GEOLOGY OF CAPE MAKKOVIK PENINSULA
AILLIK, LABRADOR

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by

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A B S T R A C T

This thesis is concerned with the most promising molybdenite-rich area on the north coast of Labrador, Cape Makkovik peninsula. The area, although only 6 square miles in size, is part of the Labrador Uranium Province and its geology is similar to the Beaverlodge and Great Bear Lake camps in the western part of the Canadian Shield.

In a reconnaissance along the Labrador coast in 1900, Daly referred to the glaciated peninsula as "a veritable museum of rock types". The map-area is underlain by an assemblage of folded metamorphosed quartzitic and amphibolitic rocks of Precambrian age which have been termed the Aillik Group. The degree of metamorphism has been largely dependent upon the original character of the rock and upon tectonic stresses which prevailed during deformation. A great number and variety of intrusive rocks ranging in composition from "amazonite" pegmatite to lamprophyre have been intruded at different times along major joint sets.

After detailed megascopic and microscopic study, parentage has been determined for those metamorphosed and metasomatized (potash-bearing) rocks which have retained some of their primary features. The relative ages of the igneous rocks have been determined and these observations, combined with radioactive age determinations, may possibly be a means of chronological correlation with dyke systems in other parts of Labrador.

The thesis is illustrated by figures and plates, and by a coloured geological map on a scale of 1 inch to 500 feet.

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Acknowledgements

This thesis, presented for the degree of Master of Science at Memorial University of Newfoundland, is the product of field work carried out during the summer of 1960 and laboratory work in the fall and winter of 1962-63. Financial assistance in the field was provided by British Newfoundland Exploration (BRINEX), and in the laboratory by the Memorial University of Newfoundland in the form of graduate fellowships (1961-63). This assistance is gratefully acknowledged here.

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(Photo by permission of Royal Canadian Airforce)

Plate I

Aerial view of Cape Makkovik and Cape Aillik with snow filled joint patterns in foreground and coastal ice in background.

GEOLOGY OF CAPE MAKKOVIK PENINSULA, AILLIK, LABRADOR

CHAPTER I

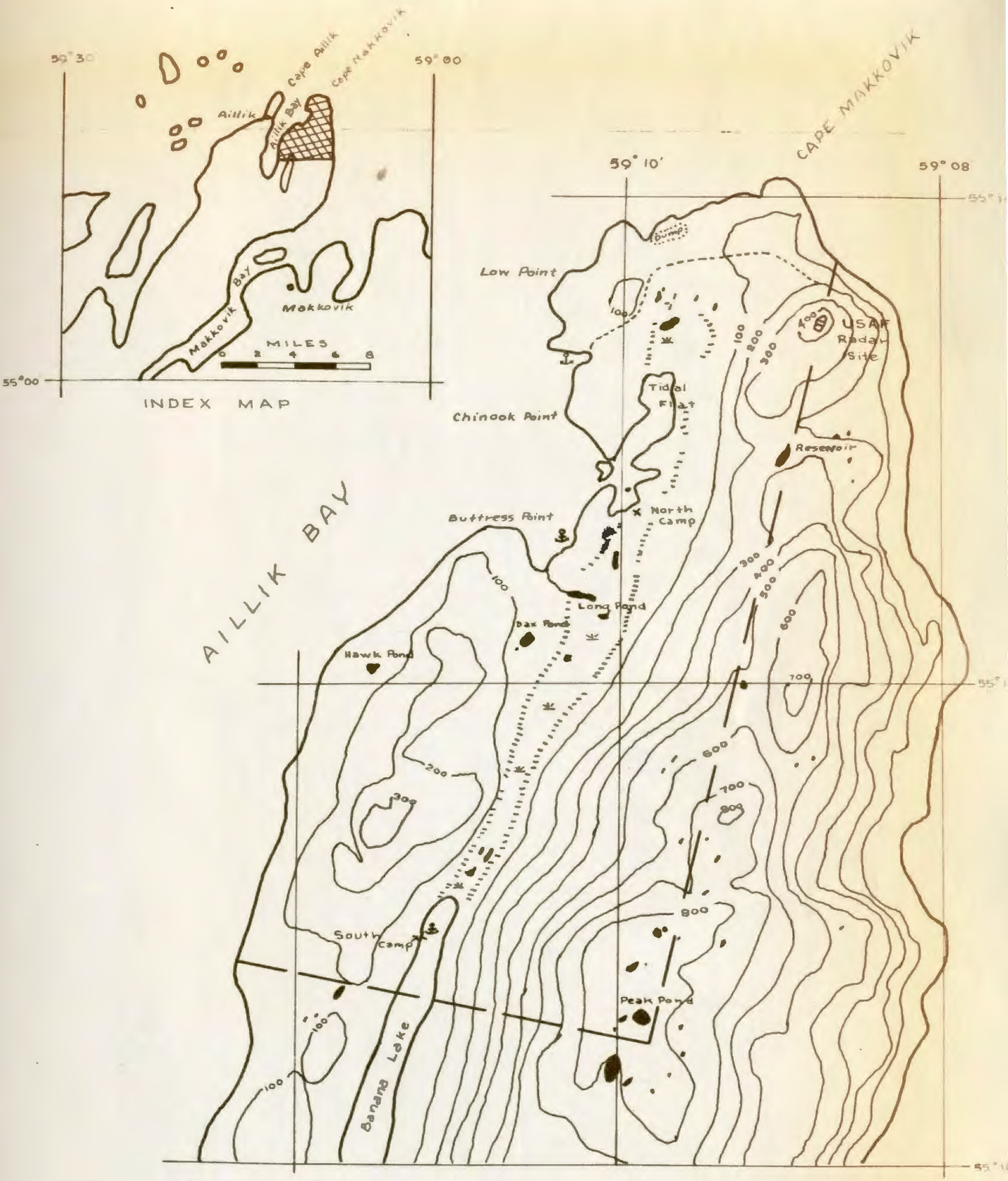
INTRODUCTION

Location and Accessibility

Cape Makkovik peninsula forms the eastern portion of a claw-like appendage jutting into the cold Labrador Sea. Aillik Bay lies to its west and Makkovik Bay to the east and south. The map-area described in this thesis is bounded by latitudes 55°10' and 55°14' north and longitudes 59°08' and 59°12' west.

The nearest settlements are the villages of Makkovik and Aillik. Makkovik is separated from the southern extremity of the Cape peninsula by a sea-inlet one to two miles wide. It has a population of 350, the majority of whom are Eskimoes. The Moravian Mission and the Division of Northern Labrador Affairs have stations there, with the Moravians looking after the spiritual and educational welfare of the community and the government operating stores, fisheries and communications. Aillik village lies on the western shore of Aillik Bay, 3 miles southwest of Cape Makkovik and is inhabited by only a few families. Cod and char fishing in summer and trapping and the seal hunt in winter are the means of livelihood in both villages.

During the summer months, the Canadian National Railways coastal boats stop at Makkovik and Aillik; from there a fishing



LOCATION OF THESIS AREA

1 3/4 1/2 1/4 0 1

Scale in miles

Contour Interval 100 Feet

— — Indicates boundary of thesis area

⚓ Seaplane landing area

Fig. 1.

boat may be chartered for a trip to the Cape. The usual means of transportation to the area is by float-equipped aircraft operating from Northwest River, 125 miles to the south-southwest. The southward drifting floe ice, and the abundance of coastal fog and adverse weather can close navigation without warning.

Previous Geological Work

Newfoundland Labrador has been for many years a land known only to the trapper, the fisherman, the missionary and the occasional visitor. Some of the early visitors were explorers who recorded observations mainly of geographical and geological features. Subsequent geological investigations along the coast, were in the form of reconnaissance expeditions sponsored by American and Canadian Universities and by the Newfoundland and (after Confederation) Canadian Governments. These surveys made important contributions to the knowledge of the coastal geology and have been supplemented within the past decade by the extensive investigations of mineral exploration companies.

Between the years 1867 - 1888, A.S. Packard (1891)[1] made observations on glacial phenomena and the geography of coastal Labrador and presented the first accurate geological data about the bedrock of the region.

1 Dates in parentheses are those of references cited in the bibliography.

In the summer of 1900, while on the Brown-Harvard expedition, R.A. Daly (1900, p. 215-216) became the first to describe the sedimentary rocks in Aillik Bay. Daly also mentioned the presence of numerous and conspicuous dykes and called the area "a veritable museum of rock types".

E.H. Kranck (1939, 1953) studied the seaboard region in 1937, 1939 and 1949 and his reports are significant contributions to the geology of Newfoundland Labrador. The Aillik-Makkovik area was one of several places selected for closer examination of the sedimentary and intrusive rocks. In the petrographic investigation Kranck was assisted by several graduate students from McGill University, two of whom wrote masters' theses on the area between Makkovik and Kaipokok Inlet. G.C. Riley (1951) described the bedrock geology and T.H. Moore (1951) concentrated on the basic dyke rocks.

G.V. Douglas (1953) examined much of the coast in 1946 and 1947 for the Newfoundland Government. In his coverage of the Tuchialic-Kaipokok area, brief descriptions of the Aillik sedimentary series and intrusive rocks were given.

A.M. Christie, S.M. Roscoe, and W.J. Fahrig (1953) compiled a preliminary map of the central Labrador coast with descriptive notes for the Geological Survey of Canada.

In June and July of 1954, British Newfoundland Exploration (BRINEX), a subsidiary of the British Newfoundland Corporation (BRINCO), began geological reconnaissance of their concession area between Kaipokok Inlet to Lake Melville. The following year, the company did a considerable amount of geological work in the Aillik-Shoal Lake area, particularly in the latter. A report by M.J. Piloski (1955), based on this work, contains descriptions of the predominating rock types with their structural and genetic relationships.

Present Work

In the summer of 1959, a BRINEX geological prospecting team of P.G. Morris (1959) and A. Montague, discovered molybdenite showings on the Cape Makkovik peninsula.

The following year, an area of approximately 5 square miles surrounding the molybdenite prospect was selected for detailed investigation by BRINEX in partnership with Southwest Potash Corporation. During most of the summer of 1960, geological mapping was carried out by the writer and assistant. Data were recorded in the field on aerial photographs at a general scale of 500 feet to the inch and at 50 feet to the inch in the vicinity of the prospect. This information was later plotted on uncontrolled overlay base maps.

In late August 1961, the writer, accompanied by Professor W.D. Brueckner of Memorial University of Newfoundland, extended the map coverage from the southern portion of the concession area to the east shore of Aillik Bay.

Laboratory studies of the specimens collected in the field were made at Memorial University in 1962 and 1963; about 350 hand specimens and 200 thin sections were examined. The percentages of various minerals in the thin sections were made by measuring the lengths of traverses across the mineral grains using a micrometer attachment. Supplementary techniques for mineral determinations included the use of a Frantz Isodynamic Separator, Index of Refraction Liquids and particularly staining methods (Bailey, 1960; Rosenblum, 1956) for identification of felspars in rock slabs and thin sections. Colour descriptions are based on those found in the "Rock-Colour Chart" distributed by the Geological Society of America (1951).

Geological data were plotted on an enlarged (1:6,000) portion of a U.S. Navy[1] preliminary topographic chart. In late 1962, a Canadian Government [2] topographic chart of Makkovik became available and though subject to revision, co-ordinate references are to this map.

1 U.S. Navy Survey, 1958, Approaches to Aillik Bay: No. 6594, Scale 1:25,000, Chart subject to revision.

2 Department of Mines and Technical Surveys, 1961, Makkovik, Newfoundland; Sheet 13 O/3, Scale 1:40,000 Advanced Information and subject to revision.

Although the work in the Cape Makkovik peninsula was begun as an investigation of the molybdenite showings, it has been expanded to include a detailed study of the metamorphic and intrusive rocks of the area. This thesis is mainly concerned with the descriptions, interpretations and relationships of these rocks.

Physiography

Cape Makkovik peninsula shows rounded topography, terminating abruptly in steep cliffs along the coastal headlands. The gently sloping hills east of Aillik Bay reach a summit of 370 feet and average 200 feet in height. The west side of Makkovik Bay is flanked by a prominent ridge with a northerly trend. In the southern portion of the map-area, the ridge is about 900 feet high and decreases gradually to 400 feet at the Cape, where it terminates abruptly in rugged sea cliffs. Separating these hills is a low-lying valley containing an elongated lake (Banana Lake, elevation 40 feet) and a long marsh up to 500 feet in width, referred to as the "Banana Lake draw". A tidal flat in the northern portion breaks the continuity of the marsh. Numerous small ponds and intermittent streams are present in the area. The names "Cape Makkovik" and "Low Point" appear on the official maps. Other topographic features have been named provisionally during the field work and these field names will be used for reference in this thesis (see Fig. 1).

Topographic features in the area are influenced by differential erosion of the various rock types. Near Low Point, and on the west side of the Banana Lake draw, amphibolite forms prominent ridges above the easily eroded granulated and feldspathic quartzite. The felsic dykes and some of the narrow basic dykes are more resistant to erosion and stand out above the meta-sediments, but the erosion of the larger and less resistant basic dykes has scarred the area with a criss-crossing pattern of crevasses.

Evidence of glaciation is shown by widespread glacial striations, chatter marks, polished roches moutonnees, erratic boulders, and valley morphology. Striae and polished surfaces are well preserved in the low-lying areas but have been obliterated by frost action on the hill summits. Chatter marks are conspicuous on the outcrops surrounding the tidal flat. The direction of ice movement, based on a combination of the features enumerated above, was towards the northeast with a mean azimuth of 025°. No evidence of multiple glaciation was observed, and ice movement was most likely related to the last glacial period.

Late unconsolidated sediments of glacial and post glacial times are present in the map-area. Near the north end of Banana Lake, depth determinations made by an induced polarization survey (Seigel, 1961) indicate about 5 feet of glacial drift and peat bog underlain by about 35 feet of marine sand and pebbles. Raised marine shorelines and wave cut benches are most extensive on the fringe of the tidal flat and east of Low Point where they surround an "island" of amphibolite. The elevation of the beach near Low Point is about 50 feet above sea level. Strand lines and remnants of whale bones can be seen and indicate that the beach was raised in recent times.

The icy Labrador Current causes a considerable difference in the air temperatures between the coastal and interior sections of Labrador. This is shown even in the relatively small area under consideration where black scrub spruce and fir are present in the slightly sheltered Banana Lake draw, and dwarf berry bushes and lichen are about the only plants on the hills. Lack of soil and vegetative cover in the area have made observation conditions ideal.

CHAPTER II

GENERAL GEOLOGY

General Statement

Cape Makkovik peninsula is underlain by an assemblage of metamorphosed sedimentary and volcanic rocks of Precambrian age. This assemblage consists of folded and altered rocks which differ from the relatively unaltered sediments of Cape Aillik, the type locality for the Aillik formation of Kranck (1939, p. 15), and the Aillik series of Douglas (1953, p. 24).

The degree of metamorphism has been largely dependent upon the original character of the rock and upon tectonic stresses which prevailed during deformation. On the east shore of Aillik Bay, south of Buttress Point, limestone beds have been transformed by stress into a tectonic conglomerate with rounded and subrounded inclusions of quartzite. Further east, pebbles in a conglomerate have been elongated and stretched to such an extent that gneissic structure has developed. Above the conglomerate, and extending throughout the length of the map-area, are pinching and swelling bands of sheared amphibolite considered to be of volcanic origin. The remaining part of the area is underlain by sedimentary rocks which are characterized by granulation and potash metasomatism.

The geology has been further complicated by the presence of a great number and variety of intrusive rocks ranging in composition from quartz monzonite to lamprophyre. Their relative ages have been determined from cross-cutting relationships observed in the thesis area. These observations, combined with radiometric age determinations, may possibly be a means of chronologic correlation or comparison with dykes or dyke systems in other parts of Labrador. The oldest intrusives are metamorphosed mafic rocks, which form dykes and sills. Two narrow dykes of pegmatite, characterized by large crystals of green microcline ("amazonite"), have been seen in the amphibolite mass near Banana Lake and are thought to be of pre-metamorphic age. The post-metamorphic intrusive rocks are fresh-looking and lack the schistosity present in the older dykes. Stocks of granodiorite with mafic clots are most abundant around the tidal flat (see Fig. 1). Intrusive sheet-like dykes of diorite and granophyre, both composite and single, form a substantial part of the bedrock; their attitudes are related to an old joint system. Later joints influenced the attitudes of large prominent dykes of diabase and porphyritic (plagioclase) diabase. The youngest and perhaps most unusual of all the intrusives are the lamprophyres, which form northwest-trending narrow dykes.

Regional evidence suggests that an anticlinal axis passes through Aillik Bay (Piloski, 1955, p. 20). The rocks of Cape Makkovik peninsula, with a north-northeast strike and dips between 45° and 70°E, appear to form the eastern flank of the anticline. However, stratigraphic relationships have not been definitely established in the thesis area due to the complex metamorphic and structural history. The most reliable criterion for correct structural observations has been the tracing of contacts between formations of different character. Much of the foliation is clearly an expression of original bedding, such as in the "marker-bed" extending south from Buttress Point.

A satisfactory classification of the metamorphic rocks has been difficult due to variations in mineral composition, fabric and origin of the primary rocks, and in the type of metamorphism. The field classification was based essentially on mineral composition and fabric; after detailed megascopic and microscopic study, parentage has been determined for those rocks which have retained some of their primary features.

