THE BEDROCK GEOLOGY OF MAKKOVIK AND

ITS RELATIONS TO THE AILLIK AND KAIPOKOK SERIES

by

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TABLE OF CONTENTS

ACKNOWLEDGMENT

A party of the Geological Survey of Canada studied an area between Indian Harbour and Hopedale, on the coast of Labrador during the field season of 1949.

The author gratefully acknowledges the guidance and advice of Dr. E. H. Kranck, who directed both the geological investigation and this thesis. The author is also indebted to Mr. and Mrs. N. Fothergill, for the use of their boat and for their kindness and perseverance during the voyage. To G. Cooper, H. Hogan and other graduate students in the Department of Geology acknowledgment is made for their aid and for criticism of this thesis.

LIST OF PHOTOGRAPHS

Plate 1: Fig. 1.

Typical Labrador Shore Line.

INTRODUCTION

General Statement

For many years Labrador has been a land of mystery. The country is not well known, though today for economic reasons, its development is more apparent. Knowledge of the geography of the country is more complete than that of the geology.

The first white man to see the coast was Bjarre Herjulvson. According to Islandic sagas [1] this took place in 986, while Herjulvson was on a voyage to Greenland. The Wolfenbuttel map of 1534 however, suggests that the original discovery was made by a person from the Azores. Up to 1890, at least six other possibilities as to the discovery of Labrador had been suggested [2]. After the first landing, men such as Cartier, Frobisher, and many others followed into what Cartier had referred to as "The Land that God gave to Cain".

The origin of the word Labrador is problematical. Some authors suggest the Portuguese word "llavrador", meaning husbandman, for farming and agriculture were important to the early explorers. Due to their phonetic

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1V. Tanner. Newfoundland Labrador I. p.43.
2Proc. Trans. Roy. Soc. Can. Vol. 7, p.52.

similarity to Labrador, both Bras d'or, from the inland waters of Cape Breton, and Brador, the name of hills near Blanc Sablon, have been suggested as an origin. G.R.F. Prowse [1] has used the human element in an effort to arrive at a solution to the problem. He believes that this land was named after Cabot's Burgundian pilot.

Previous Work

Accurate geological reports of coastal Labrador were first presented in 1891 by A. S. Packard. From 1890 to 1895 Low explored the interior of Labrador and some coastal sections. A few years later, in 1899, R. A. Daly accompanied Dellabare on the Brave expedition. The next summer while on the Brown-Harvard expedition, he covered a section of the shoreline between Makkovik and Hopedale, which was not revisited by geologists for many years. Recent investigators of this particular area include Tanner, Kranck and Douglas. The northern section of the Labrador coast has been studied by A. P. Coleman, and a memoir on the Hamilton Inlet district was written by Kindle. During the summer of 1949 a geological survey on a scale of four and eight miles to the inch was carried out between Indian Harbour and Hopedale. This thesis is concerned with some of the more detailed observations made on this survey, between Makkovik and

[1] G. V. Douglas, New F. Dalhousie Exped. to Labrador 1946, p. 4.

Kaipokok inlet .

Location, History, and Means of Access.

Makkovik is situated on the west side of Makkovik Bay at 55°05'N 59°10'W. Aillik, about ten miles north of Makkovik, is on the north west side of Cape Aillik, just north of Aillik Bay. It lies at 55°15'N. 59°13'W. Southwest of Cape Aillik is Kaipokok Bay with Long Island at its entrance.

The village of Makkovik, primarily a Moravian Mission station, was first established in 1900. A few years ago the mission house was destroyed during the winter by fire. It is now rebuilt and serves the natives along the coast as far south as Cape Harrison. Its northern influence is shared with the station at Hopedale, which was founded in 1782.

Aillik is a small permanent fishing and trapping village. Its population is augmented during the summer months by "planters" who arrive from Newfoundland for the fishing season. A small trading post is located in the village, and serves itinerant as well as local trade.

Transportation along the coast is difficult to obtain. During the summer the Canadian National Steamships operate a freight and passenger service between St. John's, Newfoundland and Hopedale, Labrador. Their ship, the S.S.Kyle sails on an approximate three week schedule. The first trip north of Cape Harrison is dependent on the time of ice break-up, which, during the summer of 1949, took place during the second week of July.

During the winter, the only means of transportation is by dog team or by aircraft that may be called in case of emergency. It is somewhat of a disgrace that an area so close to the main centers of Canada should be so completely cut off from the rest of civilization.

Summer travel along the coast, by natives, liviers, and visitors is made by "flat". This is a shallow draft, wide-beamed, open or half decked 25 foot boat, with a one or two cylinder inboard engine. Canoes are invaluable for geological work as many of the bays have rocky, shallow entrances.

Physiography

Between Indian Harbour and Hopedale the physiography of the coast is quite variable. (Plate 11, Fig. 1.) West of Cape Harrison and south of the Adlavik Islands lie the Benedict Mountains with a relief of about 2500'. This range trends northwest from near Tessiujaluk. Near Big Brook the strike changes to the northeast and the range terminates at Monkey Hill, just south of the head of Makkovik Bay. From Makkovik, north to the south shore of Kaipokok Inlet a low series of hills are seen close to the water, and with one exception, a hill of some 1300' in Makkovik Bay, the

Plate 2

Fig. 1. Cape Makkovik

Fig. 2 Aillik Peninsula with Aillik in the background.

relief of the northeasterly striking hills is less than 500 feet. This decreases on the Aillik peninsula to less than 200 feet. (Plate 11, Fig. 2.) The low-lying ground is generally underlain by fine-grained quartzite and the ridges consist of granitic rocks or are capped with basic intrusions. In the Kaipokok area the relief is moderate. On the north the terrain becomes more rugged, though hills do not appear to exceed 1500 feet. The influence of bedrock on topography can be clearly seen in the district.

The drainage of the coastal section is accomplished by small, ill-defined streams that descend from the higher hills such as the Benedicts. Kaipokok river flows from the interior and enters Kaipokok inlet after leaving Micmac Lake. Makkovik river, a typically youthful stream, flows on a course parallel to Kaipokok Bay and enters Makkovik Bay over a series of rapids. The head of the bay is under tidal influence, and has been aggraded by sandy material. This outwash delta may be traced seawards for about half a mile. The extent of sandy material appears to be controlled by the deposition of the river and the modifying effects of the tide. Many glacial erratics are found in this sandy area. Big Brook, the only other large river in the immediate vicinity, drains a section of the country to the southwest of Adlavik Bay. Its estuary is also filled with sand and silt.

The lack of a mechanical load in many of the other rivers may be due to the scarcity of transportable material in the region that they drain or to the presence of small lakes which collect the river loads before the streams reach the sea.

The drainage system is not well defined in the interior between Micmac Lake and Mt. Benedict; however, the general trend is in a northeasterly direction. North of the Kaipokok river a definite system has been established. Both physiographic and structural features trend to the northeast.

The section between Makkovik and Kaipokok is a good example of a skerryguard coast undergoing emergence. That this emergence is taking place is shown by such features as raised beaches and terraces, wave-cut benches above sea level, first hand reports by old fishermen as to blocked off runs and tickles, as well as the increased number of islands now present. (Plate 3, Fig. 1).

The whole area underwent glaciation and characteristic glacial forms are common. Makkovik Bay resembles a small fiord, but the lack of certain characteristic features needs to be explained. The head is shallow and the entrance is bounded by a series of islands and ledges. It does not present a typical U-shaped, valley profile but one, that is in part, modified by glaciation; possibly the result of erosion at the edge of the continental ice sheet.

In many areas of the bays a peculiar offshore bar or boulder barricade [1] has been noted. It is conformable with the shore line, usually 10 to 50 yards from the beach, and

[1]V. Tanner. Newfoundland Labrador, p. 287.

and consists of angular and a few rounded boulders, all haphazardly orientated. On the seaward side the depth increases rapidly while towards the shore, at low tide, a very shallow pseudo-lagoon is formed. It is possible that the angular boulders of these bars were deposited as lateral moraines from the fingers of the marginal face of the continental ice sheet. The present features of the barriers represent the results of the reworking of these moraines by waves, tides and ice.

The direction of ice flow in the area is hard to determine. In any location near sea level one must distinguish striae, chatter marks and crescentic gouges made by sea ice from their counterparts formed by the action of land ice. Daly shows a gradual change in the direction of ice movement recorded by striae from 070° in the south to 055° in the north. In the vicinity of Aillik a general movement of 040° is evident. It is apparent that the area underwent at least two periods of glaciation. Whether or not other periods occurred may be determined only by more detailed work. A thin layer of the continental ice sheet has modified a previously formed mature topography [1] and the resultant profile was further altered by mountain glaciation. Small valley head cirques and small valley glaciers are still present in the Torngats.[2]

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[1] A. P. Coleman. Extent and Thickness of the Labrador Ice Sheet. Bull. G.S.A. Vol. 31. 1920.
[2] N.E. Odell. Present Landscape of Northern Labrador. Sc. Progress. Vo.. 33, # 131.

