite into the Simon Bay complex on Nithi Mountaon; and (3) a small stock of porphyritic quartz monzonite into the older diorite rocks around Alf Lake.

That the Glennanan intrusives were emplaced in a highly fluid state into the epizonal environment is indicated by: (1) the steep attitude of weakly developed flow structures along the margins of the granite and granodiorite adjacent to the Simon Bay complex;

(2) sharply bounded, uncontaminated chilled margins in the outer granite zones which are gradational inward to coarse-grained porphyritic rocks in the interior zones; (3) perthite megacrysts in the chilled margins of the granite zone which contain structurally oriented inclusions; and (4) granophyre in the granite and quartz monzonite zones. Chemical and mineralogical variation of the rock zones are consistent with the formation of the Glennanan complex by differentiation of a parent granodiorite magma. The following hypothetical sequence of events is proposed to explain the asymmetrical zoning of these intrusions. Differentiation of a homogeneous magma at depth by diffusion of alkalis and volatiles produced an alkali-rich magma near the top of the magma chamber. Large potash feldspars which crystallized in this region were drawn off in the first injection of magma and concentrated along the margins of the crystallizing granite zone. Successive injections of quartz monzonite, and finally granodiorite, into the eastern edge of the earlier phas es while they were still crystallizing followed quickly upon one another. Complete mixing of each injection of magma along the contacts produced wide gradational contacts between the different rock zones. Wall rock contamination did not affect the overall development of these rock zones.

The intrusion of the Glennanan complex subjected the earlier intrusives in the map area, particularly the Endako quartz monzonite to intense fracturing and local block faulting. Strong northeast fraction zones were produced at this time, which in places can be observed to offset the earlier northwesterly set. The author postulates that while the Glennanan complex was still cooling, a new magma, which was later intruded to form the Casey quartz monzonite-alaskite, was forming at depth. Arching of the roof rocks in response to the upward pressure of this new magma below resulted in a renewed very strong period of fracturing along the regional northwest and northeast zones of weakness. The Casey magma penetrated the country rock along these major fracture zones to form the large discordant dike and stock in the map area. These bodies were possibly intruded in advance of the main actively stoping Casey quartz monzonite intrusive which was emplaced just north of the map area (Carr, 1965). That the Casey intrusives in the map area were emplaced into the epizone by forceful injection of a mobile largely liquid magma is indicated by: (1) the fine-grain size and wide chilled border zone; (2) the lack of foliation, xenoliths and brecciation along the contacts; and (3) the presence of miarolitic cavities.

The last major period of igneous activity is represented by the weakly foliated Stellako quartz monzonite in the eastern part of the map area. Its emplacement was controlled in part by northeast trending facture zones. An upper mesozonal to lower epizonal depth of emplacement is suggested by: (1) chilled and unchilled margins; (2) gneissic zones along the margins which conform to the trend of the wall rocks; (3) brecciated contacts and feldsparthization of the Simon Bay wall rocks; and (4) a sharp discordant contact along the Stellako River which truncates the Casey quartz monzonite-alaskite. The author favors a lower epizonal depth of emplacement which is compatable with the earlier epizonal plutons of stage III and IV and the epizonal Fraser quartz monzonite plug which probably intrudes the Stellako quartz monzonite.

A grouping of biotite radiometric age dates around 140 million years (Middle Jurassic) for the Endako, Glennanan and Stellako intrusives was determined by Dr. W. H. White of the Geology Department, University of British Columbia. These results are in agreement with the author's hypothesis that Topley stages II to V, represent a relatively short continuous period of epizonal intrusion, following the emplacement of the more deep seated mesozonal Simon Bay complex. Because the Topley rocks are probably intrusive into the Takla Group (Upper Triassic to Jurassic), the author concludes that the intrusive rocks in the map area are probably of Lower Jurassic to Lower Cretaceous age.

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GEOLOGY OF THE ENDAKO AREA BRITISH COLUMBIA
LEGEND
Eocene
Endako Group
11 Intermediate to basic lavas
Cretaceous
Topley Plutonic Rocks
10 Fraser quartz monzonite
9 Pond quartz monzonite
8 Stellako quartz monzonite
7 Casey quartz monzonite-alaskite
Upper Jurassic
6 Glennanan (6a) granite, (6b) quartz monzonite, (6c) granodiorite, (6d) aplite
5 Francois granite
4 Endako quartz monzonite
3 Simon Bay diorite complex
2 Menard quartz latite
Lower Mesozoic
Takla Group
1 Acid volcanic tuffs and breccias
SYMBOLS
Geological contact defined, assumed, geophysical
Outcrop boundary
Drift-covered area
Foliation, inclined, vertical
Shear, inclined, vertical
Fault, defined, assumed
Lineament
Gravel road
DH Diamond drill-hole
Mo Molybdenite occurence
D Dike
Scale 0 1 mile 2
magnetic declination 26° 30'
CNR
SAVORY L.
ENDAKO
Endako River
HIGHWAY 16
DESERTER L.
ALF L.
Simon Bay
FRASER LAKE
Mouse Pt.
FRASER LAKE
SEAS L.
Hartman's Hill
MUDHOLE L.
POND L.
CASEY L.
Mine Rd.
Glennanan Rd.
Endako Orebody
MacDonald L.
Stellako River
Stellako Rd.
Shotgun Cr.
NITHI MTN.
FOSTER Ls.
MARY L.
Nithi River
FRANCOIS LAKE
Menard Resort
HAZELTON AND OOTSA LAKE STRATA
54°00'
125°00'
E.G. BRIGHT