Although the rocks in the area are considered to be Precambrian in age, a fossil of a solitary coral embedded in a cobble of fine-grained light grey limestone was found on the beach west of Long Pond. The fossil is conical in shape with a length of 2 cm. and a diameter of 1 cm. Closely spaced septal grooves and interseptal ridges are present but the internal arrangement of septa could not be seen, even in a transverse thin section. Apparently the fossil is a rugosan coral from a Paleozoic outlier and may have been brought by coastal ice or by a glacier during the last ice age.

The following Table of Formations summarize the geology of the map-area as interpreted by the writer.

TABLE OF FORMATIONS

		Assemblage	Lithology
Quaternary	Recent	Beach deposits (modern and raised)	Gravel and sand
		Lake and river deposits	Sand, silt and bog
	Pleistocene	Glacial deposits	Gravelly till and erratics
Precambrian (and younger?)		Post-metamorphic intrusive rocks	Peridotite, lamprophyre
			Diabase, porphyritic (plagioclase) diabase
			Granophyre, pegmatitic granite
			--Metasomatism, Mineralization
			Quartz monzonite - granodiorite
			Quartz diorite-monzonite
			Hornblende diorite
			--Metamorphism --------------
		Pre-metamorphic intrusive rocks	"Amazonite" pegmatite-graphic granite
			Epidiorite
			Augen schist, Augen gneiss
		Meta-sedimentary and Meta-volcanic rocks	Aillik Group: Quartzite-metamorphic granite, chloritic amphibolite, biotite schist, minor carbonate rocks

AILLIK GROUP

Introductory Statement

The name "Aillik formation" was introduced in 1939 by Kranck in his description of the rocks at Aillik, the type locality of the sedimentary formation. In 1953, Douglas and Kranck informally used the name "Aillik Series," employing the term "series" for a Precambrian assemblage of divisible formations bounded by faults. However, "series" is now a time-stratigraphic unit and should not be used in a rock-stratigraphic sense, (AAPG, 1961, p. 651). For this reason the term "group" is more appropriate than "series" and the name "Aillik Group" will be used in this thesis.

On Cape Makkovik peninsula, the Aillik Group consists of metamorphosed sedimentary rocks, with subordinate amounts of meta-volcanic rocks. A major tectonic shear zone with a north-northeasterly trend passes through the Banana Lake draw and divides the Aillik Group into two separate parts. An attempt has been made to place the lithologic units on either side of this shear zone in a normal stratigraphic sequence (see Table 2). However, apart from the conglomerate and pure quartzite units which have distinctive relict textures and structures, the remaining units for various reasons will not be described in a stratigraphic sequence.

To the east and west of the shear zone there is evidence of progressive feldspathization and granitization of quartzite. Although disrupted by bands of amphibolite and by minor shearing, it is desirable to treat this transitional sequence as a unit to avoid unnecessary descriptive repetitions. These rocks cannot be correlated by normal stratigraphic methods, primarily because of their compositional and textural alteration.

The distinctive bands of mylonite, in and to the immediate east of the Banana Lake shear zone, have been formed by intense shearing and granulation. This unit although mappable, is a structural one and will therefore be described as such.

Meta-volcanic rocks, consisting of chloritic amphibolite and biotite schist, crop out on the west side of the shear zone. These rocks have been included within the Aillik Group (see Table 2), but because of their mode of origin and possible tectonic repetition will also be described as a separate unit.

Table 2

Aillik Group

Meta-sediments and Meta-volcanics

(Age relationships shown are somewhat uncertain as the amount of tectonic displacement along Banana Lake shear zone is unknown. There is also a possibility of tectonic repetition of some of the units, particularly the amphibolite.)

Area west of Banana Lake shear zone	Area east of Banana Lake shear zone
Chloritic amphibolite, biotite schist	Feldspathic quartzite (feldspathized in part); minor bands of fine-grained grey quartzite and biotite schist
Feldspathic quartzite-metamorphic granite	Quartzo-feldspathic mylonite gneiss (with discoid plates and bands)
Chloritic amphibolite, biotite schist	Mylonite quartzite, (with feldspar augen).
Pure quartzite (meta-quartz sandstone)	
Feldspathized banded quartzite	
Micaceous grey quartzite Quartzite gneiss-conglomerate gneiss Tectonic conglomerate, crystalline lime-stone, arkose-quartzite	

CONGLOMERATE GNEISS UNIT

Introductory Statement

The Aillik conglomerate exposed on the high hills south of Aillik village, and the deformed conglomerate at Makkovik village, have been briefly described by Kranck (1939, p. 15) and Douglas (1953, p. 25). The conglomerate 'formation' at Aillik is from 1,500 to 1,800 feet thick and consists of well preserved boulders of gneiss, grey granite, green schist, and quartzite. At Makkovik, pebbles in a quartzose conglomerate have been drawn out into thin lenses with a transition into a quartzite-gneiss. From Kranck's descriptions it appears that the conglomerate schist at Makkovik village is similar to the conglomerate gneiss unit present in the thesis area.

The conglomerate gneiss unit crops out on the east side of Aillik Bay and forms a long narrow band extending south-southwest of Buttress Point. Tectonic conglomerate, crystalline limestone, and arkose-quartzite form the western margin of the unit; quartzite gneiss and conglomerate gneiss form the central portion; and micaceous grey quartzite the eastern margin, with a combined exposed stratigraphic thickness of about 1,500 feet. These rocks have a fairly uniform north-northeast strike with dips of 45° to 60°E.

Tectonic Conglomerate

Name and distribution

In his descriptions of the Aillik-Makkovik area, Kranck (1953, p. 16) stated that on the east shore of Aillik Bay "limestone layers have been transformed into tectonic flow breccias, with angular fragments of quartzite". The writer has used the term "tectonic conglomerate" (Howell, 1957, p. 293) because the rock closely simulates a normal conglomerate rather than a breccia.

Two exposures of tectonic conglomerate appear on the east shore of Aillik Bay, about 1,500 feet southwest of Hawk Pond. The northern one is 200 feet in diameter and is completely surrounded by granophyre. Approximately 700 feet to the south, a larger oval-shaped outcrop of similar composition has been intruded by granophyre, diorite and epidiorite dykes and is surrounded by beach deposits.

Description

The tectonic conglomerate is in an excellent state of preservation. Rounded and subrounded fragments of buff coloured quartzite up to 3 feet in diameter lie in a fine-grained dark grey carbonate matrix which has a lower relief due to differential erosion. The fragments compose the bulk of the outcrop although limestone is locally abundant as flow bands containing granules and lenses of quartz and feldspar. The fragments and flow-banded matrix have a trend parallel to the foliation of the conglomerate gneiss to the east.

The quartzite fragments as seen in thin section are fine to medium-grained and have a recrystallized granoblastic fabric. Quartz, and to a lesser extent feldspar, are the chief constituents with varying quantities of calcite, actinolite, diopside, hematite and magnetite. Microcline has selectively replaced most of the distorted plagioclase crystals and has been unaffected by granulation. Lamellar twinned calcite has been introduced into the quartzite along small fractures and is not an original component.

The matrix is very much like a fault gouge with rounded and crushed isolated grains in a carbonate paste. Calcite composes 80 to 90 percent of the matrix with an increase in the proportion of impurities near the granulated boundaries of the quartzite. Minute whorls and trailing wisps of quartz, feldspar and biotite grains in the matrix between the fragments are indicative of rotation and flow respectively.

Relationships and origin

The tectonic conglomerate is isolated from the conglomerate gneiss and relationships between the two are uncertain. It is possible that the carbonate matrix is an extension of the crystalline limestone beds near Hawk Pond. The fragmentation could be attributed to contemporaneous deformation or tectonic deformation of quartzite but the latter process is the most obvious explanation. As a result of tectonic movements, closely jointed blocks of brittle quartzite were enclosed in a carbonate matrix. Subsequent rotation of the blocks with mutual crushing and rounding of the fragments produced a rock simulating a conglomerate.

Crystalline Limestone

Name and distribution

Previous workers have made brief reference to a strongly recrystallized salmon-red limestone at the south end of Aillik Bay. Several such lenses of carbonate, stained by iron oxide and containing large crystals (up to 2 cm. diameter) of sphene, crop out along the east shore of the bay. These lenses do not exceed 1 foot in thickness and are usually less than 100 feet in length.

The largest beds of crystalline limestone were seen about 500 feet north of Hawk Pond, where they are interbedded with arkose-quartzite and quartzite gneiss. The carbonate beds are up to 10 feet in width and about 400 feet in length; to the north they extend under the bay, in the south they are dissected by granophyre and diabase dykes and covered by beach deposits.

Description

The crystalline limestone is greenish grey in colour, and fine to medium-grained. Laminae consisting essentially of mafic minerals, parallel the bedding planes and are conspicuous due to differential erosion.

In thin section, calcite constitutes about 80 to 90 percent and has been recrystallized with a subparallel arrangement of grains of different sizes accentuating the foliation. Lamellar twinning in the calcite may have been formed by twin-gliding during the time of deformation.

Irregular prisms and aggregates of diopside and actinolite with minor quantities of quartz and plagioclase, form the laminae and probably represent siliceous and argillaceous impurities in the parent limestone.

<u>Origin</u>

The origin of the carbonate rocks in the thesis area is difficult to account for because the original character has been obscured by postdepositional changes. The association with quartz-rich sediments indicates rather unusual conditions during the time of formation and the alternating layers of varying grain sizes and composition are suggestive of original detrital deposition.

Some of the more strongly recrystallized carbonate rocks such as the 'salmon-red' limestone are of uncertain origin. Although these form thin conformable layers in the quartzite, a rock of similar composition grades into a coarse-grained white calcite vein west of Hawk Pond. This vein is probably, at least in part, a tectonic feature produced as a result of rock flowage under locally intense pressure or stress. Gliding planes in the calcite would facilitate movement of this sort. This topic will be discussed further in connection with the association between calcite veins and lamprophyre dykes.

Arkose-quartzite

Name and distribution

The name "arkose-quartzite" (Howell, 1957, p. 15) is used here for a quartzite with a notable amount of feldspar and having in part the character of an arkose. The rock has a granitic appearance but differs from the metamorphic granite to the east in its more uniform grain size and its more obvious stratification. The arkose-quartzite is interbedded with crystalline limestone to the northwest of Hawk Pond.

Description

The arkose-quartzite beds are less than 10 feet thick with bedding planes still intact. The beds are very compact and have a smooth weathered surface as contrasted with the crumbly nature of the adjacent quartzite gneiss and crystalline limestone. The arkose-quartzite is a fine to medium-grained buff coloured rock with streaky greenish grey bands of mafic minerals subparallel to the bedding planes.

In thin section, the felsic minerals have a granoblastic fabric but in places there is a trace of compositional banding of mineral grains. Quartz comprises about 15 percent of the rock, shows sutured boundaries and is not conspicuous. Anhedral grains of plagioclase (25 percent) have indistinct discontinuous twin lamellae; staining methods are necessary to distinguish between the more strained forms and quartz grains. A few less deformed plagioclase grains have a composition of oligoclase (An 20) which may not be representative of the rock as a whole. Microcline (50 percent), with undeformed twin lamellae has selectively replaced most of the plagioclase grains.

Thin bands rich in amphibole, magnetite and sphene grains, define the bedding planes. Sodic hornblende, altered in part to biotite, occurs as irregular prisms up to 5 mm. in length. Calcite and pyrite are present as disseminated grains and in the form of minute veinlets.

Origin

The nature of the original depositing medium and environmental conditions are again uncertain as bedding planes and rounded grains of sphene are the only relict structures. Apart from the secondary microcline, there is no evidence of authigenic growth of feldspar; the plagioclase is probably a detrital mineral derived from an old crystalline land mass. The original nature of this rock, as suggested by the composition, was probably that of an arkosic sandstone.

Quartzite Gneiss and Conglomerate Gneiss

Name and distribution

The name "quartzite gneiss" is used here for a highly sheared and granulated siliceous rock with flexured microcline-rich bands. In field mapping, it was not differentiated from the conglomerate gneiss into which it grades.

The name "conglomerate gneiss" is used here for a siliceous rock in which pebbles have been sheared or dragged out into lenses, thin sheets, or spindles paralleling the foliation (after Wahlstrom, 1955, p. 378).

Quartzite gneiss and conglomerate gneiss form the central and greater portion of the conglomerate gneiss unit. Brief mention of their distribution has already been made and a general and specific description follows.

General description

Although these rocks have been mapped as conglomerate gneiss, there are numerous local variations essentially related to pebble form and distribution. The gneiss is not completely conglomeratic and consists of sporadic white, pink and grey relict pebbles in a white to light grey quartzose matrix.

Differential weathering of pebbles and matrix is not pronounced. Instead, there is an overall granular reflective surface which is quite dazzling on a sunny day and aids in recognition of the unit on an aerial photograph.

Description of pebbles

"Pebble" is used in this description in the "relict" sense for a smoothed rounded stone which has been stretched. Most of the pebbles in the conglomerate gneiss are lens-like with an average diameter of 3 inches and a thickness of 1/2 inch. The largest cobble seen had a diameter of 10 inches and a thickness of 2 1/2 inches.

From the shoreline to the amphibolite mass in the southern portion of the unit, alternating concentrations of felsic and mafic pebbles parallel the strike of the foliation. The whitest pebbles consist almost entirely of fine-grained (0.1 mm. diameter) granular quartz and the more impure pebbles have a pink colour due to the presence of iron oxide. Grey pebbles with granoblastic and sutured quartz and minor amounts of deformed plagioclase contain as much as 30 percent of finely disseminated grains of magnetite. The rock also contains fine-grained chlorite lenses up to 10 inches long and 2 1/2 inches thick. These were probably formed by shearing of an argillaceous layer and do not represent deformed pebbles.

In the Hawk Pond area, sporadic lens and spindle-shaped pebbles of fine-grained, granoblastic, pink quartzite or granite are present. Where the shearing has been intense, only granulated streaks indicate the former presence of pebbles. With further granulation and development of a banded structure the rock becomes indistinguishable from gneisses in other parts of the thesis area.

Near the Buttress Point shoreline, green and grey-coloured quartzite beds having an average thickness of 3 inches with an azimuth of 010° and a dip of 65°E, contain an imbricated arrangement of granulated quartzite pebbles. The pebbles are discoid in form with a vertical plane of symmetry bearing 025° or an inclination of 15° to the bedding planes. This orientation of pebbles is not considered as evidence of current bedding, but is probably due to differential shearing stresses along the bedding planes.

Description of matrix

The matrix forms the greater proportion of the conglomerate gneiss. However, there are places where pebbles are scarce or absent; for this reason the term "matrix" can only be applied to the conglomerate gneiss as a whole.

Under the microscope, the matrix has a fine to medium-grained granoblastic fabric with felsic minerals (0.2 mm. average diameter) comprising 75 to 85 percent. Quartz, occuring as strained and sutured grains, is the predominant felsic mineral. Local concentrations of plagioclase and microcline grains seldom exceed 30 percent, as indicated by the staining of 25 rock slabs. Colourless, minute, rounded prisms of apatite occur in trace amounts.

The most conspicuous and abundant dark minerals are diopside, tremolite-actinolite and specular hematite which have a foliation parallel to relict bedding planes. Diopside occurs as bands and clusters of stout (2 mm. diameter) subhedral prisms; the tremolite-actinolite prisms are slender and have fibrous terminations. Basal sections of these minerals are euhedral to subhedral. Thin scales of specular hematite, blood red on thin edges with well developed rhombohedral faces, are present in parallel layers. Trace amounts of rounded grains of zircon and sphene and of iron oxide are nearly always present. Secondary fluorite, in subhedral crystals (1 mm. diameter) with octahedral cleavage, was seen in trace quantities throughout the southern portion of the unit.

Description of quartzite gneiss

Because of the intimate association of quartzite gneiss and conglomerate gneiss no attempt was made in the field to map them individually. The quartzite gneiss may represent a more intensely deformed equivalent of the conglomerate or disrupted and deformed beds of quartzite or both.

The quartzite gneiss may best be seen in the area to the west and north of Hawk Pond. There, fine-grained granular quartzite has a medium grey colour with uneven but generally closely spaced feldspathic bands (up to 1 cm. thick) weathering buff to light-brown. A closer inspection reveals that the bands form flexured tight folds with an axial plane subparallel to the bedding of adjacent competent rocks. These small-scale folds have been induced by tectonic forces with consequent granulation of the mineral constituents.

Under the microscope, the quartzite gneiss is somewhat similar to the matrix of the conglomerate gneiss except that mafic minerals are rare and plagioclase grains form bands rather than clusters. Some of the bands consist of fresh looking microcline grains surrounding fractured eyes of quartz. The microcline grains also have an optical orientation and continuity subparallel to the margins of the flexures. These facts indicate that following cataclasis, the porous bands acted as channelways for potassium-rich solutions.

Origin of conglomerate gneiss

The origin of the conglomerate gneiss is difficult to establish because most of the primary sedimentary features and the original composition have been obscured by metamorphism.

Rounded pebbles and subrounded detrital zircon and apatite grains are the only indications of original and possibly waterworn shapes.