To the south the extent of valley glaciation was not great for such glacial forms as cirques and U-shaped valleys are few in number and then only partially developed.

Except for small glaciers that might have been located in the Benedicts, it is hard to imagine that a period of mountain glaciation existed in the vicinity of Makkovik.

LEGEND

Tertiary — Recent: River Deposits and Glacial Deposits

Tertiary: Raised Beaches.

Pleistocene: Skerryguard Coast.

NONCONFORMITY

Pre-Cambrian

Igneous

Pyroxenite

Gabbro

Diabase

Lamprophyre (younger)

Granite (Strawberry) ?

Rhyolite Intrusive

Pegmatite

Lamprophyre

Granite

Pegmatite

Amphibolite

Metamorphic

Hopedale gneiss? Granite gneiss.

Quartzite gneiss

Sedimentary

Limy argillaceous formation

Sandstones and Interbedded conglomerates.

Plate 3

Fig. 1. Raised Beaches at Aillik

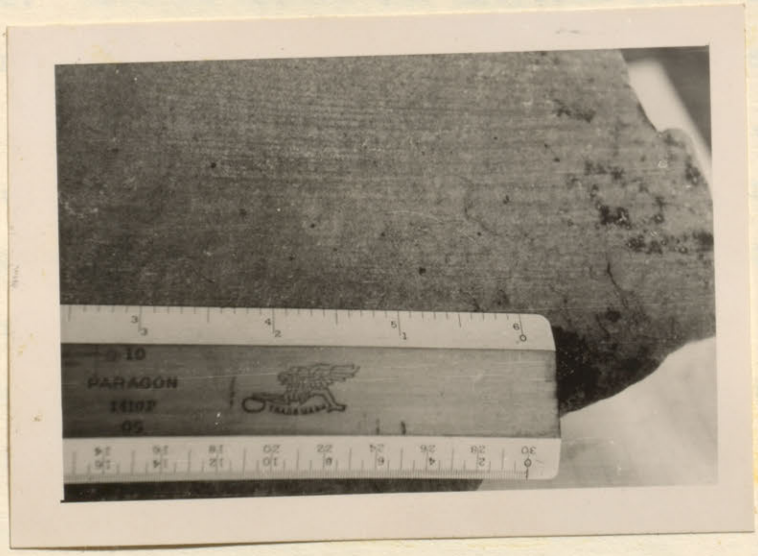

Fig. 2. Bedded Aillik Quartzite.

GENERAL GEOLOGY

In as much as differences of opinion occur concerning the general geology of the coastal area of Labrador, this discussion will be confined to that section between Makkovik and Kaipokok.

Makkovik, Aillik, and Kaipokok have their own definite characteristic groups of Pre-Cambrian rocks:

Makkovik -- deformed sediments and related granite;

Plate 3: Fig 2. Aillik -- undeformed sediments and related granites,

Kaipokok -- granite and gneiss.

The rock types and succession at Aillik and Makkovik are very similar although one major exception is noted: the sandstones and conglomerates at Aillik are relatively undeformed whereas the sediments at Makkovik have been strongly disturbed. Between Aillik and Kaipokok quite a change occurs. The sediments grade into rocks that become more granitic and gneissic. Basic dykes, numerous around Aillik, decrease in number towards Kaipokok. The table of rock formations given on the preceeding page is valid for the district, however, in any one area some rocks may not be present.

The sediments, known as the Aillik series, evidently were deposited upon an old basement complex as quartz, granitic, and diabasic pebbles have been found in the conglomerate. At Aillik these sediments (Plate 4, Fig. 1) are well preserved and ripple marks, (Plate 4, Fig. 2), cross-bedding, and mud cracks are quite common. After the deposition

Plate 4

Fig. 1. Bedded Aillik Quartzite.

By. E.H. Kranck.

Fig. 2. Ripple Marks in Aillik Quartzite.

By E.H. Kranck.

of the Aillik formation a series of intrusions took place composed of rock types that vary from aplite to gabbro. The age relationship of these intrusives was established in the field without much difficulty, however, the relation of the Strawberry granite to the Makkovik Bay granite was not definitely obtained as the two granites were never seen in contact.

At Makkovik and Aillik the first intrusions were of basic composition. Small steeply dipping amphibolite sills and dykes, up to two feet in width, cut the quartzite, conglomerate and the quartzite gneiss. The sills are more common than the dykes which are confined to the Aillik area. South of Long Island the older amphibolites are not present and the first intrusions were of a dioritic nature. The amphibolites have been shattered in many areas and fracture systems present in the quartzites may be traced through the mafic sills.

A microcline quartz rich pegmatite cuts the sediments, gneisses, and amphibolites but is cut by the "older granite". This pegmatite is a deformed massive dyke-like body, which is evidently related to the period of granitization and granite intrusions. The granite within the map area varies in composition, texture, and age. Some authors have claimed that only one period of granite intrusion has taken place and that there is only one granite. This conclusion does not seem to be valid. At least three granites have been found and although they may be of the same general period of intrusion, each has a definite age relationship within the group. In the Kaipokok district two types of granite were found. One, a dark grey gneissic rock with lineation of its mafic components, has many inclusions, and appears to be a product of granitization; the other, a light grey massive rock without inclusions intrudes the gneissic granite. Both these granites cut a granite gneiss that is the predominant rock along the north shore of Kaipokok Inlet. The Aillik district has outcrops of at least three types of granites which include rhyolite dykes, fine-grained granites, similar to the Makkovik Bay granite, and coarse-grained pink granites. The oldest granite appears to be the fine-grained variety. With the exception of the rhyolite dykes which are not found around Makkovik, the granites of Aillik and Makkovik are similar as to composition and texture. Just prior to the intrusion of granite, it is thought that the whole district underwent a period of granitization which resulted in the formation of the gneiss and some of the non-intrusive granites.

Following this period of igneous activity, rocks in the three localities were intruded by a series of lamprophyre dykes and sills. (Plate 5, Fig. 1). These rocks are relatively undeformed; one or two lamprophyre are cut by "older" pegmatites. The basic intrusives are usually fine-grained and are composed predominantly of hornblende, actinolite, and altered plagioclase feldspar of composition An 35%. The dykes and sills vary from six inches to fifteen feet in thickness with an average thickness of two or three feet. They exhibit slightly chilled contacts against other rocks. In the Makkovik area two sets of dykes are found, one with a northwesterly strike and dip of 30° west, while the other has an easterly strike and a steep dip to the south. The dyke exposures in the Aillik peninsula are more numerous than in the Makkovik area and two additional sets are found. One of these has a northerly strike and low westerly dip, while the other has a northeasterly strike and a low southeasterly dip. A slight change in the nature of intrusion is noted along the shore of Kaipokok Bay, for south of Long Island, some diorite dykes and sills are found. The diorites and lamprophyres outcrop in sets that have the same average strike and dip as in the other two localities.

Petrologically the lamprophyres may be divided into two groups:

1. Hornblende rich;
2. Feldspar rich.

An age relationship between them is evident, as the hornblende-rich varieties cut the feldspar dykes and sills. More field work is needed, however, before determining which of the sets is the younger.

Following the injection of the "older" lamprophyres an intrusion of undeformed pegmatite took place. All the older granites as well as the older lamprophyres have been cut by these pegmatites. This period evidently marked the beginning of a second intrusion of granite. Following the pegmatites an injection of rhyolite dykes occurred. These dykes, which vary from an inch to approximately a foot in width, are microporphyritic and consist of microcline, microperthite, and some plagioclase, set in a glassy groundmass. The Strawberry granite is tentatively related to the rhyolite, however, this age relationship was obtained by a comparison of "Strawberry type" granite with intrusive rhyolite in an area farther to the north. Strawberry granite within the map area is found in contact with the Aillik formation, and is cut by the younger lamprophyres. Within the Makkovik district the Waterfall granite appears to be younger than the Makkovik Bay granite. Along the shore of Kaipokok Bay the gneissic granite is intruded by a medium-grained, grey granite. It is possible that the Strawberry granite and the younger granites of Makkovik and Kaipokok were intruded during the same period of igneous activity.

Along the coast the general sequence of granites may be tabulated as follows:

Plate 5

Fig. 1. Lamprophyre.

Fig. 2. Diabase Porphyry.

Strawberry granite	.... Coarse red intrusive granite.
Waterfall granite ???	....
	.... Coarse grey granite.
Makkovik Bay granite and	.... Fine intrusive granite.
inclusion bearing gneissic granite	.... "Granitized" granite.

After this last period of igneous activity a further injection of basic dykes and sills took place starting with the intrusion of sets of porphyritic and hornblendic lamprophyres. These sets were emplaced with strikes and dips similar to those of the older system of lamprophyres. The only difference between the two systems is that one cuts the granite, whereas the older one is cut by the granite.