The present composition, with a predominance of quartz and feldspar in both pebbles and matrix, indicates derivation from an old crystalline land surface. Any argillaceous material which may have been present in the original sediment was probably winnowed away by wave and current action.

The fact that cross-bedding and ripple marks have been seen in quartzites near Aillik village, indirectly suggests the possibility of widespread shallow water conditions during early Precambrian time. The geographic source from which the sediment was derived is unknown and probably impossible to deduce.

Micaceous Grey Quartzite

Distribution

A distinctive, fine-grained, micaceous grey quartzite marks the eastern boundary between the conglomerate gneiss and a light grey to white coloured feldspathized quartzite. The grey quartzite is in sharp conformable contact with the feldspathized quartzite and it has been traced from Buttress Point to the amphibolite west of Banana Lake. Although the eastern contact is fairly sharp, within 25 to 50 feet to the west the micaceous grey quartzite progressively grades into the conglomerate.

Description

The micaceous grey quartzite, as seen near the contact with the feldspathized quartzite, is a fine-grained, medium grey coloured rock superficially resembling an argillaceous sandstone. Thin (0.5 to 1 mm.) variable spaced stratified layers of white quartzo-feldspathic material are present but not continuous.

In thin section, quartz composes 40 to 50 percent with 25 to 30 percent microcline, 5 to 10 percent plagioclase, 10 to 15 percent biotite and chlorite, 5 to 10 percent specular hematite, minor quantities of actinolite and magnetite and a trace of apatite and zircon.

The felsic minerals show effects of granulation and recrystallization. Quartz grains are strained and have fused and sutured boundaries. Plagioclase twin lamellae are distorted and partly obliterated; some are selectively replaced by microcline. The coarser mafic minerals with their fibrous prisms and micaceous plates are oriented in a plane of foliation parallel to the bedding and mask the felsic minerals. Grains and aggregate stringers of specular hematite and magnetite also lie in the plane of foliation and probably indicate relict bedding planes.

The layers are made up of particles (up to 0.3 mm diameter) of angular quartz, rounded plagioclase, and a minor amount of fibrous tremolite-actinolite.

Origin -

The micaceous grey quartzite grades into the conglomerate and is indicative of a depositional change. Evidence suggests that the conglomerate was a product of deposition of fluvial and near-shore currents; to ascribe to the parent of the micaceous quartzite a particular depositional environment based on composition alone is rather hazardous. Even the composition is not entirely reliable as it is difficult to separate those minerals formed by sedimentary processes and those formed by post-depositional processes. However, climate, drainage and parent rock materials may have all been factors affecting a depositional change. Accelerated erosion, possibly caused by tectonic instability, would lead to interruption of weathering processes and promote the transport of unstable minerals such as feldspar. The media into which this material was accumulating would have to be incapable of efficient separation and removal of these particles by processes such as winnowing and washing.

QUARTZITE UNIT

Name and distribution

The type locality of the Aillik quartzite is at Cape Aillik and has been briefly described by Daly (1902, p. 215-216), Kranck (1939, p. 15; 1953, p. 16,20) and Douglas (1953, p. 25). There, exposed quartzite beds with a thickness of 100 feet have well preserved bedding planes and cross-bedding as indicated by thin red, green and grey layers of clay material.

In the thesis area, relatively pure meta-quartz sandstones are also well preserved although their margins show the effects of dynamic metamorphism and metasomatism. The best exposures are on the hilltops to the west of the Banana Lake draw where they form pinching and swelling bands up to 150 feet thick and up to 1,500 feet in length. Smaller exposures of quartzite less than 300 feet in diameter are also present on a large island at the entrance to the tidal flat, east of Chinook Point (Fig. 1), and north of the former USAF dump.

Description of Banana Lake quartzite

The quartzites west of the Banana Lake draw are remarkably well preserved with distinctive closely spaced bedding planes. Their weathered surfaces have been polished by glacial action and are white to light grey in colour with small streaks of reddish-brown iron oxide. Due to the abundance of fine-grained granular quartz, the exposures have a vitreous appearance not unlike that of a large vein of quartz.

Thin sections of quartzite from this area are composed of 95 to 98 percent quartz with fibrous tremolite-actinolite, chlorite, magnetite and calcite. The quartz grains are sutured and have a granoblastic fabric, although in one thin section grains of quartz showed a dimensional and crystalographic orientation parallel to the plane of bedding as defined by mafic minerals. Minute, strained (2V ca. 5°) calcite grains are associated with the mafic minerals and are most likely of primary origin.

Description of Tidal Island quartzite

Pure quartzite is exposed on the island at the entrance to the tidal flat. This band of quartzite is 250 feet long and 180 feet wide and its continuity is interrupted by granitoid rocks and the sea. Many pinching and swelling bands of amphibolite and dykes of diabase and lampropyre have cut it and on the aerial photograph it resembles a coarse breccia.

The quartzite has a massive appearance although fine bands of magnetite and hematite in the eastern 40 foot margin indicate bedding planes. Apart from the eastern part, stained by iron oxide, the remainder of the rock has a white to buff colour and consists almost entirely of fine-grained (average diameter 0.6 mm.) granular quartz.

In thin section, the quartzite is composed of 98 percent quartz with minor amounts of fibrous amphibole, magnetite and secondary calcite. Sutured and fused grains of clear quartz show no indication of primary boundaries.

Description of Chinook Point quartzite

The Chinook Point quartzite has an exposed length of 300 feet and a width of 50 feet. Apart from outcrop size, it is a replica of the large oval shaped mass of quartzite west of the Banana Lake draw.

Description of quartzite north of the USAF dump

The quartzite at this locality has an exposed length of 300 feet and an exposed width of 100 feet. It differs from the other localities by a greater abundance of impurities. These form thin bands (up to 2 cm. thick) parallel to the bedding planes and contain fine to medium grains and aggregates of epidote, red garnet and chlorite.

In a thin section of a relatively pure quartzite, grains of quartz (average diameter 0.08 mm.) are sutured and fused, accounting for the glassy appearance as seen in the hand specimen. Traces of zircon, magnetite and calcite define the planes of bedding.

Contact relationships

The largest quartzite mass west of the Banana Lake draw and the quartzite near Chinook Point, lack exposed contacts on their western side but to the east are in contact with amphibolite. Boudins of quartzite enclosed in amphibolite along the contacts indicate movement of these rocks under stress. Evidently the amphibolite was the less competent rock during the time of deformation and behaved as a plastic mass.

The sharp contact relationships of the tidal island quartzite have been previously described. The placement of this quartzite in the Table of Formations is uncertain because of its isolated nature.

The quartzite near the USAF dump has only one observable contact which is conformable with underlying micaceous and feldspathic quartzites.

Origin of the quartzites

The parent rock of the relatively pure quartzite in the thesis area is undoubtedly of a quartz sandstone which originated under tectonically stable conditions. According to Pettijohn (1956, p. 30), the prolonged weathering of an old crystalline land mass would eliminate minerals such as feldspars and with a repeated washing and winnowing of material in the shore zone would give rise to a quartz sand.

Feldspathic Quartzite-Metamorphic Granite Unit

Introductory Statement

"Magmatic emanations may enter pre-existing rocks and the reconstituted mineral assemblages may be identical with those formed in truly magmatic granites (Read, 1957)". In the thesis area, there is strong evidence of progressive feldspathization and granitization of quartzite to the point where it is indistinguishable from igneous granite. Although widespread metasomatic replacement has taken place, the possibility of intrusive emplacement of some of the smaller bodies cannot be excluded.

Problems of Classification

As mentioned previously the classification of these rocks has been difficult for a number of reasons. In the field mapping it was often impossible to distinguish between orthoclase and plagioclase due to the crumbly nature of the hand specimen. Some of the larger reddish coloured subhedral feldspar crystals resembling phenocrysts were thought to be of a second origin but in places appeared to be porphyroclasts or remnants in a granulated groundmass. On a larger scale, feldspathized quartzites with relict sedimentary features graded into granitized rocks and often the placement of boundaries was arbitrary and the retention of genetic names was largely a matter of intuitive interpretation. Another complication related to classification was the fact that massive rocks graded into gneissic rocks of similar composition over short distances. Critical contacts between granitic looking rocks and amphibolite bands were sheared and relationships could not be determined with certainty.

The widespread and varied effects of granulation, recrystallization and potash metasomatism were only fully recognized after a microscopic study. This was particularly true of the rocks in the eastern part of the thesis area, which appeared in the field to be essentially a homogeneous unit (see Fig. 2).

In classifying these problematic rocks, field and microscopic evidence justifies the use of the term 'quartzite' with modifying names for the processes it has undergone. The term is used in the metamorphic sense for a rock consisting essentially of quartz. However, this is not to suggest that the parent was a pure quartz sandstone. The more granitic looking rocks may have been feldspathic or arkosic sandstones.

Feldspathized Banded Quartzite

Name

The name 'feldspathized banded quartzite' has been applied to those quartzites having a stratiform foliation (i.e. banded structures of uncertain origin, found in metamorphic rocks, G.S.C. 1951) and in which feldspathization (replacement of plagioclase by microcline) has taken place. It is in part a metasomatic granite.

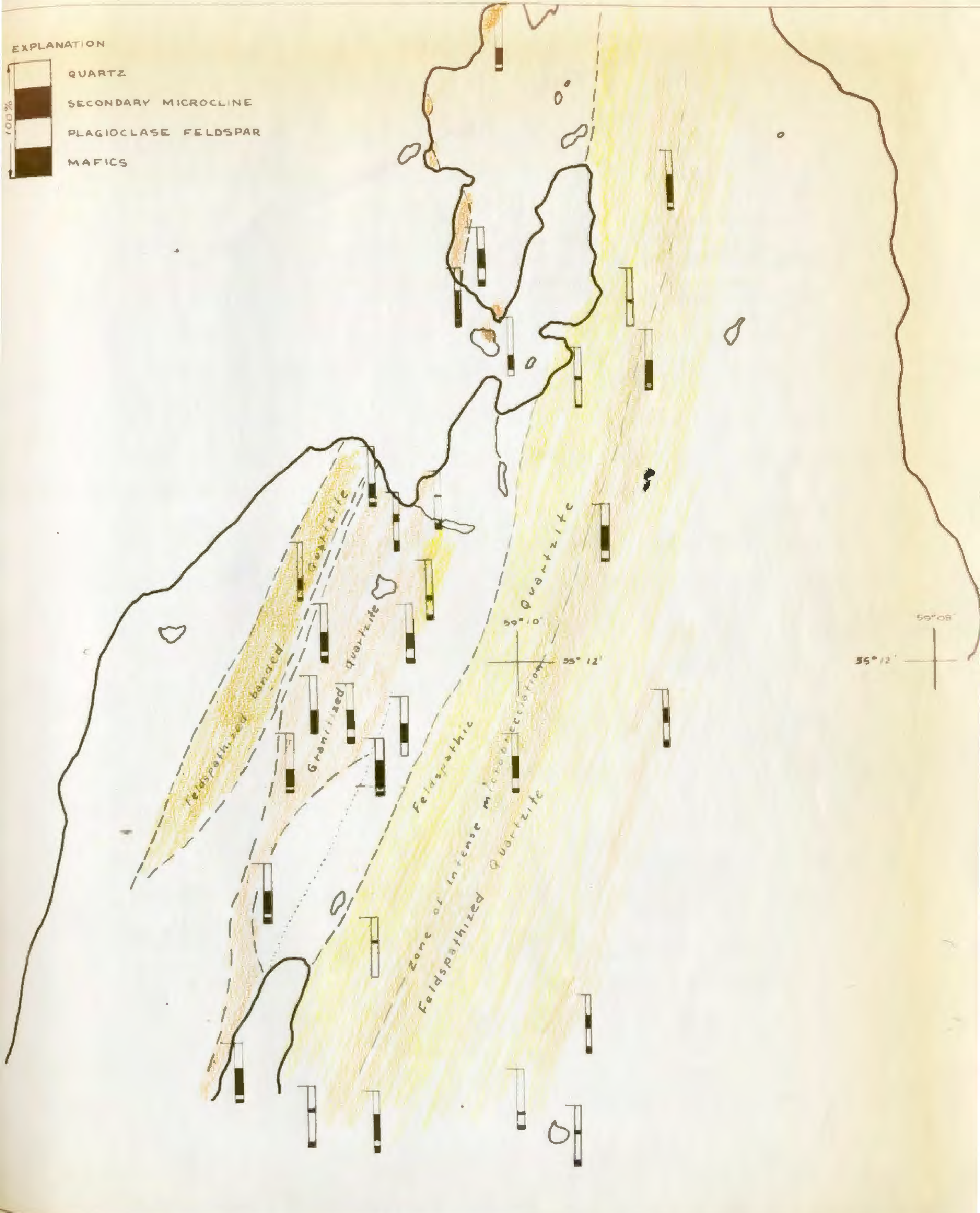


Fig. 2. Graphic representation of mineral percentages in quartzitic rocks.

Distribution and contact relationships

A large elongate mass of feldspathized banded quartzite crops out on the west side of the thesis area and extends from Buttress Point south-southwest to the amphibolite mass northwest of Banana Lake. The micaceous grey quartzite marks the western boundary but to the east the only observable boundary is a sheared contact with amphibolite. There appears to be a tectonic pinching out of amphibolite and fine quartzite in this area; between these sporadic exposures, feldspathized quartzite grades, into a granitized quartzite immediately to the east.

A much smaller exposure, less than 400 feet in diameter, was seen on the coast to the northeast of Low Point. The western portion has been intruded and covered by sheets of granophyre and the eastern boundary is in sheared contact with amphibolite.

Description

The feldspathized banded quartzite has a white to light grey colour on the weathered surface and is fine to medium-grained. Mafic minerals, weathering dark grey to black, are concentrated in alternating bands usually less than 1 cm. thick. These resemble relict bedding but may be of metamorphic origin. At Buttress Point there are places which have escaped intense deformation, and stratification is revealed by layers of contrasting colour, grain size and mineral composition. Throughout the remainder of the area and particularly east of Low Point, the origin of the bands is uncertain. Field criteria suggest that at least some of the biotite and amphibole forming these bands has been introduced into the quartzite from the nearby amphibolite during the time of metamorphism.

The rock as a whole has been modified by shearing and microbrecciation, particularly in the area to the south of Buttress Point. Lenticular fractured eyes (average diameter 3 mm.) of clear quartz form approximately 35 percent of a typical hand specimen. These eyes are oriented parallel to the foliation of the mafic bands and lie in a streaky granulated matrix of quartz, feldspar and chlorite. The rock may be somewhat feldspathized with the development of small (diameter up to 1 cm.) reddish coloured porphyroblasts of microcline which resemble hives.

As seen in thin section, the quartz eyes show the effects of strain and granulation but have been fused and sutured at the point of fracturing. Quartz also forms about 25 to 30 percent of the groundmass as minute (average diameter 0.06 mm.) angular grains which appear to be fused or welded together. Anhedral, interlocking grains of plagioclase (average diameter 0.1 mm.) with distorted chessboard lamellae, form streaky clusters up to 1 centimeter in length and account for the streaky appearance of the hand specimen. Although the twin lamellae of the plagioclase are strained and somewhat faded, their index of refraction is lower than that of quartz and indicates a composition ranging between albite and oligoclase. Microcline is present as a secondary mineral, as shown by the fact that it has selectively replaced much of the plagioclase and has been unaffected by granulation. The total feldspar present averages 30 percent, 2/3 of which is microcline. Accessory and secondary minerals include magnetite, chlorite and calcite; all except chlorite show good crystal form. Striated octahedral crystals (average diameter 0.03 mm.) of magnetite are arranged in wisps parallel to the foliation and minute veinlets (0.05 mm. thick) of unstrained calcite transverse it. Chlorite (var. penninite) occurs in the form of minute rosettes and has a characteristic anomalous blue interference colour.

Feldspathic Quartzite

Name

In the field, quartzose rocks containing feldspar as a principal constituent were mapped by previous workers and by the writer as "feldspathized quartzite". A development of porphyroblastic feldspar could be seen in some specimens; because of this much of the feldspar was considered to be of secondary origin. However, due to the effects of weathering it was often impossible to make such a distinction and the term became unsuitable. Petrographic studies have shown that these rocks have been affected by potash metasomatism, but in some areas the ratio of secondary microcline to plagioclase is so small that the term "feldspathic quartzite" is more appropriate and characteristic of these rocks as a whole.

The name "feldspathic quartzite" is used here for those recrystallized rocks in which abundant coarse euhedral to subhedral grains and eyes of feldspar are randomly distributed in a finer-grained quartzose matrix.

Distribution

Apart from the intrusive rocks, feldspathic quartzite forms the bulk of the rock in the eastern part of the map-area. Similar but smaller exposures are present to the east of Dax Pond, where they grade into granitized quartzite (see Fig. 2).

Description

Throughout the map-area, exposures of feldspathic quartzite have a superficially uniform appearance. They are medium light-grey rocks with conspicuous coarse (up to 1 cm. diameter) feldspar grains comprising 40 to 60 percent and fine (up to 5 mm. diameter) eyes of clear quartz forming about 20 percent. The groundmass of the rock is a fine-grained mixture of quartz and feldspar with minor amounts (average 5 percent) of mafic minerals. Except for thin bands of impure quartzite near Peak Pond and the occasional thin bands of biotite schist, primary sedimentary structures are indistinct. Parallelism of flakes of biotite and hornblende and tabular segregated clots of magnetite indicate a north-northeast stratiform foliation with dips of 60° to 70° E.

During the mapping of the rocks to the east of the shear zone, it was noticed that some of the coarser euhedral to subhedral feldspars often graded into areas characterized by augens or eyes of feldspar. After these features were plotted on a map, it became apparent that the eyes of feldspar, together with associated lenses of quartz, were most abundant in zones of fracturing coincident with the stratiform foliation.

Under the microscope, the more massive rocks have a faint foliation but towards the fractured zones, there is a progressive attrition of the augens with development of a microscopic banded structure. Evidence of such micro-deformation can be seen particularly in the quartz grains. In the relatively undeformed rocks the majority of the ellipsoid quartz grains are oriented with their C-axis parallel to the strike direction of the rock. Intense strain patterns closer to the zone of fracturing can be seen and with the development of fractures the eyes show longitudinal separation in a horizontal plane intersecting the trend of the rock. At the zone of fracturing, the separated portions have been extremely fractured; where the separation was small, they have been fused together.

One of the most interesting features revealed in the microscopic study of the feldspathic quartzite is the fact that there appears to be a relationship between micro-deformation and potash metasomatism. The better developed crystals of plagioclase feldspar (chessboard albite) were only slightly affected by metasomatism, but towards the zone of fracturing a progressive increase in the degree of replacement by microcline is noticeable (see Fig. 2). Much of the deformation of the plagioclase has been relieved by slippage along cleavage planes with offsetting of twin lamellae. In those areas where metasomatism is pronounced, strain has caused the twin lamellae to fade and disappear.

The groundmass of the rock, as seen in thin section, consists predominantly of a fine-grained (average diameter 0.08 mm.) fragmental mixture of quartz and plagioclase with minor amounts of somewhat coarser grains and flakes (average diameter 0.5 mm.) of mafic minerals. The proportion of quartz to plagioclase is variable but on the average there is a slightly higher percentage of quartz. The quartz grains are angular to subrounded and have been fused or welded together. Some of the twin lamellae present in the plagioclase (An 10), although slightly bent, have survived granulation. Mafic minerals are most abundant along the zone of fracturing, although they seldom exceed 10 percent of the rock. On the average, they comprise only about 3 percent of a typical thin section. Sodic amphibole (probably riebeckite), is the most common mafic mineral and occurs in the form of randomly distributed columnar to fibrous poikiloblastic prisms. Occasionally it forms sheaf-like clusters and thin discontinuous bands. It is strongly pleochroic with X = greyish olive, Y = moderate yellowish brown and Z = dusky blue green to black. The interference colours and figure are usually masked by the deep blue colour. Biotite occurs mainly as an alteration product of amphibole. Other minerals include rounded grains of zircon, wedge-shaped crystals of sphene ($+2V = 40^{\circ}$) and minute crystals of magnetite, pyrite and epidote.

Granitized Quartzite-Metamorphic Granite
(Hornblende gneissic granite)

Name

Previous workers along the coast of Labrador have mentioned and described the widespread exposures of "granite" formed by granitization of quartzite.

In the thesis area, the more strongly recrystallized rocks were mapped as hornblende gneissic granite. The term is an inclusive one for a variable but transitional sequence of rocks ranging from granitized quartzite to metamorphic granite. The name granitized quartzite is used here for those rocks which have been affected by processes of metamorphism and metasomatism but have retained in part a quartzitic appearance. The name metamorphic granite is used for those rocks which also have been affected by similar processes but have an igneous appearance.

Distribution

Hornblende gneissic granite, as a pinching and swelling band, extends from the west shore of Banana Lake, through the amphibolite and north-northeast to Chinook Point. Smaller exposures surrounded by beach deposits fringe the shoreline from Chinook Point to Low Point (see Fig. 2).

Description

The granitized quartzite is a buff weathering siliceous rock which has been enriched in amphibole and modified by potash metasomatism. Dynamic metamorphism has destroyed all primary sedimentary structures which may have existed but has produced a variety of micro-structures and a secondary foliation parallel to the regional trend. As was seen on the east side of the Banana Lake draw, a relationship between shearing and metasomatism also exists on the west side of the draw.

The granitized quartzite to the south of Dax Pond resembles a coarser grained equivalent of the feldspathic quartzite in the fracture zone on the east side of the draw, but is more sheared and contains a greater abundance of amphibole and biotite. The contacts with the amphibolite are sheared; however, tapering off-shoots up to 1 foot thick consisting of coarse crystals of amphibole extend from the amphibolite into the quartzite for a distance of several yards. Similar veinlets have been seen in isolated exposures of quartzite several hundreds of feet from the amphibolite. The amphibole appears to diffuse from these veins into the surrounding rocks along planes parallel to the general trend of the rock. As seen in thin section, the amphibole in the vein is a sodic variety (probably riebeckite) with deep blue to black pleochroism. About 10 feet from the vein the amphibole alters gradually to a dark brown biotite. The writer is of the opinion that much of the biotite and amphibole present in the quartzite originated from veins such as these by a synkinematic granitization process.

To the east and west of Dax Pond, a transition can be seen between feldspathic and feldspathized quartzites and granitized quartzite. The transitional zone is usually less than 100 feet thick but because of the slight differences in composition and appearance of the rocks on either side it is by no means a distinctive feature. The placement of arbitrary boundaries between the rocks has been dependent upon the absence of primary sedimentary structures and an increase in feldspar and mafic minerals within the granitized quartzite.

Between Dax Pond and Low Point, the rocks are weakly foliated and occasionally massive. The more massive rocks frequently have an igneous appearance and differentiation between them and granitized quartzite is not only difficult but dangerous. The "granite" near the shoreline west of Long Pond contains rounded and corroded blocks of granitic composition which the magmatists would interpret as xenoliths and the granitizationists as fragments formed by sedimentary and metamorphic processes. Near Chinook

Point, quartz-feldspar veinlets stemming from the metamorphic granite were seen cutting unmetamorphosed hornblende diorite. The probable explanation of this feature is that during metasomatism, alkaline fluids were present and penetrated the diorite along fractures.

The composition and fabric of the hornblende gneissic granite is extremely variable. Quartz forms 40 to 65 percent, feldspar 30 to 65 percent and mafic minerals form up to 15 percent of the rock. The high content of quartz indicates that the "granite" is not a normal igneous body. In hand specimen, the quartz is clear to smoky in colour and commonly appears as randomly distributed fractured eyes up to 5 mm. in diameter. The feldspars are a light olive grey in colour, grading to a pale reddish orange in the more igneous looking rocks. They occur as subhedral to euhedral laths up to 1 cm. in length and in places show a sub-parallel arrangement. Bands of mafic minerals, consisting essentially of stubby euhedral to subhedral prisms of hornblende and flakes of biotite, indicate the trend of the rock.

In thin section, quartz eyes show a preferred orientation with their C-axis parallel to the plane of foliation as defined by the mafic minerals. Minute stringers of dust-like inclusions can be seen in individual grains of quartz. In several grains, minute (0.008 to 0.016 mm. in length) acicular crystals, possible rutile, were oriented parallel to the C-axis of the quartz.

The plagioclase feldspars invariably have deformed discontinuous twin lamellae and an index of refraction lower than that of quartz. Microcline, a secondary mineral, comprises the bulk of the feldspars and has sharp undeformed twin lamellae. However, a peculiar myrmekitic texture with an intergrowth of albite-oligoclase and vermicular quartz, bordering on a microcline-microperthite, is a typical feature of the metamorphic granites near Chinook Point. The origin of this texture is not clear; it is a late crystallization feature of the normal granites in the thesis area.

The mafic minerals are predominantly sodic hornblende and biotite with minor chlorite. Accessory and secondary minerals are present but seldom exceed 3 percent of the rock. Rounded grains of apatite, zircon and sphene occur in trace amounts. Magnetite and pyrite form minute crystals and limonite and hematite occur mainly as a stain. Minute (up to 1 mm. diameter) subhedral-anhedral crystals of a yellowish brown garnet (close to grossularite in composition) with anomalous anisotropism, occur in aggregates near and within fractures in the plagioclase. Associated with the garnets are euhedral to subhedral prisms of pale yellowish green epidote which have anomalous blue interference colours on thin edges. Calcite and fluorite are present in trace quantities and have been seen in only a few thin sections.

MYLONITE UNIT

Introductory Statement

This unit is essentially a structural one and extends from Cape Makkovik through the tidal flat to Banana Lake. It is characterized by fine-grained quartzitic rocks which have been affected by extreme microbrecciation during fault movement along the Banana Lake draw. The metamorphism has been predominantly cataclastic with little or no growth of new crystals. Subsequent potash metasomatism appears to have been dependent upon the presence of porphyroclasts of plagioclase feldspar rather than groundmass feldspar.

The unit has been divided longitudinally into two parts; each part has its own distinctive features which are apparently related to pre-existing beds of contrasting composition and texture. On the west side of the unit is a mylonitic quartzite which is important economically because it contains molybdenite. Adjacent to the mylonitic quartzite and to the east is a narrow band of quartzo-feldspathic mylonitic gneiss.

Mylonitic Quartzite

Distribution and contact relationships

The mylonitic quartzite extends throughout the length of the thesis area with its western margin unexposed and its eastern margin in a sharply gradational contact with mylonite gneiss. The northern portion to the west of the Cape is highly dissected by dykes and stocks. South of this point to Banana Lake, a covering of bogs and salt water obscure relationships with the rocks to the west. Diamond drilling near the south end of the tidal flat has shown that the mylonitic quartzite is in sheared contact with amphibolite.

Description

In the field it was difficult to distinguish between a normal fine-grained quartzite and one of similar appearance formed by granulation. Consequently, the quartzite in the Banana Lake shear zone was not recognized as a mylonite until petrographic studies were made.

The mylonitic quartzite is a yellowish to greenish grey rock with a pocked or mottled weathered surface. Except for the occasional bands and streaky clots of mafic minerals, it has a more or less homogenous structure without stratification or foliation. Small (up to 1 cm. diameter) stubby porphyroclasts of feldspar from about 10 to 15 percent of the rock and have a higher relief than the friable granulated groundmass.

In thin section, the groundmass is made up of rounded and fragmental equidimensional grains (average diameter 0.04 mm.) of quartz and feldspar. Quartz forms the bulk of the groundmass and is usually highly strained. Deformed discontinuous twin lamellae present in the plagioclase feldspar are also indicative of strain. The lack of fusion between the grains of quartz and the fractured nature of the plagioclase account for the friable character of the hand specimen.

Feldspar porphyroclasts of albite-oligoclase composition form about 10 to 15 percent of a typical thin section. These porphyroclasts have undergone rotation and are severely fractured and deformed. Microcline with undeformed twin lamellae is also present in small amounts and seems to have a replacement affinity only for the porphyroclasts of plagioclase.

Mafic minerals, predominantly pyroxene, form up to 15 percent of the rock. In thin section the pyroxene is in the form of euhedral to subhedral prisms which occur as oval-shaped clusters (up to 2 mm. in diameter) and occasionally as veinlets. The pyroxene is deep green in colour and is pleochroic with X = moderate yellowish green, Y = pale yellowish green and Z = light olive brown. The extinction angle (X:C) is about 5^{o} but is often impossible to observe exactly. The optic sign appears to be negative with an optic angle of about 85^{o}. The dispersion is extreme. These properties indicate that the pyroxene is sodic in composition and is probably acmite.

Other minerals present are apatite, sphene, magnetite, pyrite, fluorite, calcite and molybdenite. These minerals and their occurrence will be described later in the chapter on economic geology.

Quartzo-feldspathic Mylonite Gneiss

Distribution and contact relationships

The quartzo-feldspathic mylonite gneiss extends throughout the length of the map-area as a distinctive band averaging 100 feet in thickness. Within several feet to the west and east, it grades into mylonitic quartzite and feldspathic quartzite respectively. The best exposures may be seen along the south-eastern side of the tidal flat.

Description

The mylonite gneiss is a product of intermediate cataclastic deformation compared with the extremely pulverized fine-grained mylonitic quartzite and the coarser, slightly crushed feldspathic quartzite. The western half of the gneiss is characterized by a finely banded appearance which gives way in the eastern portion to a streaky rock containing numerous discoid plates aligned parallel to the banding.

The banding is marked by differences in grain size, colour and composition. Fine to extremely fine grains of quartz and feldspar form white to buff parallel bands which are accentuated by greenish grey streaks and wisps of mafic minerals. Further east, the attrition has not been so severe and the whitish bands become discontinuous and discoid plates, about the size of a silver dollar, can be seen. These discoid plates form about 15 to 25 percent of the rock and consist of extremely granulated powdery material superficially resembling a hardened lump of white sugar.

The only survivors of the deformation which has taken place are small eyes of quartz and feldspar which increase in number and size towards the contact with the feldspathic quartzite. Spindle-shaped quartz eyes (up to 5 mm. length) have an average length to width ratio of 3 to 1, and are aligned with their major diameter parallel to the foliation. Nodules of stubby feldspar grains (up to 5 mm. diameter), although not abundant, are conspicuous by having a higher relief than the matrix.

In thin section, quartz and to a lesser extent feldspar are the principal constituents. Movement of the rock masses has ground and milled them to a very fine size and they now show such effects as rounded boundaries, undulatory extinction and distorted twin lamellae. In contrast to the mylonitic quartzite, the quartz particles show a greater amount of fusion, which is probably related to frictional heat provided during metamorphism.

Wisps and streaks of finely divided amphibole define the mafic banding. Fibrous prisms of pale green tremolite-actinolite are aligned with their long axes in the plane of foliation but also occur as minute veinlets which transgress the foliation. Trace amounts of rounded apatite and calcite grains, wedge-shaped sphene and crystals of magnetite and pyrite also occur mainly in the mafic bands.

The discoid plates were found to consist almost entirely of extremely fine grains (average diameter 0.04 mm.) of quartz with a minor amount of feldspar. Their outline, grain size and composition suggests that prior to deformation they were fragments or pebbles of quartzite.

The larger ungranulated remnants of quartz and feldspar have also been affected by stress. Eyes of quartz have been internally fractured but have managed to retain a continuous outline. Anhedral porphyroclasts of chessboard albite are fairly coherent with much of the stress being taken up by slippage along cleavage planes.

Potash metasomatism has not noticeably affected any of the finer grained material and is apparently restricted to the larger feldspar porphyroclasts. An irregular finger-like growth of microcline, pseudomorphic after albite, can be seen but is confined mainly to the centers of the porphyroclasts.

AMPHIBOLITE UNIT

Introductory Statement

Within the thesis area are numerous sill-like bands of chloritic amphibolite and biotite schist whose origin is uncertain. For this reason, the rocks have been named according to their mineralogical composition and genetic terms such as "greenstone", have been avoided. A description of these enigmatic rock types follows.

Biotite Schist

Distribution

Thin conformable bands of biotite schist crop out on the east side of the Banana Lake draw, along the shore between Buttress Point and Chinook Point, and near the shore to the west of the American dump. The bands are up to 20 feet thick but generally range between 2 to 5 feet. On the hills to the east of the draw, the bands have been traced for hundreds of feet but along the shore they are covered in part by beach deposits and by salt water at high tide.

Description

The thin bands of biotite schist on the east side of the draw are dark grey in colour and have a pock-marked weathered surface. Some have a higher than normal radioactive count although no primary uranium minerals were seen. Typically, they are fine to medium-grained rocks rich in biotite with a well developed foliation. Occasionally, fine bands of quartz are intercalated with the biotite to give the rock a gneissic character. With an increase in quartz the rock grades into an impure quartzite and probably represents a metamorphosed argillaceous sandstone.

Along the sea shore, particularly west of Long Pond, black coloured bands of biotite schist are in sharp contact with granitized quartzite. The bands are isoclinally folded and since the foliation in the schist and the quartzite is secondary, to describe their relationships as conformable or sill-like is perhaps inaccurate and even misleading.

In the hand specimen a schistose structure is not always apparent because the flakes of biotite are of a very fine size and are closely spaced.

As seen in thin section, biotite forms about 70 percent of the rock as small (up to 1 mm. length), ragged elongated flakes with a length to width ratio of 5 to 1. The biotite is pleochroic (X = yellowish grey, Y = Z = greyish brown), and shows a preferred orientation with the Z-axes aligned in the plane of schistosity. Crystals of sphene are invariably present in the biotite. Oligoclase-andesine feldspar (An 30) forms about 25 percent of the rock and occurs as ragged lenticular prisms (0.5 mm. length) with only a slight dimensional orientation. The twin lamellae are thick and a selective alteration of the lamellae to fine-grained sericite can be seen. A small amount of a blue-green sodic amphibole is also present and is apparently a recrystallized metamorphic mineral as it shows a sieve structure with inclusions of feldspar and apatite. Chlorite occurs in even smaller quantities and is pseudomorphic after biotite.