Two large porphyritic diabase dykes (Plate 5, Fig. 2) approximately 30 feet in width, striking northeast by east and dipping 75° to the north may be traced across Aillik peninsula by means of the aerial photographs. They outcrop along strike on the east shore of Aillik Bay, and two similar dykes were observed near Drunken Harbour, about 20 miles west of Aillik. Diabase cuts the younger lamprophyres and the rhyolite but was not seen in contact with granite. On one outcrop south of Aillik, a basic complex was observed that exhibited a gradational change from lamprophyre through diabase to gabbro. In a few cases, offshoots from diabase dykes were gabbroic in composition.

A series of pyroxenite dykes, approximately two feet in width, with a vertical dip and average strike of 345°, are the youngest intrusives in the area. These have been called "Aillikite" by E. H. Kranck.[1] They are present at both Makkovik and Aillik, however, none were seen in the area adjacent to Long Island. In this district the younger steeply-dipping diorite dykes have the same trend as the Aillikite dykes, however, the absolute age of the diorite is not known.

Explanations of the structure between Kaipokok Bay and Makkovik have been suggested by V. Douglas and E. H. Kranck, however, they are based on field work undertaken on even a smaller scale than that of the present survey. The first of these hypotheses is as follows: According to Douglas [2] the sediments were folded into an asymetrical anticline with the fold axis striking east-west across Cape Strawberry. He also states, that from information derived from the attitude of drag folds on the shore of Kaipokok Bay, that this anticline plunges steeply to the west. The second explanation put forth by Kranck is far more general and is qualified as follows "Correlations, therefore, cannot be regarded as well founded till large areas have been not

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[1] E.H. Kranck.- Bull. 19 Newfoundland Geological Survey, p.26
[2] V. Douglas.- Labrador.- Set 3, Vol. 3. p.10.
Defense Research Board Publication.

only sufficiently mapped, but also tectonically analysed".[1] The explanation involves very strong tectonic deformation and complete recrystallization within the area.

With information obtained during the field season, combined with that gathered by Dr. E. H. Kranck during his previous trips, a slightly more detailed statement may be made. It was found that the direction of lineation was almost constant throughout the map area. The average plunge is north in the northern half of the district, south in the southern half, and in most cases is about 30°, although it varies from 5° to 70°. If one assumes that this is a B lineation then a relationship between the direction of major movement and the axial line of the folds may be obtained. Schistosity in the majority of cases is parallel to the bedding, occasionally it cuts the bedding and where this happens the direction of plunge of the major folds may be obtained. Drag folds south of Long Island may be used also to interpret the structure. Data from the above three structures indicate the presence of a highly disturbed series of closely-spaced plunging anticlinesand synclines with their axial lines striking north by east. These folds plunge to the north in the vicinity of Long Island and Aillik, and to the south near Makkovik and

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[1] E. H. Kranck.- Bull. # 19. Newfoundland Geological Survey. P. 28.

Marks Bight. Folding and metamorphism is far less intense at Aillik than at Makkovik or Kaipokok.

A large vertical shear zone striking northeast, on the south shore of Kaipokok Bay marks the contact between the Hopedale gneiss and older granites and sediments. Other faults may be observed on the air photographs as well as on various outcrops within the area, but, again due to the nature of the survey, detailed investigation was not possible. A strong rectangular joint system has been developed from the intersection of dykes, faults and minor fractures.

With this review of the general geology in mind, a more detailed treatment of the geology of the Makkovik district is to be discussed.

THE SEDIMENTARY ROCKS OF THE MAKKOVIK AREA

Description

The oldest determinable rocks in the Makkovik area are deformed quartzites and interbedded conglomerates. These sediments are confined to regions near the coast with their western border found at Tern Island, about ten miles southwest of Makkovik.

As these rocks are generally deformed and recrystallized, and in many cases appear similar to granite, a map unit of these sediments is a matter of personal judgment. In this discussion only rocks that show apparent bedding, either on a large scale or in hand specimens are considered as quartzites. The remainder have been classed as quartzite gneiss or granite gneiss.

The quartzites are found in small masses with obscure boundaries or in beds up to 20 feet thick, usually interbedded with a deformed pebbly conglomerate. The latter formations usually have steep dips and the strike of the Schistosity, which is generally parallel to that of the bedding, has a north-south trend. Where the more massive quartzite is found the attitude is more flat lying, however, the north-south trend is still apparent. East of Cape Strawberry a large area of quartzite may be observed along the shore. It extends from Cape Strawberry south to Pomiadluk point. It was at this location that R. A. Daly, in 1900, first noticed these sediments.

Plate 6

Fig. 1. Deformed Conglomerate By E.H. Kranck.

Fig. 2. Deformed Conglomerate. By E.H. Kranck

Gradational characteristics of the sediments have been observed in outcrops. A quartz rich conglomerate will grade into an arkosic quartzite, which in turn passes into a mica schist. In each of these formations apparent bedding may be seen where schistosity in many cases is parallel to the bedding. Grain size and color changes of the formation permits determination of the strike and dip.

The conglomerates are particularly common in an area immediately around Makkovik. In a few places such as north of Big Island, the conglomerate has an outcrop width of 80 feet, although the common thickness is 10 feet. Many beds of a few inches thick were observed interstratified with a finely-bedded quartzite. Pebbles, up to six inches in diameter and with an average size of two inches, were found in both deformed and undeformed strata. In relatively undeformed conglomerates, mafic and grantic pebbles may be observed. Rounded quartz eyes are scattered through the specimens and the matrix is fine-grained to aphanitic usually dark green in color. The deformed rocks show a variation from those in which pebbles are slightly elongated parallel to the schistosity, to those in which the pebbles are represented only as schlieren, (Plate 6). The plunge of the lineation of these pebbles is generally steep to the south.

The quartzites are all fine-grained or aphanitic and their outcrops show a wide range of colors. Massive grey bands grade in multicolored, finely bedded strata. The majority of the quartzites are dark in color however they have an arkosic composition. The massive varieties (Plate 7, Fig. 1) are predominantly rich in quartz and feldspar and are slightly coarser-grained than the finely bedded bands. Megascopic mineral identification is somewhat difficult due to the minute grain size. Some of the finely bedded specimens appear rich in mica, but under the microscope the percentage of mica found is considerably less than supposed.

Relatively undeformed quartzite along the shore in the Makkovik area is exceedingly rare. All outcrops observed show signs of movement. South of Big Island, however, a top determination was made on a finely cross-bedded band of quartzite. The strike of this formation was 010° with a dip to the west of 80°. Tops were found to be to the west. Plate 7. Fig 2.

In many locations the primary features of the sediments have been destroyed. Highly schistose variations are quite common and schistosity often cuts across the bedding.

Under the microscope all specimens present a fine-grained granulose aggregate of unequigranular crystals. Areally the mica-rich varieties are found north of Big Island and the albitic species are located towards the western limit of the quartzite occurrence. All specimens from Makkovik contained both potash and plagioclase feldspars and accessory minerals with or without ferromagnesian.

Plate 7

Fig. 1. Massive jointed quartzite.

Fig. 2. Bedded quartzite at Makkovik.

Petrology and Mineralogy of the Sedimentary Rocks

The quartzites (Plate 8, Figs. 1, 2) may be classified as to their feldspar content. In one group plagioclase feldspar is predominant and in the other both potash and plagioclase feldspars are present. Either group may or may not contain muscovite mica.

Minerals determined in the sediments include:

quartz,
potash feldspar - perthite - microperthite,
plagioclase feldspar,
biotite and muscovite,
anphibole,
pyroxene
as well as
rich garnet (greenish yellow)
sphene,
zircon,
apatite,
fluorite,
tourmaline
and
clay minerals,
calcite,
chlorite,
sericite,
epidote & zoisite,
saussurite

and opaque minerals such as ilmenite and magnetite.