The biotite schist near the American dump is about 200 feet thick and is in sharp contact with bedded quartzites. It is the largest single band of biotite schist present in the thesis area and perhaps the most peculiar. It is greenish grey in colour and although the original structure has been partly obliterated by shearing, appears to be made up of small rounded fragments (average diameter 2 cm.) resembling miniature pillow structures. These fine-grained "pillows" fit closely upon one another and the intervening spaces are filled with a thin layer of calcite. Differential erosion has leached away most of the calcite near the surface and the rock has a porous, ashy appearance.

In thin section, the most noticeable feature is that the "pillows" are made up of ragged elongated flakes (average length 0.2 mm.) of biotite which are concentrically arranged and enclose small anhedral grains of feldspar, quartz and magnetite. The biotite flakes form about 50 percent of the rock and are pleochroic with X = colourless and Y = Z = pale olive. Rounded grains of plagioclase (An 25) form about 40 percent of the rock and are commonly untwinned. The remainder consists of calcite, fused quartz grains and a minor amount of magnetite and tourmaline. The tourmaline is pale green and occurs as sparsely distributed columnar aggregates. It is of metamorphic origin but it cannot be shown that boron was introduced during the time of metamorphism.

The origin of the biotite schist at this locality is puzzling because of its two-fold character. The ashy, porous appearance and the concentric structure of the fragments are suggestive of a tuffaceous origin but the modifying effects of metamorphism and shearing are difficult to evaluate. Petrographic work indicates that movement and recrystallization of some of the constituents has occured. The fact that the larger biotite flakes are warped shows that internal movement persisted to the close of metamorphism.

Chloritic Amphibolite

Distribution and contact relationships

Two large closely spaced masses of amphibolite crop out between the east shore of Aillik Bay and Banana Lake. Halfway between the northern end of the lake and Dax Pond, they diverge and pinch out into thin discontinuous bands. The westernmost band terminates at Buttress Point and the easternmost one presumably extends under the west side of the Banana Lake draw as it is exposed near Dax Pond. From Dax Pond to just east of Low Point, the exposures of amphibolite pinch and swell and the continuity is broken by an assemblage of igneous dykes and stocks and by beach deposits.

To the west of Banana Lake, the amphibolite transgresses the conglomerate gneiss, the micaceous grey quartzite and the banded feldspathized quartzite. Although the contact with these rocks is clearly defined, shearing has obliterated all criteria indicative of intrusion or extrusion. Throughout the remainder of the area, the amphibolite bands are conformable with the quartzites and are also sheared.

Description

Amphibolite is best exposed in the large masses to the west and north of Banana Lake. In several places, the amphibolite masses contain what appear to be relict "pillow" structures. These are closely spaced ellipsoidal bodies about 2 feet in length, outlined by a ring of epidote and carbonate minerals. No amygdaloidal or vesicular structures could be positively identified. Elsewhere, the shearing has been more intense and the amphibolite has been partly converted to chlorite and biotite schist. The schistosity throughout the area trends in a north-northeast direction and dips 50° to 60° E.

The amphibolite is a foliated rock, medium to coarse-grained, greenish black on weathered surfaces. Megascopic schistosity is inconspicuous in some of the coarser grained types which contain little or no mica. For the most part, the rock is composed of 60 to 75 percent amphibole and the remainder predominantly feldspar. Small veins and clusters of epidote are nearly always present.

In the more schistose varieties, chlorite occurs as an alteration product of amphibole and the rock is dark green in colour. Green to black prismatic needles (up to 3 mm. length) of amphibole lie with their long dimensions in the plane of schistosity. The feldspar grains are anhedral, and are masked by the mafic minerals.

Under the microscope, amphibole and plagioclase feldspar are the essential constituents, although in some of the more schistose rocks the ferromagnesian minerals are chloritized and the feldspars are saussuritized. The amphibole appears to be common hornblende but may contain considerable soda. It occurs as euhedral to subhedral prisms with well-developed prismatic cleavage. The longer prisms define a lineation but in some slides are warped and flexured. Commonly the amphibole has a sieve structure and contains numerous inclusions of plagioclase, pyrite, magnetite and apatite. It is pleochroic (X = yellowish grey, Y = greyish olive green and Z = dusky blue green), has an extinction angle (Z:c) about 20°, and is optically negative with a large optic angle. In the more schistose rocks, the amphibole is altered in varying degrees to chlorite (var. penninite). The penninite is pleochroic (X = pale yellow green, Y = Z = green), has straight extinction, and has a small optic angle with a negative sign. It is nearly isotropic, with abnormal blue (Berlin blue) interference colours. The plagioclase in the amphibolite has an average composition of andesine (An 35) and occurs as anhedral grains, either untwinned or with a combination of albite and pericline twin lamellae. The epidote or clinozoisite occurs as irregular grains, is colourless to pale yellowish green and has anomalous interference colours. Other minerals include quartz, garnet, sphene and zircon.

PRE-METAMORPHIC INTRUSIVE ROCKS

Introductory Statement

In the thesis area, the older dyke rocks have been affected by metamorphism and metasomatism, and with the exception of the "amazonite" pegmatite are of uncertain parentage. It is probable that the structurally similar augen schist and augen gneiss may be in part protoclastic rocks and were originally of dioritic and granodioritic composition. These rocks are cut by dykes of epidiorite which resemble schistose diorites. The "amazonite" pegmatite and graphic granite are isolated from all the other dyke rocks and appear to have been emplaced during tectonic deformation.

Augen Schist and Augen Gneiss

Distribution

Two closely-spaced, steeply dipping dykes of augen schist extend from the coast just south of the Cape to the northern end of the tidal flat. From there, a single band is exposed along the east shore of the tidal flat, across to the tidal island, north along the shore to Dax Pond and finally, southwest to the pure quartzite where it is covered by a peat bog. Smaller discontinuous exposures are present in the vicinity of the American dump.

The augen gneiss has been seen only near the Cape and along the sea-shore to the west of Long Pond. Near the Cape the dykes have a vertical dip and transgress the feldspathic quartzite; close to

Long Pond they appear to be in conformable contact with granitized quartzite.

Description of augen schist

The dykes of augen schist are from 10 to 50 feet thick and average 30 feet in thickness. The rock has a fairly uniform appearance, characterized by conspicuous knobby augen of white feldspar set in medium dark grey, fine-grained groundmass. The augen are stubby, slightly rounded and range from 3 to 10 mm. in diameter. They are usually evenly distributed and form about 25 percent of the rock. The groundmass shows a schistose banding of fine flakes of biotite and very fine grains of feldspar. Schistosity is best developed where the dyke trend closely parallels the regional trend of the bedrock. Streaky clots of mafic minerals accentuate the schistosity but it is uncertain if they represent modified igneous schlieren or metamorphic segregations.

The contacts of the augen schist with the surrounding rocks are sharp and straight. Some of the larger dykes contain relict chilled margins up to 2 feet thick consisting of hornblende-biotite schist with a few sparsely distributed augen.

In thin section, the augen have a rounded outline and are only slightly fractured. Where the shearing has not been intense, undeformed closely spaced Carlsbad-albite twin lamellae can be seen. Pericline twin lamellae are also present and are confined to individual albite bands. Some of the augen are marginally zoned with saussuritized cores. The composition of the feldspars near these cores is oligoclase-andesine (An 30) but is more sodic toward the rim. The average composition is oligoclase (An 20). Secondary microcline is rare although staining by sodium cobaltinitrite indicates the presence of potash along fractures in the augen.

The groundmass consists of approximately equal amounts of mafic and felsic minerals. Biotite, and amphibole to a lesser extent, are the most abundant of the mafic minerals and occur as small (up to 0.2 mm. length) flakes and grains which define a linear structure. Minute (average diameter 0.06 mm.) grains of oligoclase feldspar account for practically all of the felsic minerals. Apatite and zircon grains occur as inclusions within the biotite. Relatively large (up to 1 mm. length) wedge-shape crystals of sphene are associated with coarse clusters of mafic minerals.

Description of augen gneiss

The dykes of augen gneiss have essentially the same structure as the augen schist but differ in fabric and composition. Conspicuous feldspar augen form about 25 percent of the rock but are greyish orange in colour and are oval-shaped with a dimensional orientation parallel to the regional foliation. There is only a minor amount of biotite and chlorite and the groundmass has a pale orange to light grey colour. In places, small eyes and streaks of quartz define a weak foliation.

Under the microscope, augen of chessboard albite show almost complete replacement by microcline. The groundmass consists of a fine-grained mixture (average diameter 0.08 mm.) of plagioclase and quartz. The grains of plagioclase have been rounded but the lamellae are only slightly bent. Their extinction angle and low index of refraction indicate a composition of albite-oligoclase. The quartz grains, which form 20 to 30 percent of the matrix, have also been rounded and are fused. Coarse grains of biotite and chlorite form about 2 to 5 percent of the rock and have a marked linear structure parallel to the poorly defined gneissic banding of the felsic minerals. Accessory minerals include apatite, zircon, sphene and magnetite.

Epidiorite

Name

Epidiorite is a diabasic, doleritic, or basaltic rock in which the augite has been altered to hornblende, so that the rock approximates the composition of a diorite. (Originated by Gumbel, 1874; Howell, 1957, p. 97).

In the thesis area, metamorphosed basic intrusive rocks which resemble meta-diorite to meta-gabbro have been mapped as epidiorite. They are essentially fine to medium-grained, weakly foliated hornblende-plagioclase rocks; varieties are characterized by phenocrysts or porphyroblasts of feldspar and scapolite.

Distribution

Numerous dykes of epidiorite are found throughout the area; they have no common trend, but usually dip steeply. Their thickness ranges from 1 to 30 feet although the majority are between 3 to 6 feet.

The best exposures are near Peak Pond and in the area near and between the two large porphyritic (plagioclase) diabase dykes.

Description of epidiorite

The epidiorite is a fine to medium-grained, weakly foliated rock. Ferromagnesian minerals, predominantly amphibole, account for 65 to 75 percent of the rock; the remainder consists of inconspicuous whitish grey grains of feldspar.

In thin section, a dusky blue amphibole, probably sodic hornblende, occurs as subhedral prisms (average length 0.5 mm.) which are altered in part to biotite and chlorite. Some of the more fibrous amphibole is pseudomorphic after clinopyroxene and may have been formed by late stage magmatic alteration, however, the quantity of amphibole formed in this way is uncertain. The clinopyroxene (probably augite) is only a minor constituent; it is colourless to grey, non-pleochroic, has an extinction angle (Z:c) about 40° and 2Vz about 60°.

Plagioclase feldspar occurs as anhedral equidimensional grains (average diameter 0.2 mm.) twinned according to the Carlsbad-albite and pericline laws. Although the lamellae are undeformed, they are not clearly visible due to the presence of fine-grained alteration minerals. Apparently saussuritization was selective in that it indicates a zoning of the plagioclase. The average composition of the plagioclase is An 25 but may not be characteristic of these rocks as a whole.

Minor amounts of quartz, apatite and sphene are also present.

Description of epidiorite (var. feldspar porphyry)

These rocks are characterized by large stubby grains of plagioclase feldspar randomly distributed throughout a fine to medium-grained mafic groundmass. The relatively large feldspar grains (average diameter 6 mm.) form 10 to 25 percent of the rock and are either relict phenocrysts or porphyroblasts. The matrix is made up essentially of black acicular to stubby prisms of amphibole. The larger prisms (up to 5 mm.) lie with their long dimensions in the plane of schistosity but the rock as a whole is only weakly foliated.

In thin section, the large grains of plagioclase are commonly euhedral and may have developed as a result of regional metamorphism. They are well-twinned according to the Carlsbad-albite and pericline laws with the pericline twinning confined to portions of individual albite lamellae. Normal zoning can also be seen and appears to be confined to the borders of the crystals. The cores of the feldspars have been saussuritized as have some of the zonal bands. Near the core, the composition is close to andesine-labradorite (An 50) and is more sodic toward the rim. The average composition is oligoclase-andesine (An 30). The groundmass feldspars appear to be of this composition but most of them have also been saussuritized.

The amphibole is green in colour and is probably actinolite (Z:C ca. 18°; 2Vx ca. 75 to 80°). It occurs as well-developed prisms and as ragged grains with inclusions of plagioclase, apatite and iron minerals. Some of the more ragged grains are pseudomorphic after clinopyroxene. A minor amount of brownish biotite, an alteration product of amphibole, occurs as randomly disposed flakes and as clusters and bands. Secondary chlorite is not abundant.

Accessory minerals include minute prisms of apatite and fine crystals of pyrite and magnetite, associated with small grains of sphene. A greyish-black mineral, probably ilmenite, was seen in reflected light; it occurs as skeletal crystals, intergrown with magnetite.

Description of epidiorite (var. scapolite porphyry)

These rocks are characterized by grains and crystals of bluish-grey scapolite in a fine to medium-grained weakly foliated matrix of mafic minerals. The crystals form 50 to 60 percent of the rock and range from 2 mm. to 2 cm. in diameter. On the weathered surface, the coarser crystals are conspicuous as they have a higher relief than the matrix.

In thin section, remnants of plagioclase grains with indistinct twinning and zoning can be seen, but most of the grains have been completely replaced by scapolite. The scapolite is colourless and is characterized by its two distinct cleavages at right angles, low relief, uniaxial negative character, and indices of refraction (NO = 1.563, NE = 1.544). It contains rounded inclusions of chlorite, biotite and amphibole and is altered along fractures and cleavage surfaces to fibrous aggregates of micaceous minerals.

A dusky blue-green amphibole forms most of the remaining portions of the rock and occurs as ragged prisms altered in part to biotite. Some of the more fibrous amphibole is pseudomorphic after clinopyroxene, but no accurate determination of the original amount of clinopyroxene can be made.

The accessory minerals (pyrite, magnetite and sphene) are associated with the mafic minerals.

"Amazonite" Pegmatite and Graphic Granite

Distribution

Two narrow dykes of "amazonite" pegmatite, in part graphic granite, appear in the amphibolite near Banana Lake. They have a northeasterly trend and dip steeply toward the northwest. Their surface continuity is broken by peat bogs although they have been traced for almost a quarter of a mile. Their thickness varies from 2 to 10 feet.

Description

Dykes of "amazonite" pegmatite have been found in several places along the northern Labrador coast and have been described by Daly (1902, p. 213-214) and Wheeler (1935, p. 44-49).

In the thesis area, the northern dyke of amazonite pegmatite is fairly uniform in appearance but the southern one is in part graphic granite.

The amazonite pegmatite is characterized by coarse (up to 6 cm. diameter) crystals of pale green microcline or "amazonite" in a fine to medium-grained matrix of plagioclase feldspar and quartz. In cut rock slabs from both dykes, amazonite formed 20 to 30 percent, vermicular clear to smoky quartz 20 to 30 percent and brown biotite 2 percent. Etching and staining of one of these rock slabs has shown that in addition to the amazonite, there is a small amount of a whitish potash feldspar.

In thin section, the amazonite twin lamellae are indistinct and distorted. Grains of fresh-looking microcline with well-defined twin lamellae are found throughout the slide, commonly in contact with the distorted grains. These undeformed grains are probably of late or secondary origin although no evidence of replacement was seen.

A somewhat similar phenomenon occurs in the plagioclase feldspars. Fresh-looking albitic feldspar is pseudomorphic after an altered distorted feldspar of oligoclase composition.

Quartz is present as strained anhedral grains but is only slightly fractured.

In several places throughout the southern dyke, the amazonite pegmatite grades into graphic granite. This is a white weathering, coarse-grained rock with a distinctive graphic intergrowth of quartz and plagioclase feldspar. Milky white to smoky brown quartz forms 60 percent of the rock; the remainder is feldspar. On a horizontal surface, the quartz grains are oval to hexagonal in outline with the major diameter (1 cm.) oriented parallel to the contacts. In cross-section, rod-like columns of quartz (up to 3 cm. length) have a dip coincident with that of the contacts. This orientation of quartz is probably a primary foliation feature. The coarse feldspar crystals are white in colour and appear to be fused.

In thin section, the intergrowth of quartz and feldspar is a conspicuous feature. The quartz rods and vermicular forms show strain extinction and fracturing but have remained intact. Unoriented stringers of dusty inclusions are present in the quartz rods. The feldspars are slightly fractured and have discontinuous and warped twin lamellae. Their indices of refraction are slightly lower than those of quartz, indicating a composition between albite and oligoclase. Apparently most of the stress has been taken up within the grains of quartz and feldspar as granulated material is rare.

POST-METAMORPHIC INTRUSIVE ROCKS

Introductory Statement

In the thesis area there are numerous igneous bodies of post-metamorphic age. At least six different periods of intrusion have been distinguished, the oldest being the period of emplacement of the dioritic rocks and the youngest being the period of lamprophyre intrusions. Descriptions of the igneous rocks, commencing with the oldest, follow.

Dioritic Rocks

(Hornblende diorite, Quartz diorite-Monzonite)

Distribution and description

In the map-area, dioritic rocks occur in part as small stocks and dykes but mainly as thin, gently-dipping, sheet-like bodies. Contacts with the surrounding rocks are sharp but chilled margins are very thin and usually less than 1 inch thick.

The sheets are tabular in form and are up to 15 feet thick. Some sheets, on the east side of the draw, lie parallel to the slope of the topography but the majority occupy an old joint set with an east-southeast strike and dips of 10 to 20°S.

Most of the sheets are between 2 to 5 feet thick and resemble andesites. These "andesitic intrusives", or more accurately hornblende diorites, are fine-grained, dark grey rocks which are

Table 3 Form and Mineralogical Composition[1] of Granitoid rocks, Cape Makkovik Peninsula

Rock Name	Hornblende diorite	Monzonite –	Quartz diorite	Granodiorite –	Quartz Monzonite	Granophyre
Form	Fine-grained Sheets	Medium to coarse grained Sheets and Stocks		Medium to coarse grained Stocks		Aphanitic Sheets and Stocks
Quartz	3	2	15	8	15	25
Microcline	8	18	3	12	42	32
Plagioclase	60	28	50	70	36	35
Apatite	tr	tr	-	-	-	-
Biotite	3	5	12	5	3	tr
Hornblende	20	40	16	2	-	-
Zircon	tr	tr	tr	tr	tr	-
Sphene	-	-	-	tr	tr	-
Magnetite	tr	tr	1	tr	tr	1
Pyrite	tr	tr	tr	tr	tr	tr
"Iron Oxide"	tr	tr	tr	tr	tr	tr
Epidote	1	tr	tr	1	1	tr
Chlorite	3	4	1	1	1	2
Calcite	tr	tr	tr	-	-	-
Kaolin	tr	tr	tr	tr	tr	tr
Sericite	-	-	-	tr	tr	3
	100	100	100	100	100	100

1 Based on average composition (volume percentage) of 5 thin sections and 5 chemically stained rock slabs per rock type.

fairly uniform in texture and mineralogy. They consist mainly of acicular crystals of hornblende with interstitial laths of plagioclase feldspar (see Table 3).

In the thicker sheets, the rock is medium to coarse-grained and the composition ranges from monzonite to quartz diorite. Primary flow banding is indicated by alignment and lineation of feldspar laths and hornblende prisms. In some of the sheets which are almost horizontal, particularly those on the shore to the south of the tectonic conglomerate, a graded layering of feldspar is parallel to the contacts (see Plate XII). This graded layering resembles the graded bedding of sedimentary rocks and is marked by a gradation in grain size from coarse grains (1 cm. length) near the sharply defined base of the layer to fine grains towards the top of the layer. The origin of the layers may be due in part to assimilation of feldspathic material and by rhythmic crystallization produced by differential settling.

A small dioritic stock, or a massive sheet with an unexposed base, appears just north of the tidal island. It intrudes amphibolite and thin sheets of hornblende diorite, but in turn is cut by quartz monzonite and lamprophyre. It is a hybrid rock and grades from quartz diorite to monzonite over several yards. Common hornblende is the most characteristic ferromagnesian mineral in the monzonite portion; it occurs as large prisms (up to 2 cm. length) near the intrusive contacts but becomes stubby farther away. As the quartz content increases, biotite tends to become more abundant at the expense of the hornblende. Plagioclase is the predominant feldspar; potash feldspar may be present but is not readily identifiable.

Under the microscope, the dioritic rocks show a variety of textures and mineralogy (see Table 3). Plagioclase feldspar occurs as felted microlites in the hornblende diorite, and as interstitial grains and laths in the quartz diorite-monzonite. Carlsbad-albite and pericline twins are common in the coarser grains; twinning is best developed in the more siliceous rocks. Normal and oscillatory zoning is also present, particularly in the small stock where complex zoning predominates. The sodic rims are fairly fresh looking, but the more calcic cores have been saussuritized. In the monzonite rocks, the core is close to labradorite (An 50); in the other rocks it is more sodic. The average composition (i.e. between rim and core) of all the dioritic rocks is close to oligoclase-andesine (An 28).

Potash feldspar, predominantly microcline, occurs as interstitial grains in the hornblende diorite; in the other rocks it commonly forms large poikilitic grains enclosing plagioclase, quartz and hornblende. Most of the grains show sharp twin lamellae but some are perthitic. Microcline apparently was one of the last minerals to crystallize.

Hornblende is the most abundant mafic mineral. In the more rapidly cooled thin sheets and contacts of stocks it occurs as acicular crystals; about a foot or so from the contacts it forms stout subhedral prisms. The hornblende is brownish green, with an extinction angle (Z:C) of about 20°. Twinning on (100) is fairly common, particularly in the coarser-grained rocks. Basal sections of hornblende are marked by green rims with brown centres and probably represents compositional zoning. Magnetic grains occur along fractures and cleavage surfaces.

Biotite and chlorite occur as independent flakes and as alteration products. Biotite is altered to chlorite. Some chlorite (penninite)appears to be altered to epidote in places but most likely represents an intimate association.

Accessory minerals are apatite, zircon, sphene, magnetite, pyrite, epidote, calcite, kaolin and sericite.

Massive Granitic Rocks

(Granodiorite-Quartz Monzonite)

Distribution and description

Two types of massive granitic rocks are found in the map-area: a medium-grained very light grey granodiorite; and a fine to medium-grained pale reddish brown quartz monzonite. Although both of these rocks tend to occupy separate areas, they locally grade into one another and are thus genetically related. The quartz monzonite, however, appears to have crystallized last.

The granodiorite crops out in several places in the area between the tidal flat, the American dump and Chinook Point. It is fairly uniform in appearance and consists mainly of unoriented subhedral prisms (average 1 - 2 mm. length) of whitish plagioclase feldspar; smaller equidimensional grains of potash feldspar and quartz are inconspicuous. The most common ferromagnesian mineral is biotite which occurs as randomly distributed flakes and clusters.

Quartz monzonite is best exposed along the eastern shore of the tidal flat. It is characterized by an almost equal proportion of pale red potash feldspar and white to light grey plagioclase feldspar. The grains of potash feldspar are equidimensional (average diameter 1 to 2 mm.), and the plagioclase feldspar are about the same size but are lath-like in shape. Quartz is present in greater amounts than in the granodiorite and is often intergrown with feldspar. Biotite and chlorite occur as small flakes.

The contacts of the granitic rocks with the quartzites are generally straight and sharp but are not always obvious. This is particularly so in the quartz monzonites where potash feldspar diffuses into the quartzites. Chilled margins are rare to absent; the most likely explanation for this is that during igneous activity the country rock was also at a high temperature.

At the southeastern end of the tidal flat, in the vicinity of the tidal island and at several places north to Low Point, the quartz monzonite has stoped its way into the amphibolitic and dioritic rocks. Xenoliths up to 12 feet in diameter show a transition from angular blocks to rounded and corroded forms with only a "ghost" or relict outline (see Plate XIV). Many of the schistose amphibolitic xenoliths have retained their original attitude which indicates a slow stoping and envelopment of the country rock by magma (see Plate XIII). Segregations of coarse grains (average diameter 1 cm.) of quartz and potash feldspar with minor molybdenite, have developed, between some of the xenoliths. This pegmatitic phase represents the last stage of crystallization of the quartz monzonite.

In thin section, granodiorite and quartz monzonite show a granitic texture without any preferred orientation.

The plagioclase feldspars in these rocks are euhedral to subhedral in form. Carlsbad-albite and pericline twin lamellae are well-developed, although near the contacts there is a tendency toward warping and distortion. An elaborate but complicated zoning pattern is present and appears to be mainly oscillatory rather than a continuous or normal type. As the microscope stage is rotated, numerous shells or layers exhibit abrupt changes from the slightly saussuritized core to the outer boundaries of the crystal and vice versa. The zoning is probably due to temperature-pressure variations in the crystallizing magma. The plagioclase is close to andesine in the granodiorite and more sodic (oligoclase) in the quartz monzonite. The cores are close to An 40, the rims near An 15 and the average is about An 25.

Microcline occurs as interstitial grains and as rims around plagioclase in the granodiorite; in the quartz monzonite it occurs as equidimensional subhedral crystals with well-developed twin lamellae and has replaced much of the plagioclase. There is a graphic intergrowth of microcline and quartz which indicates that microcline was present before crystallization ceased.

Quartz occurs as small anhedral interstitial grains in the granodiorite; in the quartz monzonite it occurs as somewhat larger, graphic and vermicular intergrowths with feldspar. Some of the grains show strain extinction and contain minute bubble-like inclusions.

Biotite occurs as lath-like flakes and is an alteration product of amphibole. It is pleochroic (X = yellowish grey, Y = Z = greyish to dusky brown), has a very small optic angle and is optically positive. Some of the biotite flakes contain minute inclusions of zircon surrounded by pleochroic haloes.

Other minerals present in the rock are shown in Table 3.

Felsitic Rocks

(Granophyre)

Distribution and description

Granophyric intrusive sheets form much of the bedrock of the map-area. They are usually associated with the older sheets of diorite, forming the upper or lower portion of a composite sheet. Their thickness ranges from a fraction of an inch up to 20 feet and averages about 5 feet. The thicker bodies have unexposed bases and are probably small stocks.

Although the granophyres are younger than the quartz monzonites (as determined by cross-cutting relationships), they have a similar composition (see Table 3) and probably originated from the same magma as a late crystallization phase.

The granophyres are aphanitic rocks and have a distinctive pale red to moderate orange pink weathered surface. Some of the thinner sheets and the margins of the thicker sheets are almost glassy and have a conchoidal fracture. In the relatively coarser rocks, lath-like phenocrysts (1 - 2 mm. length) of whitish feldspar form about 30 to 40 percent; in the fine grained glassy varieties they decrease in size and number and become inconspicuous. Occasionally, one can see large grains (up to 4 mm. length) of quartz with their long dimensions parallel to the contacts. The only observable mafic minerals are thin flakes (up to 3 mm., average 0.5 mm. length) of biotite and chlorite which appear to be sub-parallel to the contacts and thus suggestive of primary foliation.

The term "felsite" was applied to these rocks during field mapping but petrographic work has shown that they are characterized by a granophyric texture. As seen under the microscope, small phenocrysts of oligoclase feldspar (An 28) are fringed and replaced by an intricate intergrowth of quartz and potash feldspar (mainly microcline). In the thicker sheets, the intergrowth radiates around the phenocrysts and is graphic with small patches of quartz showing simultaneous extinction; in the thinner sheets and chilled margins of the thick sheets, the intergrowth is spherulitic and is confined to the groundmass. The remainder of the groundmass, of the thick sheets consists of fine grains (average diameter range 0.05 to 0.15 mm.) of quartz and microcline with minor amounts of accessory and secondary minerals. Some of the chlorite (penninite) has a hexagonal outline and shows percussion and pressure figures. Minute grains of finely disseminated magnetite have been altered to iron oxide, accounting for the reddish colour of the rock.

Late Mafic Dykes

(Diabase-olivine diabase, porphyritic (plagioclase) diabase)

Distribution and description

Intrusive, steeply-dipping dykes of diabasic rocks are fairly numerous throughout the area. The majority of them have a northeast to east-northeast trend and have been influenced by a major joint set. The largest dykes are up to 200 feet thick and have chilled margins from 8 to 12 feet thick. One of the most prominent of these is a medium-grained diabase which can be traced from the shore just south of the Cape across to the tidal flat. To the south of this dyke, two large dykes of porphyritic (plagioclase) diabase can be traced across the peninsula and have been seen on the west shore of Aillik Bay to the south of Aillik village. The large dykes have high relief and from the air appear as sinuous, worm-like bodies. The smaller dykes are up to 25 feet thick but tend to have low relief because of their highly jointed nature.

The diabase dykes are of several ages, as shown by their cross-cutting relations. The porphyritic diabase is probably the older of the two; near Buttress Point, it has been split by a 75 foot thick diabase dyke with chilled margins. However, on the shore to the west of Long Pond, the same porphyritic dyke contains autoliths of diabase in its chilled margins. As determined by cross-cutting relationships, the diabase is younger than the granophyric rocks and older than the lamprophyres.

The diabase and olivine diabase are fine to medium-grained rocks, although their apophyses and chilled margins are aphanitic to glassy. On weathered surfaces they are pale yellowish brown to black and on fresh surfaces are dark grey. Some of the coarser-grained dykes, such as the one near the tidal flat, show spheroidal weathering with the development of a thin brownish black crust. This dyke is also characterized by a diabasic texture with randomly oriented laths (average length 3 mm.) of bronzy coloured feldspars and interstitial stubby mafic minerals. In the finer-grained rocks, the relationships between the grains cannot be seen megascopically.

The porphyritic (plagioclase) diabase is a conspicuous rock with whitish euhedral to subhedral feldspar phenocrysts in a fine-grained greyish matrix. The phenocrysts form varying concentrations but average 35 to 40 percent of the central portion of the dyke; in the chilled diabasic margins they are rare to absent. The phenocrysts are lath-like to tabular (on 010) and are up to 8 inches in length but average 1 to 3 inches. Normally, the largest crystals are in the centre and have a random orientation; the smaller crystals are found toward the chilled margins, indicating a primary foliation. However, about 2,000 feet east of Long Pond in a vertical exposure of porphyritic diabase, a well-developed flow structure can be seen. The major axes of the phenocrysts dip away from the centre towards the contacts (lineation of axes ca. 40°WSW.), indicating an eastward and upward rising magma in which the phenocrysts were also moving.

Although the plagioclase phenocrysts appear to be fresh, in thin section they show considerable alteration to sericite, kaolin and a little epidote. Alternating thick and thin lamellae can be seen but there is no evidence of zoning. Stringers of chlorite and magnetite lie along the composition planes as do numerous clear to greenish rod-like bodies (average length 0.04 mm.) of an unidentified mineral (epidote?). The specific gravity, indices of refraction and extinction angle could not be precisely determined but the composition appears to be in the andesine range (An 30 to An 50).

Under the microscope, the diabase, olivine, diabase and the groundmass and chilled margins of the porphyritic diabase, are characterized by diabasic and ophitic textures; thin apophyses and stringers consist of acicular microlites in a glassy groundmass (hyalopilitic texture).

The variation in the proportion of the different minerals in these rocks is as follows:

	Variation (Percent)	Average (Percent)
Andesine, Labradorite	25-65	55
Pyroxene	25-50	35
Olivine	0-10	3
Biotite	0-5	2
Magnetite, ilmenite (?)	3-8	4
Chlorite	0-3	2
Serpentine	0-3	tr.
Others (amphibole, secondary albite, calcite, epidote) sericite, kaolin)	1 & less	tr.

The plagioclase feldspar occurs as subhedral lath-shaped prisms (up to 10 mm. length, average 1 mm.) which have been strained due to mutual interference during growth. Carlsbad-albite and pericline twin lamellae are present and the cores of the feldspars show normal zoning. The plagioclase in the fresh rocks has a composition of labradorite (An 60) but in the highly saussuritized rocks averages An 45.

Pyroxene (augite) occurs as interstitial anhedral grains but most commonly as poikilitic grains enclosing and enveloping tapering laths of plagioclase feldspar. Inclusions of olivine and apatite have also been seen. The pyroxene is non-pleochroic and its pale red colour is attributed to the presence of titanium. Some of the grains show good cleavage and parting (100). The optic angle ($2V_z$) is about 45° to 50° but the extinction angle (Z:C) is difficult to observe, probably about 45°. An hour-glass zonal structure with dark iron rims around the periphery, is conspicuous only in those pyroxenes which have undergone selective alteration. In the highly altered rocks, fibrous amphibole is pseudomorphic after pyroxene.

Olivine is present as an accessory mineral rather than as an essential constituent. It forms small (up to 0.4 mm. diameter) euhedral to rounded grains and is easily distinguished from the pyroxene by its optic angle ($2V_x$ ca. 75 to 85°), colourless appearance, and alteration. The euhedral crystals have brown and green rims of a chloritic mineral (iddingsite? bowlingite?) which has been discoloured by iron oxide. There is considerable corrosion and replacement of both euhedral and anhedral grains by olive green serpentine with formation of a magnetite dust around the former crystal and in fractures.

Iron rich biotite occurs as small flakes between the feldspars, is associated with pyroxene and is probably a deuteric alteration product. It is pleochroic with X = yellowish brown, Y = Z = dark reddish brown.

Accessory minerals include euhedral prisms of apatite, (up to 1 mm. length) and subhedral-anhedral grains of magnetite.

Non-feldspathic Mafic and Ultramafic Rocks

(Hornblende peridotite, Monchiquite and Alnoite)

On the basis of their texture and mineralogical composition, the mafic and ultramafic rocks in the thesis area have been divided into two groups for descriptive purposes:

1. Hornblende peridotite
2. Lamprophyre a) Monchiquite
   b) Alnoite, ("Aillikite")

Hornblende Peridotite

Distribution and description

This rock has only been seen in the small cove near the American dump and near Low Point. In both localities it is surrounded by beach deposits and its dimensions are not fully known. Near the dump, it is in contact with amphibolite and has an exposed width of about 15 feet; near Low Point it cuts granitic rocks and has an exposed width of 20 to 30 feet. However, its texture and composition suggests that it may be related in age to the period of lamprophyric intrusions.

The rock is medium to coarse-grained (up to 1 cm.) and has a peculiar black weathering mottled surface. It is made up of greenish black subhedral to anhedral mafic minerals which in places appear to be predominantly amphibole and in others entirely pyroxene. In the field it was mapped as hornblendite and pyroxenite.

Under the microscope, the rock is composed of 40 to 50 percent amphibole, 35 to 40 percent olivine, 10 to 15 percent pyroxene and 15-20 chlorite-serpentine.