Plate 8

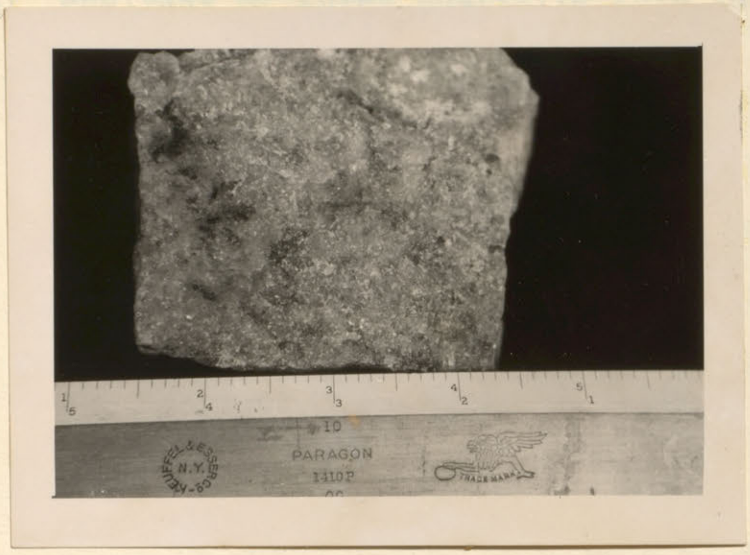

Fig. 1. Massive quartzite

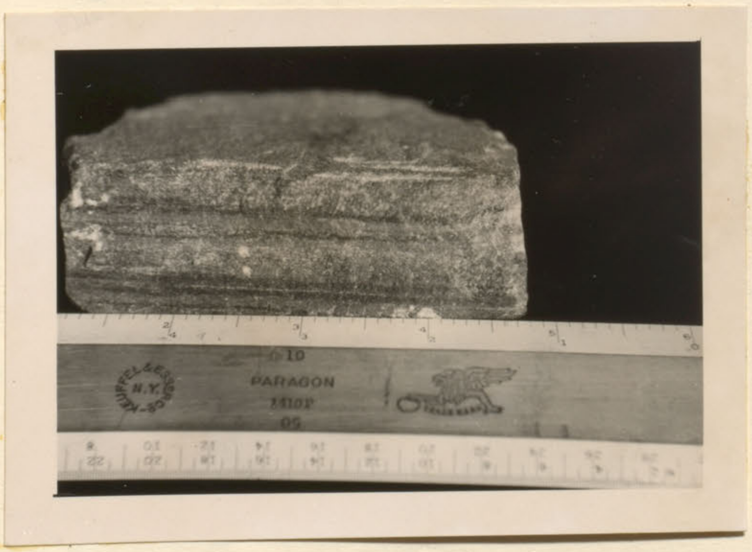

Fig. 2. Bedded quartzite

Rosiwal analyses of three quartzite thin sections show a variation in mineral composition:

Quartz	23.6	24.6	33.7
	15.6	28.5	24.9
perthite	22.05	23.4	9.3
plagioclase	27.10	20.2	5.6
ferromagnesian	.18		
muscovite		2.2	
biotite			11.7
sericite			14.8
diopside		.8	
magnetite	6.5 (1)		
apatite	+	+	+
sphene	+	+	+

In terms of percentage composition of the oxides the composition is as follows

SiO_2	64.9	74.39	71.65
Al_2O_3	12.6	14.9	15.82
Fe_2O_3	9.7 } 1		.22
FeO	4.3		.35
K_2O	6.0	9.8	8.56
Na_2O	3.0	2.2	.6
CaO	.5	.67	.1
MgO		.18	3.29
P_2O_5	+	+	+
TiO_2	+	+	+

The quartz of the sediments presents a variety of shapes and sizes. Width ranges from .02 mm. to over 1 mm. The average size of the grains is approximately 0.15 mm. Both rounded and irregularly shaped grains are present, though irregular grains with a width of 0.07 mm. are the most common. In a few cases the rounded crystals have a dark border, possibly a rim of iron oxide. Both types show undulose extinction and Bohm's Lamellae although in several cases the grains with irregular borders show complete extinction and have no lamellae or striations. Inclusions are present in the quartz but are of such small dimensions that they are unidentifiable under the microscope.

Abnormal optical properties of some quartz grains were noted. Some crystals appear to have a larger 2V than normally believed for strained quartz.[1] In some of these strained crystals a 2V of 5-15° with a positive sign was determined. Many of the quartz grains show a slight deviation from a uniaxial mineral although crystals with undulatory extinction occasionally show uniaxial positive interference figures. Quartz and feldspar appear to be closely related in the sediments. In many cases the quartz appears as small orientated lake-like masses in layers between feldspar bands. In other cases the quartz and feldspar have typical granular structure, and in a few cases interlocking quartz and feldspar crystals were evident.

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[1] A. N. Winchell. Elements of Optical Mineralogy. Part II.

The feldspars found in thin-section include orthoclase, microcline, perthite, microperthite, albite and oligoclase. These minerals are usually anhedral and have an average width of 0.1 mm. They vary from tabular to equidimensional in shape and sometimes show a marked orientation, elongated parallel to the foliation.

The plagioclase feldspars are remarkably fresh in appearance. Albite is generally free of visible alteration products. Determination of the above mineral when neither twinning nor cleavage was present was made by comparing its refractive indices with balsam and then obtaining its 2 V and sign. Some oligoclose crystals have conspicuous 001 cleavage. Twining according to the Carlsbad and albite rules was seen in various grains.

Potash feldspars, on the average, are of larger size, generally above 0.3 mm. in width. Some of these crystals have dusty or dark rims and in a few cases appear rounded in outline. Microcline has been altered and many grains have a dusty or flakey appearance. Polysynthetic twinning is very common in both microcline and perthite crystals. The perthitic feldspar presents a variety of textures such as string, vein, and patch types.[1] Microperthite grades in perthite and in all cases the percentage of plagioclase visible in these minerals is very small.

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[1] O.A. Andersen. From E.E. Wahlstrom. Introduction-Theoretical Igneous Petrology. p. 80.

Microperthite appears to be the most common.

Stress has affected all the feldspars. Broken cleavage traces, undulatory extinction and bent crystals are visible in most sections. It may be noted however, that, in general, the albite crystals show fewer deformation characteristics than the other feldspars.

Normal optical properties of most plagioclase feldspars are observed. Albite has an average 2V (approx.) of about 75°, and is positive in sign. The γ index is less than balsam and on sections parallel to $010 \perp Z$ $x \wedge 001 = 20^{\circ}$. This according to Winchell [1] is in agreement with albite of the composition An 5 - 10 %. Oligoclase has an average 2 V of (+) 80° but ranges to (-) 80°. α is always less than balsam with β generally equal to it. The extinction angles vary slightly. On sections parallel to $010 \perp Z$. $x \wedge 001 = 10^{\circ}$. This would be classified [2] as an oligoclase of composition An 15%.

The abnormal characteristics noted were the relationship of the extinction angle to the refractive indices, and variations of 2 V. The measurements of 2 V, however, not being made on the universal stage, are at best, only approximate, but even with this factor considered some measurements were extremely low.

The optical characteristics of the potash feldspars are

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[1] A. N. Winchell. Elements of Optical Mineralogy. Part 2.
[2] Ibid.

somewhat confusing. A few determinations show low indices of refraction, a low negative 2 V of 60^{o}, and in sections $\perp x$ $z \wedge$ 010 gives an angle of 89 - 90°. In all probability this may be classed as a soda orthoclase. Microcline has properties evidently determined by the percentage of plagioclase in the crystal. Its 2V is negative and the angle is usually large. The extinction angle on sections $\perp x$, and taken from the optic plane on 010 is 88^{o}, however, in sections on 001 $x \wedge$ 010 may be less than 10^{o}. It appears then that this feldspar may be classified as a soda microcline.

Mica occurs as biotite, muscovite, and sericite. Biotite is normally found in elongated orientated subhedral flakes that range in length from 0.05 mm. to 1 mm. and average about 0.2 mm. Their width varies from 0.01 mm. to 0.1 mm. and averages 0.05 mm. Biotite is dark greenish brown in color and has pronounced absorption. The majority of these crystals show the effects of stress by bent crystal forms as well as fractured cleavage. Rounded anhedral and tabular subhedral grains of colorless mica are present. In some cases a slight pleochroism is noted. The average size of the rounded crystals is about 0.1 mm. Generally cleavage is not visible under the microscope and it appears as if many of the crystals are cut parallel to the basal face, however, in some cases, cleavage is just not developed. Sericite occurs as small flakes, usually colorless, but occasionally with a slight green pleochroism.

Optically the biotite exhibits iron rich characteristics in its pleochroism. The 2 V is negative and very small. The optic plane is parallel to 010. Some crystals show a partial alteration to chlorite as evidenced by its rich green color and low birefringence. Its pleochroic formula is

x - dark green,

Y - medium green,

z - yellow green.

Muscovite also exhibits iron rich properties. It has a very low negative 2 V which varies from $15^{\circ}\pm$ to $30^{\circ}\pm$ The low optic angle is characteristic of the iron rich variety. The optic plane is normal to 010 and strong birefringence of second order yellow is observable. The optical properties of secondary white mica are difficult to determine. The mineral is colorless and in some cases a faint green pleochroism is seen. It is difficult to classify the mineral as sericite however when found with its characteristic interference colors , in association with potash feldspar, the classification is probably correct.