The amphibole (hornblende) occurs as stubby euhedral prisms and as large poikilitic plates which enclose grains of olivine and pyroxene. Although somewhat similar to the pyroxene, it can be distinguished by cleavage, uniform relief, colour and extinction angle. It is slightly altered to chlorite and some of the prisms have fibrous terminations which may be pseudomorphic after pyroxene. However, because of its poikilitic nature and optical properties, most of the amphibole is considered to be a magmatic reaction product rather than a deuteric alteration product of olivine and pyroxene.

Olivine occurs as rounded colourless grains and as inclusions in amphibole and pyroxene. It is a magnesium-rich variety as indicated by a large optic angle (2V ca 90°). Some of the grains have been slightly granulated but this is probably due to expansion caused by serpentinization rather than dynamic processes. Colourless to pale yellowish green fibrous stringers (average 0.02 mm. thick) of serpentine have formed along fractures and terminate at the rim of the grain.

Pyroxene (hypersthene) forms subhedral to anhedral grains (up to 1 mm. diameter) and occurs in the interstices between the amphibole prisms. Some of the grains contain inclusions of olivine and magnetite and appear to be rimmed by amphibole. The pyroxene is pleochroic (X = orange pink, Y = pale yellowish brown, Z = clear green) has straight extinction and like the amphibole, has a large optic angle (2V ca 90°).

Chlorite and serpentine are present as secondary minerals but it is not always possible to distinguish between them due to iron oxide infiltration. The chlorite occurs as flakes (up to 3 mm. length) and is pseudomorphic after amphibole. It has a small optic angle (-2V:5°) and is weakly pleochroic (X = colourless, Y = Z = pale green). The serpentine mineral is usually fibrous with a central lining of finely powdered magnetite.

Carbonate minerals have not been seen and apatite occurs in trace amounts.

Monchiquite

Distribution and description

Lamprophyre dykes, close to monchiquite in composition, occur along the coastal fringe, particularly near Low Point. They have a southwesterly trend and are usually vertically dipping. The dykes (up to 5 feet thick) are characterized by a porphyritic texture with brownish black books of biotite (up to 3 cm. diameter) in a medium-grained (up to 6 mm. diameter), black weathering matrix of mafic minerals. Most of the matrix consists of subhedral prisms of pyroxene with small oval patches (up to 3 mm. diameter) of carbonate forming about 5 percent.

In thin section, the rock is composed of about 70 percent pyroxene, 15 percent biotite, 5 percent carbonate, 5 percent magnetite, 3 percent olivine and 2 percent apatite.

Pyroxene occurs as randomly oriented euhedral to subhedral prisms and to a lesser extent as poikilitic plates enclosing euhedral to subhedral prisms of apatite. The pyroxene has a medium optic angle (2Vz ca 50°) and a moderate extinction angle (Z:C ca 40°). On (110) cleavage grains the indices of refraction (n1 = 1.695, n2 = 1.715) indicate a composition close to salite on Parker's curves (1961, p. 892).

Biotite, although forming conspicuous phenocrysts, is not as abundant as pyroxene. It also occurs in the groundmass as rectangular laths and shreds. Rims of the biotite show a more intense pleochroism than the centres.

On rims, X = light brown Y = Z = greyish brown, centre X = pale yellowish orange Y = Z = light brown.

The rock shows only slight alteration compared with the intensely altered alnoite variety. Calcite and magnetite are late forming minerals. The magnetite indicates the euhedral outline of a now altered mineral (probably olivine originally) and the calcite occupies the central portion.

Alnoite

Proposed name

In 1937-38, on the basis of chemical analyses, E.H. Kranck proposed the name "Aillikite" for these ultramafic type rocks.

Although close to alnoite in composition, Kranck noted that in comparison with the original alnoite from Alno, Sweden, the Aillik rock had a higher content of carbonate, more ferric iron and considerably less alumina. In a later report, Kranck stated that the name "Aillikite" should be regarded as strictly local, and not representing a new rock.

Distribution and description

Alnoite or aillikite dykes occur throughout the area but are most abundant along the coast. The usual trend is northwesterly; most of the dykes have a vertical dip, but a few are almost horizontal. The contacts are sharp but irregular and where the dyke cuts quartzitic rocks an infiltration of reddish brown iron oxide and thin stringers of calcite can be seen. The dykes (up to 5 feet thick) have phenocrysts of biotite (up to 1 cm. square) in a fine-grained groundmass (average diameter 1 to 2 mm.) consisting essentially of olivine and carbonate. The weathered surface is friable and has a rusty or moderate yellowish brown crust. The fresh surface is a dark greenish grey.

In thin section, these rocks have a porphyritic texture but their composition is rather variable, even in the same dyke. Of the ten thin sections examined, only two were reasonably unaltered. The variations in the proportion of the different minerals are as follows:

	Percent
Biotite	30 to 40
Olivine	10 to 40
Pyroxene	up to 15
Magnetite	3 to 6
Carbonate	10 to 50
Chlorite, serpentine	up to 10
Apatite	up to 2

Biotite occurs as anhedral to subhedral phenocrysts and as rectangular laths (up to 1 mm. length) in the groundmass. In some rocks it is more abundant in the groundmass where it forms felted laths surrounding small crystals of olivine. It resembles somewhat the biotite in the monchiquite but has darker shades of pleochroism with reddish brown iron-rich borders. The optic angle is very small (2Vx: 5°).

Olivine is an essential constituent and in the relatively coarser rocks occurs almost exclusively as clear euhedral phenocrysts (up to 3 mm. diameter). It has a large optic angle (2V = 85 to 90°). In the finer grained rocks, it is smaller in size and is altered to carbonate.

Pyroxene forms euhedral to anhedral grains (up to 1 mm. diameter); along with the olivine, it probably crystallized early. It is a groundmass mineral and probably formed a much greater percentage of the rock before alteration masked its presence.

Most of the carbonate appears to be a product of late alteration and some of it may even be hydrothermal.

CHAPTER III

STRUCTURAL GEOLOGY

Introductory Statement

The regional structure between Seal Lake and Aillik, has been described in a paper by Beavan (1958, p. 137-145). Beavan also noted the geologic resemblance of the Aillik-Kaipokok area to the Beaverlodge and Great Bear Lake uranium camps.

Regional evidence in the Aillik-Shoal Lake area suggests that an anticlinal axis passes through Aillik Bay, the anticline plunging north (Piloski, 1955, p. 20). Piloski has stated, however, that the regional structural picture is not clear due to the lack of suitable marker beds and the metamorphosed nature of the rocks.

The rocks of Cape Makkovik peninsula have a north-northeast stratiform foliation and dip between 45 and 70°E. Stratigraphic relationships have not been definitely established due to the complex metamorphic and structural history. The foliation is a secondary or metamorphic feature although in places it is clearly an expression of original bedding. The writer has found that the most reliable criterion for structural observations is the marker bed extending south from Buttress Point; the mylonite gneiss along the east side of the Banana Lake draw can also be regarded as a marker bed as it appears to be related to primary bedding.

Folding

Throughout most of the map-area, the considerable degree of metamorphism, the gradational lithology and the lack of reliable marker beds make it difficult to determine what folding has taken place on a relatively large scale.

Even though the two large marker beds continue in an undeviating northerly trend, there is the possibility of repetition of strata along strike by isoclinal folding. Tight folding of this kind has been indicated on a small scale by folded mafic bands on the tidal island and in several places along the coast.

If Piloski's interpretation of structure is correct, the rocks in the map-area form the eastern flank of the Makkovik anticline.

Faulting

There are numerous minor faults or shears within the area but few are of major extent. Closely spaced, northerly trending and steeply dipping shears are common in the amphibolitic and quartzitic rocks, particularly along the sea shore to the west of Long Pond; the shears displace the epidiorite dykes by a few tens of feet. A northwest trending arcuate shear near the Cape has been traced for about 2,000 feet.

Previous workers have placed an assumed north-northeast trending major fault along the Banana Lake draw to just west of Cape Makkovik. Unfortunately, this area is a marsh up to 700 feet in width. Diamond drilling along the draw, however, has indicated the presence of numerous closely spaced small shears (see mylonite unit, page 49) but the amount of cumulative movement or displacement is unknown. The two large porphyritic (plagioclase) diabase dykes which cross the peninsula are not exposed near Long Pond; detailed mapping in this area suggests that the dykes may be offset as much as 100 feet with the west side moving south. If this is so, it indicates a late movement as the shear was formed during the time of metamorphism.

On the northwest side of the tidal flat, in a small northeast-trending drift-filled valley, the surrounding rocks have acquired a reddish colour due partially to an increase in potash and partially to the introduction of hematite. A fault breccia consisting of coarse (average diameter 1 cm.) angular, reddish chert-like fragments in a matrix of calcite and chlorite, is present in several places. This evidence suggests that fault movement has taken place along the depression but the amount of displacement is uncertain.

It is quite possible that there has been a slight movement along some of the major joint planes, especially those over a mile in length. The north-northwest trending fracture between Dax Pond and Hawk Pond is slickensided; the eastern half of a large porphyry dyke appears to have moved about 15 feet north with respect to its western counterpart. However, in the other joints, displacement is not apparent.

Jointing

In the map-area, there are three major joint sets which have formed a rhombohedral joint system. They are marked on the ground by prominent lineaments, which are clearly visible on aerial photographs. Some of the joints can be traced for over three miles and often resemble large crevasses, with a gap of 10 to 30 feet between the walls and a depth of about 100 feet. Although there are slight variations in direction and dip within each set, their representative attitudes are as follows:

Set No.	Trend	Azimuth	Dip
1	ESE	ca 110°	10° to 20°S
2	ENE	ca 070° to 080°	80°N to 80°S
3	NNW	ca 165° to 175°	85°W to 85°E

In many instances it is difficult to ascertain the origin of these joints and to distinguish between tension and shear joints. As mentioned previously, the joint system has influenced the trend of many of the dykes; movements at right angles to the joing surface probably produced the fractures in to which the magma has penetrated. Some of the north-northwest trending joints show slickensides; this does not prove that the fractures originated under shearing stress, as displacement may have been later than the time of parting.

On a smaller scale, some of the igneous bodies such as the granophyre stocks and diabase dykes have a rectangular columnar jointing (see Plate XV). These joints are considered to be tension joints produced by a decrease in volume because of cooling.

A peculiar type of jointing, unique to the area, was found in a thin (about 2 to 3 feet thick) flat-lying sheet of hornblende diorite which cuts the southern exposure of tectonic conglomerate .

It has been described by Kranck (1961, p. 163-168); it is somewhat of a coincidence that the writer also came across the exposure during the last evening of field work. The sheet has a well developed, vertically dipping, east-southeast joint set, a less perfect vertical set intersecting the ESE set at 20°, and an imperfect set intersecting the ESE set at 70° (see Plate XII B). The ropy or twisted appearance on the horizontal surface is misleading as the joints are composed of elongated sigmoidal rods. If the parted rods are pulled out, ripple shaped impressions can be seen on the joint surfaces. The jointing was probably produced after the rock had consolidated as there is no relation between the mineralogic texture and the rods, which one would expect if the rock was plastic. The probable origin of the feature is that the sigmoidal rods were produced by a horizontal force couple, the angle of inclination of the rods making an angle of approximately 45° to the direction in which the couple was acting.

Age of Deformation and Orogeny

Folding, faulting and jointing have affected the region and the map-area over a long and continuous period, probably ceasing towards late Proterozoic time.[1] The sequence of events is as follows:

1. Deposition of sedimentary and volcanic rocks of Aillik Group.
2. Folding.
3. Intrusion of early dykes.
4. Metamorphism and shearing; formation of mylonitic and cataclastic rocks.
5. ESE joint set formed.
6. Joints filled with intrusions of dioritic composition.
7. Emplacement of granodiorite and quartzmonzonite stocks.
8. Metasomatism and mineralization.
9. Injection of granophyric sheets along ESE joint set, resulted in composite sheets of diorite and granophyre.
10. ENE joint set formed.
11. Intrusion along ENE joint set of porphyritic diabase, diabase and some of the peridotites.
12. NNW joint set formed.
13. Intrusion along NNW joint set of late diabase dykes and lamprophyres.
14. Erosion

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1 Absolute age determinations now being made on samples of quartz monzonite and lamprophyre by the Radioactivity Laboratory of the Geological Survey of Canada.

CHAPTER IV

METAMORPHIC GEOLOGY

Introductory Statement

Metamorphism in the map-area has been dependent not only on the intensity of metamorphic processes but also on the character of the original rocks. Beds of limestone, conglomerate and pure quartz sandstone have retained their distinctive character, their original features are still recognizable. On the other hand, some of the early igneous dykes and sills were metamorphosed to the extent where they are now lithologically similar to pelitic sediments.

Metasomatism resulted in an alteration of the composition of many of the rocks and overshadowed some of the effects produced during the earlier period of regional metamorphism.

Metamorphic Facies

It has not been possible to outline distinct zones of regional metamorphism in the map-area because of retrograde (dynamic) and replacement effects. The rocks are probably of medium grade metamorphism, equivalent to the intermediate metamorphic zone (mesozone) in the old depth zone classification. In the more recent classification of Turner and Verhoogen (1960), the rocks seem to fit the staurolite-almandine subfacies of the almandine-amphibolite facies. The typical assemblages of the various derivations are as follows:

1. Quartzo-feldspathic: quartz, plagioclase (albite-oligoclase), sodic amphibole, (specularite, sphene).

2. Calcareous: a) calcite, diopside, (grossularite).

b) calcite, diopside, tremolite-actinolite, (sphene).

3. Basic: a) hornblende, plagioclase (An 25-An 35), almandine, epidote (biotite, chlorite, quartz, sphene).

b) hornblende, plagioclase (An 30-An 35), epidote (biotite, sphene).

Metamorphic Structures

The metamorphic structures in the map-area are due mainly to stresses and differential pressures which have caused folding, shearing, granulation and flowage. Later metasomatism has led to the development of porphyroblasts.

Field and petrographic criteria indicates that foliation in the Aillik Group is secondary; in the case of the meta-sediments it has been inherited as shown by the presence of relict structures. Foliation is best developed in the schists and amphibolites and is not related to the attitudes of their contacts. Lineation, when present, is expressed by the alignments of ellipsoid pebbles or "rods" in the conglomerate, by prisms and flasers of quartz, feldspar and amphibole in the quartzites, and by prisms of amphibole in the amphibolite. The foliation and lineation are probably due to deep burial, with subsequent flowage and recrystallization parallel to the attitudes of old bedding planes.

The fact that the Aillik Group of rocks has undergone movement is shown by structures which have developed in rocks of diverse competence. Flow structures have developed in the quartzites and carbonate rocks, as well illustrated by the quartzite gneiss and tectonic conglomerate. Boudinage between the amphibolite and quartzites, with rods of quartzite aligned down dip, indicates stretching movements in a north-northeasterly direction. Evidently the amphibolite was quite plastic as it engulfed fractured beds of quartzite and penetrated even the smallest cracks. (See Plate IX).

A summary of the effects of metamorphism and metasomatism are shown in Table 4.

Table 4

Summary of Effects of Metamorphism and Metasomatism

Original Rock	Metamorphism followed by Metasomatism
Diabase, Gabbro	Epidiorite (recrystallization and scapolitization; porphyroblastic fabric)
Diorite, granite	Augen schist, augen gneiss (porphyroclastic and porphyroblastic fabrics)
Andesite	Amphibolite (recrystallization; fracture and flow structures)
Sandstone	Quartzite → Feldspathized Quartzite → Granitized-Quartzite → Metamorphic Granite (deformation, rupture, granulation, differential movement of grains, slight chemical reconstitution and development of porphyroblasts) Quartzite ↓ Mylonite gneiss
Conglomerate	Conglomerate Gneiss (rodding and destruction of pebbles)
Limestone	Crystalline Limestone (flow structures)

Metasomatism

Potash metasomatism

The replacement of plagioclase by potash feldspar is a common phenomenon in granites and other silicate rocks. In the map-area, one cannot escape the conclusion that metasomatic addition of potash to the rocks has resulted in a partial replacement of plagioclase by microcline; and thus appears to be a postkinematic feature. In many thin-sections, one can see that plagioclase of albite-oligoclase composition has been strained and brecciated; pseudomorphs of unstrained microcline can be seen in what appears to be a volume per volume replacement.

Potash metasomatism has been restricted to the felsic meta-sedimentary and meta-igneous rocks; the intensity of replacement was largely dependent upon the extent of microbrecciation. The potash was probably derived from the quartz monzonite and granophyric rocks. An excess of potash in the crystallizing magma and a gradient between the magma and the country rock probably provided the thermal energy needed to activate the process. Granulated and strained grains of quartz and feldspar evidently stimulated reaction and solution, as did shear planes and fractures.

Inherited or authigenic plagioclase

Some of the plagioclase feldspars in the feldspathic quartzites have idiomorphic outlines but there is no evidence to indicate authigenic or secondary growth. Similarly, in the augen schists some of the augen are euhedral to subhedral; the presence of Carlsbad-albite and pericline twinning and complex zoning indicates relict magmatic origin of these porphyroclasts.

Pneumatolysis

In the map-area, retrograde effects such as scapolitization, uralitization, chloritization, saussuritization and sericitization have been noted, particularly in the pre-metamorphic mafic rocks; the pre-metamorphic felsic rocks show only slight secondary alteration and are remarkably fresh-looking under the microscope.