Minor quantities of amphibole and pyrorene are present in the sediments in which some bands are more mafic than others. No areal distribution of the two ferromagnesian minerals was noted. The amphiboles appear as small aggregates of anhedral crystals and as individual subhedral crystals of tabular form. The pyroxenes are found only in small granular aggregates comprised of crystals with a width of 0.1 mm. (Plate 9, Fig. 1.). The optical properties of the

Plate 9

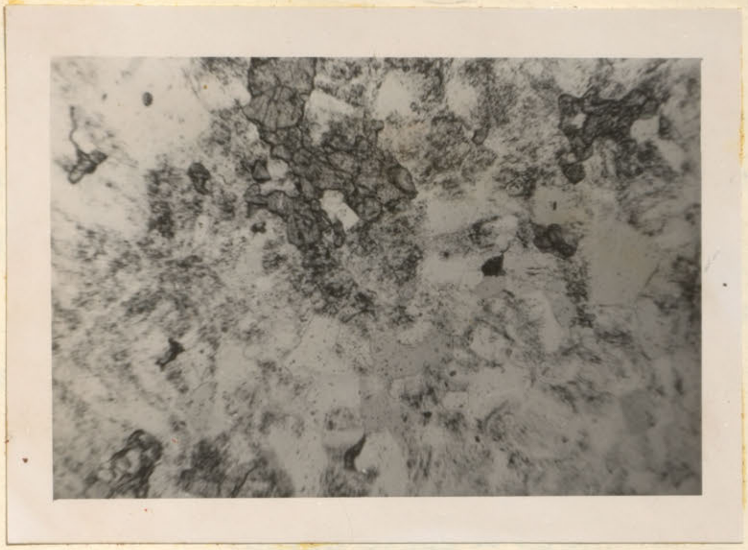

Fig. 1. Pyroxene Med. Power, open nicols X 44.

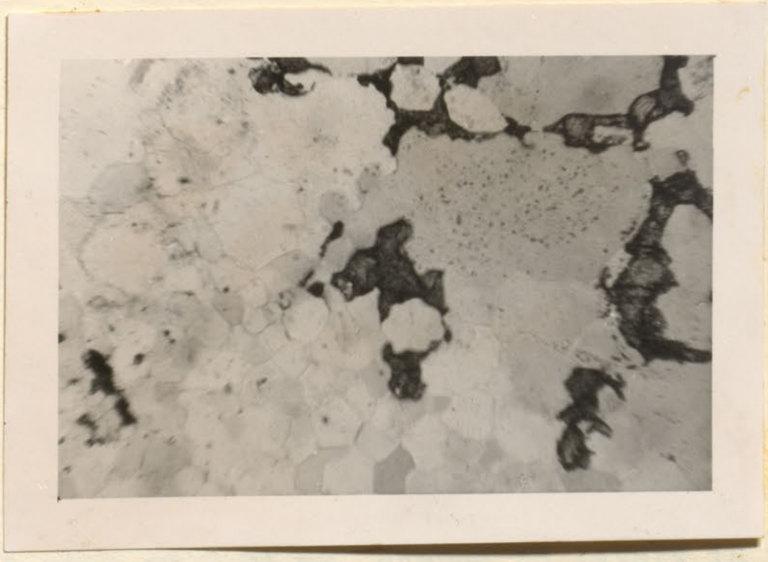

Fig. 2. Garnet Med. Power, open nicols X 44.

pyroxene are as follows: $Z \wedge C = 35^\circ$

$$+2V = 60^\circ$$

The mineral is light green in color and very slight green pleochroism is noted.

The optical properties of the amphibole indicates the presence of riebeckite:

$$X \wedge C = 5^\circ$$

Large negative 2V.

Optic plane ⊥ 010.

The mineral has an intense blue-green color and is strongly pleochroic with a formula X = dark blue-green and Y = yellowish blue.

Yellow green garnets are seen in both hand specimens and thin sections. These minerals are usually found in anhedral aggregates, with individual crystals of 0.08 mm. in width. Some of the grains are rounded with a black film around the borders. The remainder have a decidedly irregular habit with an occasional subhedral outline. This mineral is in all probability andradite. (Plate 9, Fig. 2). In many cases garnet, sphene, and iron minerals appear to have a close relationship.

Discussion

The quartzites show the effect of granulation, recrystallization and alteration. Many specimens show a banding suggestive of bedding. In an individual band layers with a granularity of 0.01 mm. change to layers in which the crystals are 0.9 mm. in width. Mica flakes are confined to layers

Plate 10

Fig. 1. Lineated Mica Med. Power open nicols x 44.

Fig. 2. Lineated Mica Med. Power crossed nicols x 44.

adjoining or within bands of microcline and microperthite. (Plate 10, Figs. 1, 2). Granulation may have also been a cause of this banding. Movement apparently took place before, during and after recrystallization, thus any of the original bedding planes would be deformed or destroyed. Granulation possibly was guided by the bedding planes. Recrystallization would be controlled, among other factors, by both planes of movement and primary structure. This would explain the presence of orientated mica in the potash bands. Granulose structure is seen in the conglomerates and purer quartzites, however, in some cases, such as in the massive quartzites near Tern Island, planes of movement were not seen. In this area deformation evidently acted upon the rock as a unit and recrystallization occurred after the movement had almost ceased. The average grain size of the quartz in this rock is about 0.2 mm. and ranges from 0.05 mm. to 1 mm. which is somewhat coarser than for the other quartzites. This evidence and the presence of possible primary structure indicates a less intense deformation than at Makkovik. No potash feldspar was observed. Albite (An 5-10%), oligoclase (An 15%) and quartz are the predominant components. Introduction of albite is thought to have taken place at a late stage after the first recrystallization. The lack of potash feldspar might be explained by the presence of excess soda in solution and the breakdown of the potassium feldspar at the time of the albite recrystallization. However, the

the absence of this feldspar might be related to the lack of intergranular space in the rock during the potash metasomatism that evidently occurred before the introduction of albite. It may be noted that granulation occurred during the introduction of the albite as is shown by the bending of the cleavage traces of some of these crystals.

Certain crystals of quartz and feldspar show primary detrital features such as dust covered contacts and rounded outlines. The rocks, however, have been too thoroughly deformed to determine definitely their original composition. It is supposed that they represent certain portions of an arkosic sandstone with a few mafic layers, the whole formation containing some calcium.

The percentage of TiO_2 in arkosic sediments [1] according to Pettijohn, is extremely low. All thin sections of rock from this area contain some sphene. These crystals in many cases show rounded and darkened borders suggesting a detrital origin. It may be possible that some of the titanium has been recrystallized in place or introduced during one of the later periods of alteration, as no fracturing of sphene crystals was observed. Both rounded and tabular grains of apatite are observed in all specimens. The percentage of P_2O_5 [(2)] is sufficient to permit recrystallization of the tabular forms. The more rounded ones appear to be detrital.

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1 F.J. Pettijohn. -Sedimentary Rocks, p. 259.
2 Ibid.

The abundance of mica and microcline in the slides examined indicates a high percentage of potassium.

This percentage is above that expected in a normal arkosic sediment and an introduction of potash is thought to have taken place.

Plate 11

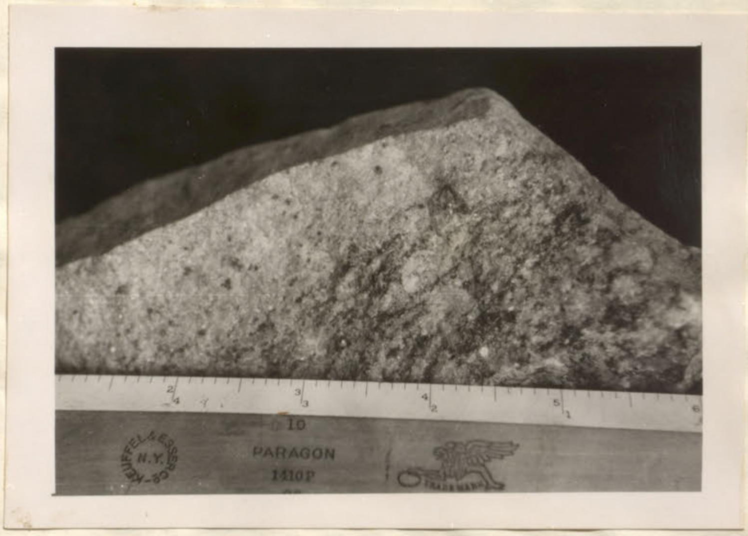

Fig. 1. Granite Gneiss.

QUARTZITE GNEISS AND GRANITE GNEISS OF THE MAKKOVIK DISTRICT

As mentioned previously differences in opinion as to the identification of sediments have occurred. Gradational changes of quartzite to rocks of gneissic appearance were visible in many areas. However, some changes were exceedingly sharp. One side of a contact was sedimentary, the other gneissic and rock identification was possible without hesitation. Two classes of gneiss were found in the Makkovik area: Those that resemble the quartzite, known as quartzite gneiss, and that one related to the granites, known as granite gneiss. (Plate 11, Fig. 1.)

The areal extent of the quartzite gneiss is similar to that of the sediments and is not found west of Tern Island. Granite gneiss is present west of Tern Island and also in scattered outcrops just south of Big Island. Both gneisses outcrop as irregular masses although in some cases bedding is apparent in the paragneiss. The relationship between the two gneisses is very confusing. In more than one locality a gradational change occurs between the two rocks whereas in other cases the contacts are clearly defined. Even though they are well defined, the nature of contacts are somewhat obscure, and all that may be said is that they are steeply dipping and have an overall north-south strike.

Both classes of rocks appear to have similar attitudes and a reflection of the regional strike is found in individual outcrops. Steep dips are generally present and lineation of the mafic portions of the rock is steep in a southerly direction.

The difference petrologically between the gneiss and the sediments is not great. Under the microscope specimens show a medium grained allotriomorphic to hypidiomorphic aggregate of leuco and melanocratic crystals. Granulose texture is sometimes present. All minerals seen in the gneisses with the exception of fluorite and allanite are found in the sediments.

The quartzite gneiss is composed predominantly of leucocratic grains with an unequigranular medium-grained granulose texture. It has a larger grain size than the sediments but one that is slightly less than that of the granite gneiss. The percentage of ferromagnesian minerals and feldspars is similar to those of the sediments. Chemically the quartzite gneiss and the sediments are very similar. Petrologically, a larger grain size and the presence of granoblastic textures imparts a slight difference but outside of gneissic structure the two rocks might be the same. It is thought that these gneisses represent a more metamorphosed portion of the sediments.

The granite gneisses are coarser grained and more mafic than the quartzite gneiss. They are composed predominantly of both leuco and melanocratic crystals with an unequigranular medium grained granoblastic texture. Mineralogically only a slight difference marks these rocks from the quartzite. A higher percentage of mafic minerals, fluorite and the presence of allanite suggests a steeper temperature gradient and a higher percentage of volatiles during the formation of the granite gneiss which are accounted for by the presence of the closely related granites.

Surface exposure of the granite gneiss exhibits strong flow structure which in many cases grades out in the quartzite gneiss. This flow structure evidently is the expression of a plastic mass under stress. The fact that it grades out into the quartzite indicates that this stress is localized, most probably due to the influence of regional metamorphism and to the formation of the nearby granite.

THE GRANITES IN MAKKOVIK BAY

Description

The presence of granites near Makkovik have produced a series of discussions concerning their origin and methods of emplacement [1]. It may be noted that the conclusions drawn differ considerably. This description of granites is primarily concerned with the granitic rock found along the north and south shore of Makkovik Bay, from the outlet of Makkovik River to Makkovik Harbour. This area is only partially included by the two previous investigators [2] and discussion on the granite found at Cape Strawberry may be seen in reports of E. H. Kranck and V. Douglas.

Granite outcrops three miles southwest of Makkovik village on the south shore of the bay. Just across the bay, from this exposure, one to the west and one to the northwest are two other small masses of granite. These areas mark the eastern limit of the Makkovik Bay granites. Other small bodies outcrop along the south shore as far as the head of the bay (Plate 12, Fig. 1.), Northwest of Tern Island, on the north shore, is an exposure known as the Waterfall granite. The extent of the majority of these outcrops was not determined due to the nature of reconnaisance traverses. Although in many cases the outcrops are limited to the shore line or for a few hundred yards from

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[1] E.H. Kranck. Bull. # 19. Newfoundland Geological Survey.
[2] V. Douglas. Labrador. Defence Research Board Publication.

Plate 12.

Fig. 1. Makkovik Bay Type Granite.

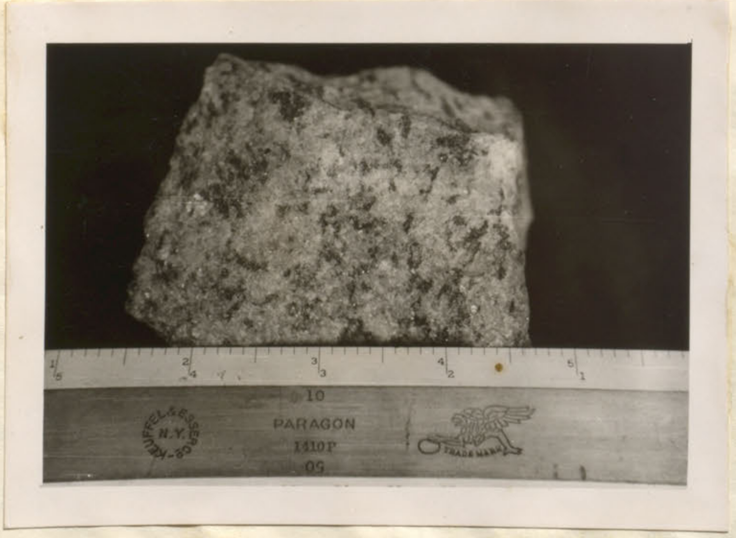

Fig. 2. Strawberry Type Granite.

it, they occasionally extend well inland.

Two other small occurrences of granite, similar to the Makkovik Bay granite were found, one on the eastern tip of Big Island, and the other, about one mile and quarter east of Makkovik village. Further east, toward the coast, stretching south from Cape Strawberry is the large exposure of Strawberry granite which has been described in detail by E.H. Kranck, G.Cooper and V. Douglas.[1] The mass intrudes the Makkovik sediments and has sharply defined discordant vertical contacts. The Strawberry granite is a pink coarse grained unequigranular massive rock. This intrusive body strikes south and outcrops of granite of Strawberry type are found in the bay northwest of Manak Island. (Plate 12, Fig. 2).

The striking feature of the Makkovik Bay granite is the almost entire lack of defined or intrusive contacts. This granite would either grade into a granite gneiss or quartzite gneiss, or pass slowly into the sediments. The Waterfall granite on the other hand exhibits sharply defined intrusive contacts with the quartzite gneiss.

The Makkovik Bay granites are homogeneous on a large scale though heterogeneous under the microscope. Erosion by sea ice produces a smooth scalloped surface and even though joint systems are present, blocks or erosional remnants of these granitic bodies are not abundant.

1. E.H. Kranck. Bull. 19. Newfoundland Geolog. Sur. p.23.
G. Cooper. M.Sc. Thesis. McGill University.
V. Douglas. Labrador - Defence Research Board Publication. Set 3, vol. 3, p.16.

Inclusions of gneiss are sometimes found in the granite but quartzite and mica schist fragments are very rare. This latter observation is significant for the granitic rocks south of Long Island in Kaipokok Bay have abundant mafic inclusions. Large xenoliths are occasionally found in the more eastern granite exposures but they decrease in number to the west. They usually have sharp blocky outlines and their composition megascopically is similar to that of the enclosing granite. Flow lines and platy linear structure, when present in the granite, may sometimes be traced into the xenolith, in which case a ghost outline is the only visible remnant.

Flow lines in the granites are quite common, and flow layers may be pronounced in parts of the more mafic exposures. As stated previously, the granites may show transitional contacts, up to forty feet wide, with granite gneiss. The classification as gneiss appears to be more or less dependent on the development of linear and flow structure. This foliation occurs towards the transitional contacts of the granite and the gneiss where, microscopically, the rocks are partially granulose. To be absolutely positive of the origin of the foliation is not possible. However, due to the lack of deformation characteristics, and because of the relationship of the granite to the supposedly related undeformed pegmatites. it is thought that the majority of these flow structures are primary. Exceptions do occur and more field work is definitely necessary before making further generalizations.

The Waterfall granite lacks foliation but possesses a slight linear structure. It is medium to coarse grained and has an equigranular holocrystalline texture. In comparison with the Makkovik Bay granite, it is coarser, more massive, of a somewhat greyer color, and because of a slightly higher percentage of ferromagnesian minerals it presents a more speckled appearance. Both these types of rocks may be classed as leucogranites.

Petrography and Mineralogy of the Granites.

Under the microscope the Makkovik Bay granite presents a medium grained allotriomorphic-granular unequigranular aggregate of leucocratic crystals. A small percentage of mafic, accessory and alteration mineral are scattered throughout the rock.

The Waterfall granite exhibits an unequigranular coarse to medium grained hypidiomorphic-granular aggregate of leucocratic crystals with some scattered ferromagnesian minerals.

The Strawberry granite is a coarse grained unequigranular hypidiomorphic-granular aggregate of leucocratic crystals with minor amounts of biotite and hornblende.

Minerals determined in the granites include:

quartz	microperthite	Biotite mica
adularia	antiperthite	amphibole
anorthoclase	albite-an 5-8% -an 8-12% -an 15-20%	
microcline		

as well as:

Apatite	Kaolin
Fluorite	Chlorite
Sphene	Sericite
and	
Zircon	Muscovite
Monazite	Epidote
Xenotime	Zoisite and Clinozoisite
Allanite	Calcite

as well as such opaque metallic minerals as magnetite, ilmenite and pyrite.

Roiswall analyses were made on ten thin sections and the results of eight of these are tabulated below. Numbers 1 - 8 inclusive are modes of various Makkovik Bay granites, 1 - 4 inclusive from the western half of the bay, and 5 - 7 inclusive from the eastern area. Number 8 is an analysis of the Waterfall granite. Tables 9 and 10 are the average of the first and second groups respectively. Table 11 is the chemical composition of the Makkovik Bay granites, in term of oxides, based on Table 9.

The grain size of quartz and feldspar crystals averages about 0.8 mm. in width and the alteration of the feldspars, which did not affect the quartz, permitted a quick method of identification of these minerals. A slight error may occur in the identification between untwinned plagioclase of composition An 8%, and untwinned potash feldspar, though sign determination and comparisons with minerals of known refractive indices were made whenever possible. The percentage of alteration products is a minimum figure as these minerals generally have a width of less than .02 mm. The accuracy of the Rosiwal analysis should be well within the range of experimental error.