It is uncertain if the presence of tourmaline prisms in one of the mafic rocks can be regarded as evidence of pneumatolytic action at high temperature. Fluorite has been seen in association with a quartz-microcline pegmatite phase of the quartz monzonite and probably resulted from a "gas" phase during consolidation of the pegmatite.

CHAPTER V

ECONOMIC GEOLOGY

Introductory Statement

As mentioned previously, the work in the Cape Makkovik peninsula was begun as an investigation of the molybdenite potential. The area was studied in detail in order to find further sources of mineralization and also to find out if swarms of dykes and sheets would make otherwise high grade ore of doubtful economic value.

Molybdenite Mineralization

Significant occurrences of molybdenite, pyrite, fluorite and radioactive minerals have been found at numerous points within the map-area. At present, molybdenite is the most important economic mineral and occurs throughout the mylonitic quartzite; it has also been found in thin quartz and pegmatic veins associated with the quartz monzonite.

The best exposures of molybdenite are between Long Pond and the southern end of the tidal flat. There, friable, rust-coloured mylonitic quartzite contains numerous stringers (up to 1 cm. thick) of molybdenite with associated malformed cubes of pyrite (up to 5 mm. diameter) and crystals (up to 0.5 mm. diameter) of "blue-john" fluorite. The stringers usually parallel but also cross the foliation and are of irregular length.

In a chemically stained rock slab, it was found that the stringers and flakes of molybdenite are actually in thin veinlets of potash feldspar. There is also a direct relationship between the amount of molybdenite and the amount of pyrite.

In addition to quartz (strained and unstrained), plagioclase and acmite, grains and flakes of microcline, molybdenite, pyrite, magnetite with traces of chalcopyrite, calcite, fluorite, zircon and sphene appear. In thin-section the veinlets consist of well-twinned microcline grains with inclusions of molybdenite and fluorite and lesser amounts of magnetite, calcite, quartz (unstrained) and sphene.

Molybdenite forms flexible hexagonal flakes (up to 0.6 mm. diameter, 0.05 mm. thick) and short, slightly tapering prisms which are intergrown with one another. In reflected light it is a metallic grey and is easily distinguishable from the other sulphides. It occurs almost exclusively in the microcline veinlets where it parallels the veinlet walls. The veinlets seem to be concentrated around large grains and aggregates of pyrite; the greatest concentration of molybdenite can be seen there. The pyrite appears to have formed during the time of deformation as it is corroded, fragmental and porous. Inclusions of chlorite are present and the pores and fractures are commonly lined and rimmed with molybdenite, magnetite and minor chalcopyrite.

Also present in the microcline veinlets are irregular grains of fluorite. The fluorite has an uneven purple colour with the deepest shade near minute impurities within the grain. It has distinctive octahedral cleavage and low indices of refraction.

An interpretation of the field observations and petrographic studies suggests the following:

1. Shear planes and fractures in the mylonitic quartzite stimulated reaction and solution.

2. Mineralization was related in time to potash metasomatism and the sulphide has been derived from a magmatic source. (Molybdenite occurs in acid segregations in the quartz monzonite and in potash veinlets in the mylonite.)

3. The veinlets of potash feldspar and molybdenite are concentrated around large clusters of pyrite which probably formed during the time of deformation.

4. Molybdenite and magnetite crystallized in fractures and cavities within the pyrite, but did not replace it.

Uranium

The map-area forms a part of the Labrador Uranium Province and has been described by Beavan (1958), Piloski (1955, 1960) and Morris (1959).

Radioactivity has been detected at numerous points throughout the area; an elongated radioactive zone closely follows the "micro-fracture zone" in the feldspathic quartzite, on the east side of the Banana Lake draw. It often shows an affinity for bands rich in amphibole-mica and carbonate, presumed to represent altered sediments; where the radioactivity is strongest, a brick red and sometimes a yellowish green alteration can be seen. Although the radioactive mineral in the thesis area has not been identified, it is considered to be pitchblende (Piloski 1960, p. 15) because of the similarity of the radioactive rocks in the Aillik area to known localities of pitchblende in the surrounding area.

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Plate II

A. Aerial view of Buttress Point (foreground) illustrating prominent diabase dykes. American radar site in top center and oil tank at extreme left.

B. Panoramic view of Cape Makkovik peninsula. Right edge of photo marks eastern boundary of map area; left edge marks southern boundary.

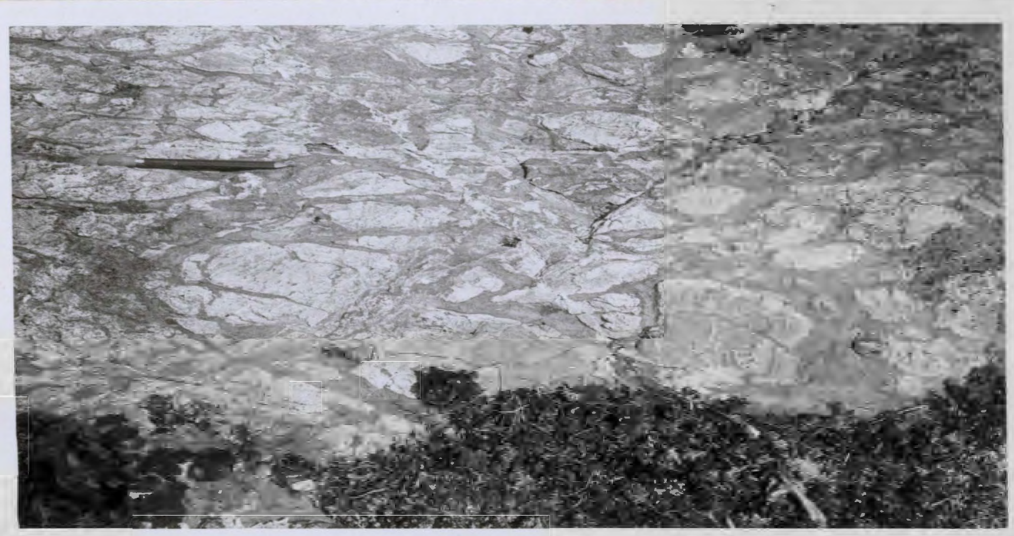
Plate III

A. Stone rings in marsh near Buttress Point

B. Chatter marks in quartz monzonite on east side of tidal flat (Page 8)

A. Tectonic conglomerate (Page 8)

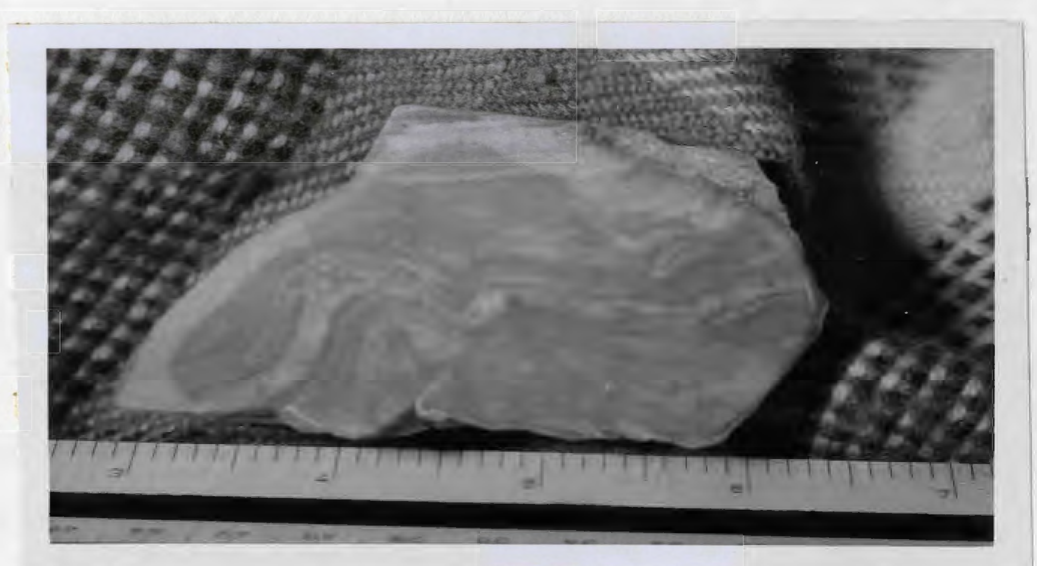
B. Flow banding in tectonic conglomerate



C. Fractured quartzite cobbles in carbonate matrix of tectonic conglomerate.

Plate V

A. Quartzite gneiss to the north of Hawk Pond (Page 24, 27)

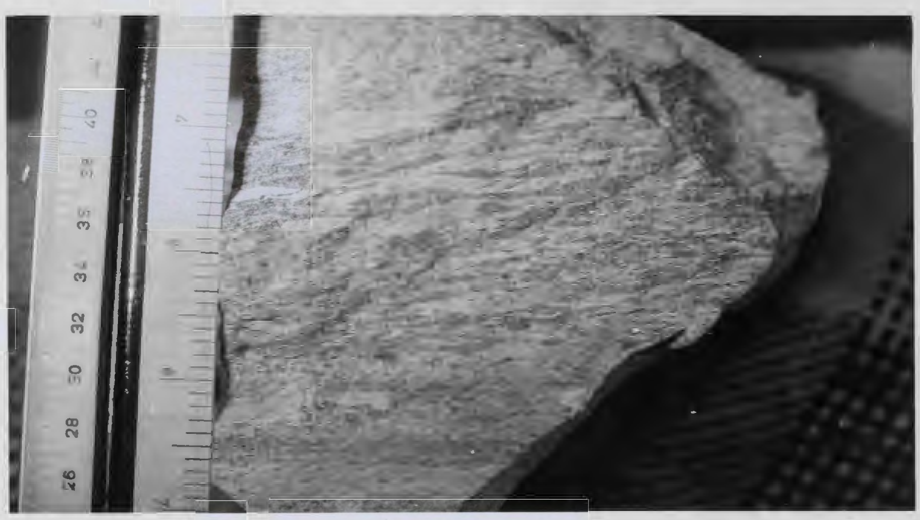


B. Close-up of cut slab of quartzite gneiss showing microcline rich band (Page 28)

Plate VI

A. Arkosic cobble in conglomerate gneiss

B. Felsic and mafic pebbles in conglomerate gneiss



C. Deformed and imbricated pebbles in conglomerate gneiss

Plate VII

A. Bedded quartzite near Banana Lake draw (Page 32)

B. Contact between feldspathized banded quartzite and amphibolite to northwest of Banana Lake, (Page 38)

Plate VIII

A. Veinlet of amphibole in granitized quartzite (Page 45)

B. Contact between biotite schist and granitized quartzite (Page 56)

Plate IX

A. Boudin of amphibolite in quartzite
(Page 34)

B. Deformed quartzite beds in amphibolite
(Page 34)

Plate X

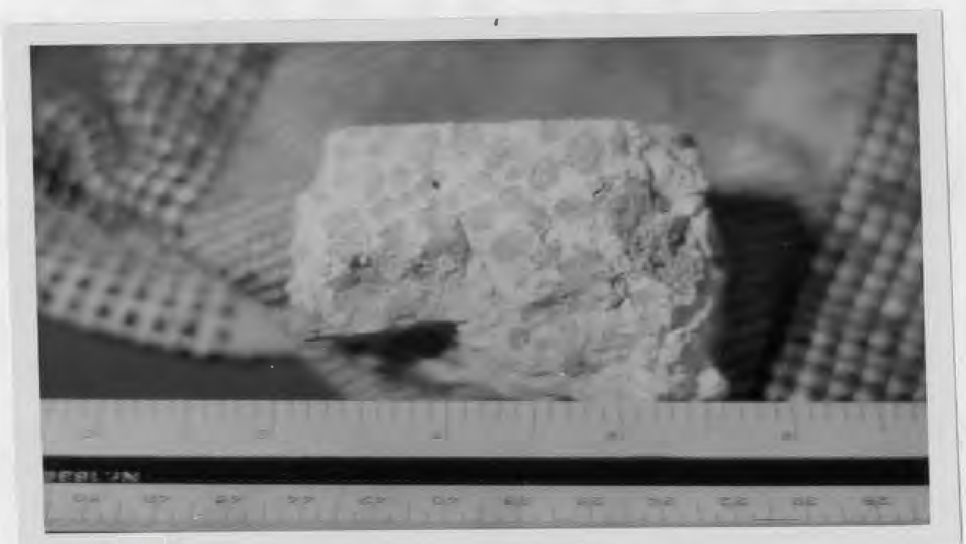
A. Sill of augen schist to west of Long Pond (Page 62, 63)

B. Augen schist with feldspar augen and mafic clots

C. Augen schist from locality to south of American dump.

Plate XI

A. Epidiorite with porphyroblasts of scapolite (Page 69)



B. Graphic granite with oval-shaped quartz rods in feldspars (Page 72)

Plate XII

A. Layering in a diorite sheet near Hawke Pond (Page 76)

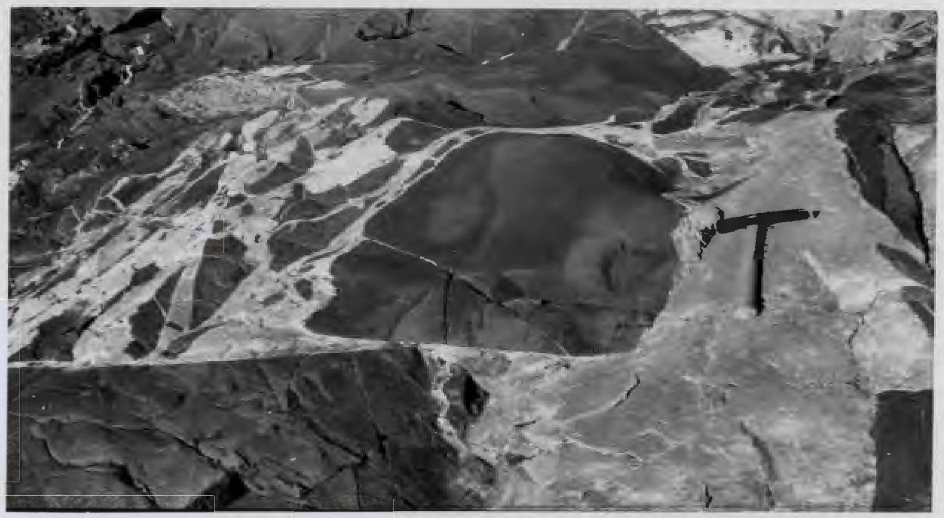
B. Sigmoid jointing in flat lying diorite sheet near Hawke Pond. Taper of pick handle indicates north (Page 98)

Plate XIII

A. Quartz monzonite with amphibolitic inclusion. To the right of the photo, the quartz monzonite is undercut by a granophyre sheet. In the bottom of the photo, both rocks are cut by a steeply dipping lamprophyre dyke (Page 80)

B. Close-up of amphibolitic inclusion in the quartz monzonite

Plate XIV



A. Initial stoping of quartz monzonite into amphibolite (Page 80)

B. Assimilation of stoped blocks by quartz monzonite

Plate XV

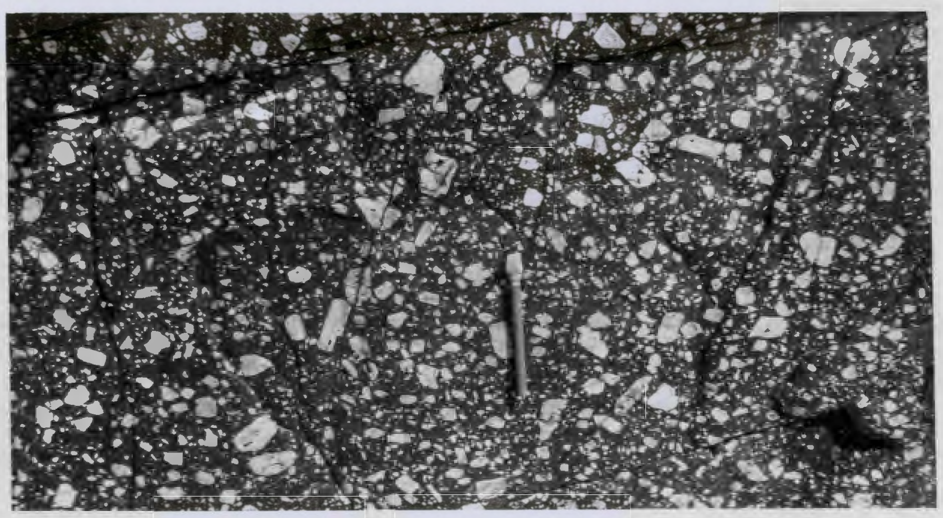
A. Vertically dipping diabase dyke near Buttress Point (Page 84)

B. Side-view of diabase dyke illustrating brick-like jointing pattern (Page 98)

C. Apophyses of diabase cutting quartz monzonite

Plate XVI

A. Porphyritic (plagioclase) diabase dyke near Hawk Pond. Note trend of phenocrysts near contact to extreme left of photo



B. Close-up of phenocrysts in diabase dyke on shore west of Long Pond

Plate XVII

A. Lamprophyre dyke cutting quartzite and diabase (location of pick) near Buttress Point