ROSIWAL'S ANALYSES OF THE GRANITES

	1	2	3	4	5	6	7	8	9	10	Chem. Anal.of #9.	
Quartz	27	23.2	35.4	36.7	34.8	31.0	32.0	36.4	30.5	32.7	SiO_2 -	77.5
Adularia	6.5		4.8						2.7		Al_2O_3	14.2
Microcline	+M.Perthite 32.5	24.0	20.0	21.8	28.0	32.4	25.4	27.3	24.5	28.6	Fe_2O_3	.3
Microcline-perthite		14.	12.9	12.5	15.1	13.7	6.6	9.0	9.8	11.8	FeO	.1
Plagioclase an 5-15%	27.4	29.3	20.0	27.6	21.4	20.2	31.6	21.0	An 15% 26.2	24.4	K_2O	6.2
Amphibole								2.7			Na_2O	2.8
Biotite		5.6				2.7	2.5	3.4	1.4	1.7	CaO	1.7
Muscovite + Sericite				1.5			1.5		1.0	.7	MgO	.5
Chlorite	2.1				.7				.5		H_2O	.2
											P_2O_5	+
Epidote + Zoisite	4.9	4.4	6.4	+			.4		3.8		TiO_2	+

Column 9 = average of Columns 1, 2, 3, 4. for Chemical Analysis.

Column 10 = average of 5, 6, 7.

The quartz crystals in the Makkovik Bay granites have sutured,sharp, or occasionally, slightly granulated contacts with other minerals. They have irregular outlines with shapes that are generally blocky. The width of these crystals varies from 0.4 mm. to over 2. mm. and averages about 1. mm. Inclusions of a small flaky mineral and a black opaque mineral, also of small diameter, are scattered without orientation through almost all grains. Strain phenomena such as rupture lines, strain shadows, and Bohm's Lamellae, are present in varying intensity. Gas bubbles and minute inclusions appear to be orientated in planes normal or parallel to rupture lines in the quartz and are visible on sections cut sensibly parallel to the C axis. Whether these inclusions and gas bubbles are related to Bohm's Lamellae or whether they are connected with some other form of deformation would be clarified only by more detailed investigation. It might be suggested, however, that two periods of quartz deformation occurred within the granites. Some post deformation crystallization took place in the area, thus the Makkovik Bay granites may have been in a semi-plastic state. Orientation of gas bubbles in quartz under a slight stress, especially in a semi-plastic state is probable. It is thought that the effects of a plastic stage of quartz deformation have been superimposed over those due to an earlier period of ruptural deformation.[1]

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[1] Anna Hietanen. - On the Petrology of Finnish Quartzites. Pages 32-36.

Potash feldspars are generally anhedral but occasionally some subhedral grains may be present. Contacts with other minerals are sharp or sometimes sutured and replacement phenomena are conspicuous. Anhedral crystals range from 0.4 mm. in width up to 2 mm. and average about 1.2 mm. Grid twinning is pronounced in the microcline and microperthite. Twinning according to other laws is rare and is limited to simple carlsbad twins, present in orthoclase. Subhedral crystals of adularia and anorthoclase have good 001 cleavage, an average length of 0.6 mm. and a width of about 0.3 mm. These grains are usually surrounded by larger crystals of microcline and plagioclase.

The plagioclase feldspars occur in two forms, one as tabular, subhedral to anhedral crystals, and the other as anhedral blocky grains. Crystals vary in length from 0.6 mm. to 1.5 mm. and average about 0.8 mm. Deformation phenomena, such as bent twinning lines, offset cleavage, and broken crystals are common in these feldspars. (Plate 13, Fig. 1). Some of the larger tabular grains have a corona of fresh plagioclase which is usually of a more sodic composition than the inner plagioclase though in two cases a slightly more calcic determination was made. (Plate 13, Fig. 2). A slight change of the optic orientation between the rim and the surrounded crystal is occasionally apparent and some zonal phenomena in various crystals indicate the possible presence of at least two types of plagioclase feldspars.

Plate 13

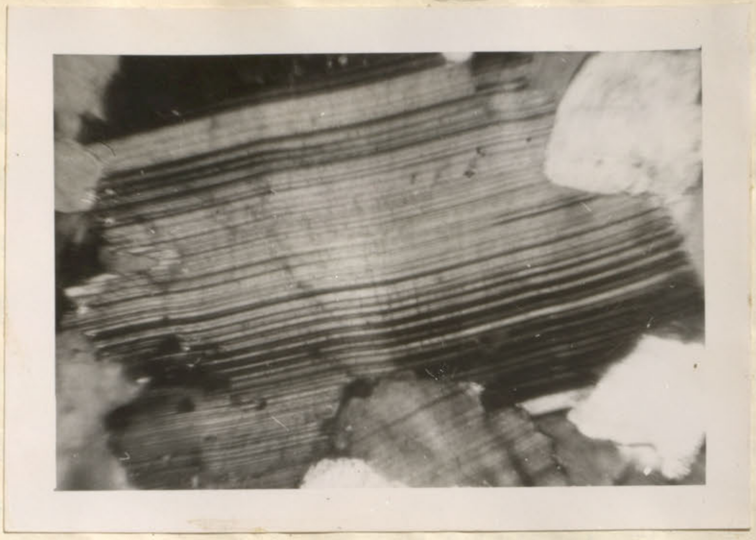

Fig. 1. Bent Cleavage. Med. Power, crossed Nicols x 44.

Fig. 2. Rim of more calcic feldspar. Med. power open nicols x 44.

Tabular crystals have a composition of An 10-15%, and less commonly, one of An 15-20%, while the coronas and subhedral grains usually consist of 5-12% of the anorthite molecule. These determinations differ slightly for individual granites. Although albite and carlsbad twins in the plagioclase feldspars are common, twinning according to other laws is rare and some twenty percent of these feldspare are untwinned.

Exsolution and replacement "perthites" are common and have a crystal habit and average grain size similar to those of microcline crystals. Perthites are twinned according to the behaviour of the host mineral although in some replacement perthites, the twinning laws governing the replacing mineral are dominant. Some perthites show the effects of superimposition of twins, in which case the twin traces are very hazy and ill-defined. Perthites in the granites may be classified according to O. Andersen's table [1] with string and patch microperthites the most abundant.

The optical properties of the potash feldspars are as follows:

Adularia Z Optic Plane $x \wedge 001 = 5^{\circ}$ $-2V\ 60^{\circ}$.

Anorthoclase Z Optic Plane $x \wedge 001 = 8^{\circ}$ Low negative 2V

and agree with those listed by Larsen [2] and Winchell[3]. Microcline, however, has properties that are more variable. Although

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1 O. Andersen. (From Wahlstrom) - Introduction to Theoretical Igneous Petrology, p. 80.

2 E. S. Larsen. Microscopic Determination of The Nonopaque Minerals.

3 A.N. Winchell. Elements of Optical Mineralogy.

its 2V is negative and always large, the extinction angles range considerably, and sections on 001 $x \wedge$ 010 varies from 15^{o} to less than 10^{o}. In this case, one similar to that of the quartzites, the optical properties of microcline may be related to the percentage of soda within the crystal lattice. Insofar as the properties of the perthites are concerned, a great variety is shown, and they are difficult to determine. Both large positive and negative optic angles are found and the indices of refraction are generally lower than those for plagioclase of composition less than An 5%.

Optically, most of the plagioclase feldspars exhibit normal properties although in some cases, whereas the indices of refraction indicate a feldspar of composition less than An 8% both the sign and size of optic angle suggest a somewhat different answer. The extinction angles of the plagioclase feldspars determined in thin section are as follows:

$\perp$	z	Optic Plane	$x \wedge 001 = 8^{o}$	An 5%,
$\perp$	x		$z \wedge 010 = 75^{o}$	An 5%,
$\perp$	x		$z \wedge 010 = 80^{o}$	An 10%,
$\perp$	x		$y \wedge 010 = 7^{o}$	An 15%.

The sequence of crystallization of the potash and plagioclase feldspars is relatively obscure. Recrystallization has been active in the region, thus it is cometimes difficult to determine the primary feldspar. Adularia and anorthoclase evidently were the first potash feldspars to form.

At the same time the more calcic feldspar started to crystallize. Microcline was next, and in part it replaced crystals of the older plagioclase. (Plate 14, Fig. 1). In some crystals this replacement was almost complete, and a replacement anti-perthite was formed. In other grains a less complete substitution was evident with the result that a gradation, from an unreplaced plagioclase, to a fully replaced one, was quite common. In conjunction with the crystallization of microcline exsolution phenomena in this feldspar resulted in the formation of exsolution perthites. A more sodic plagioclase was next to crystallize. This occasionally gave rims around the more calcic feldspars as well as forming anhedral grains of plagioclase of composition An 5 to 12 %. It replaces, to a small extent, microcline, with the formation of replacement microcline perthite (Plate 14, Fig. 2), but it does not replace adularia or anorthoclase. This late albite is always present and forms in conjunction with, or later than, the microcline. (Plate 15, Fig. 1). In some cases it may occur in two stages in which case the sequence of crystallization becomes most confused.

Biotite mica (Plate 16, Fig. 1) and amphibole are present in minor quantities in the thin sections examined. Both minerals are subhedral and have an average grain size of about 0.4 mm. Biotite is medium brown and has high interference colors. Amphiboles are of the common hornblende system and have a greenish brown color, although occasionally

Plate 14

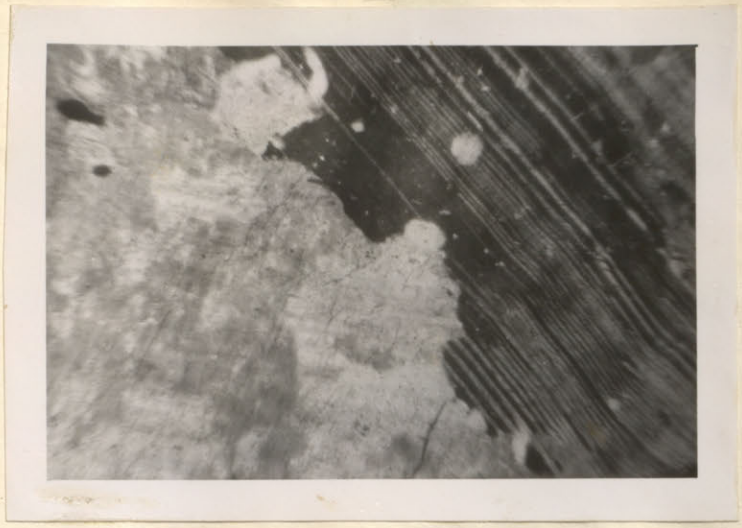

Fig. 1. Microcline replacing Plagioclase medium power crossed nicol x 44.

Fig. 2. Replacement perthite medium power crossed nicol x 44.

Plate 15

Fig. 1.

Albite replacing Microcline.

Medium power crossed nicol x 44.

some green varieties with low interference colors are present.

Accessory minerals are present in varying amounts with sphene and apatite the most abundant. The average size of subhedral sphene is about 0.2 mm. in length and the length of tabular crystals of apatite averages about 0.08 mm. Sphene may crystallize during an early or late stage. In some cases a breakdown of ilmenite producing sphene, definitely affects the surrounding plagioclase feldspar, and thus sphene may crystallize after the feldspar. Apatite forms at an early stage and is found as inclusions in all the younger minerals. Fluorite forms anhedral colorless or purple grains, and stringers, that occur along the contacts of other minerals. (Plate 16, Fig. 2). In some cases it appears to replace the plagioclase feldspar. The stringers are usually about 0.1 mm. long and the anhedral masses have a width of about 0.8 mm.

The most common alteration minerals are muscovite, sericite, kaolin and the epidote group. These minerals are all of small granularity and usually occur as blades, or in dust-like masses. The average length of the blades is about 0.02 mm. Minerals of the epidote group replace all plagioclase feldspars except the rims of late albite. They are found in the microcline and microperthite but not in adularia or anorthoclase. Epidote is also found surrounded by mica and hornblende. The more calcic the mineral, the greater the extent of alteration into epidote,

Plate 16

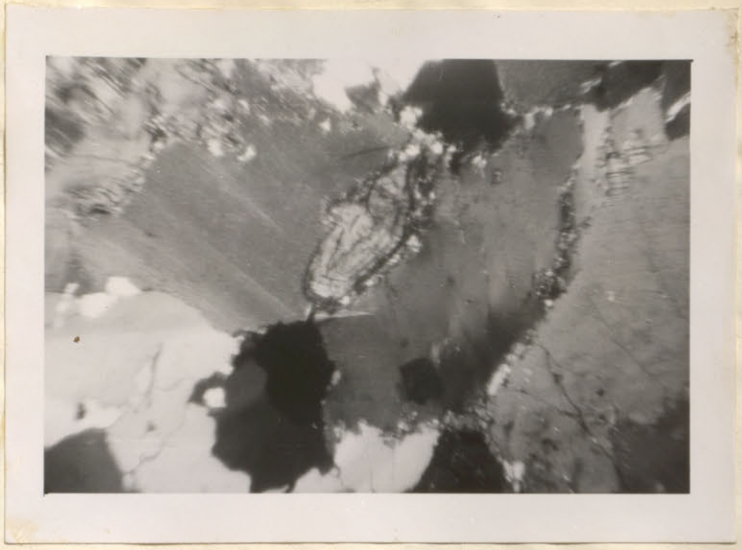

Fig. 1. Mica and Quartz surrounding Allanite
Med. power crossed nicol x 44.

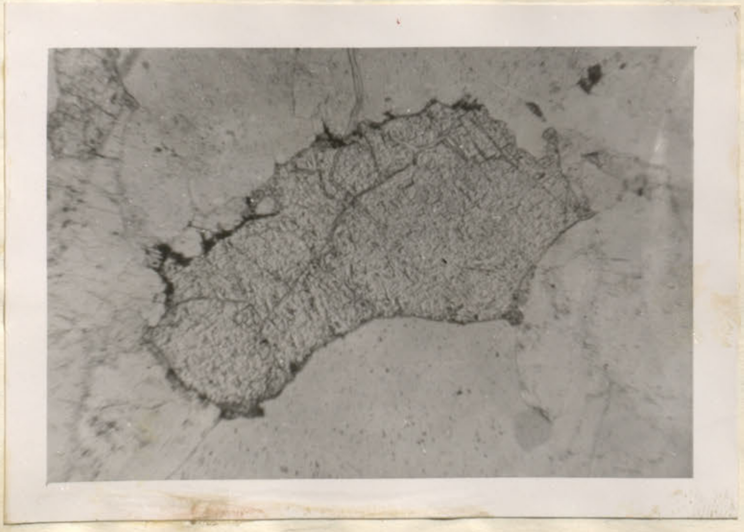

Fig. 2. Fluorite, Med. Power open nicol x 44.

which forms anhedral grains of 0.05 mm. width. (Plate 17, Figs. 1, 2). Muscovite and sericite partially replace all feldspars though late albite is only very slightly attacked. A mineral suggesting kaolin is scattered in minute dusty particles through all minerals and appears to be concentrated in microcline and plagioclase feldspar. It is seen in quartz and in very small amounts in the late albite. Muscovite occasionally replaces green biotite and some investigators believe this color to be due to alteration by certain metasomatic processes. In occasional cases epidote grains appear to grow out of green biotite crystals, and under these circumstances the interference color of the biotite is generally of a low order. Muscovite and biotite may be primary or secondary. Biotite is probably all primary, though alteration to biotite and epidote from hornblende may occur. Muscovite, however, is difficult to classify as either primary or secondary. In some cases it encloses biotite and in others it replaces it. Similar relationships to the feldspars are found. In all probability both primary and secondary muscovite are present with the secondary type the most abundant.

The preceeding description of minerals is one that is characteristic of the components of the Makkovik Bay granites. The following account concerns the minerals of the Waterfall granite. The components of this granite are similar, in many respects, to those of the previously

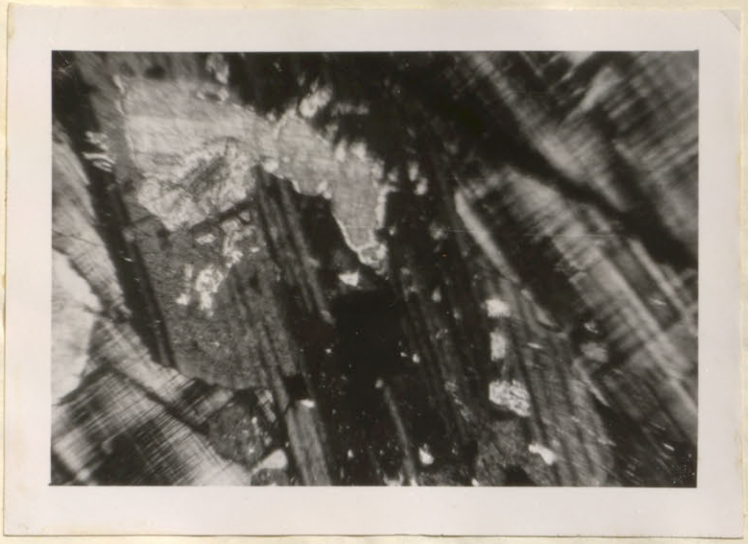

Fig. 1. Epidote & Mica in Plagioclse.

Med. Power crossed Nicol x 44.

Fig. 2. Epidote and Mica in Plagioclase.

Med. Power open nicol x 44.

described granites, although some exceptions are pronounced. In the thin sections examined, quartz crystals have no deformation characteristics. Albite, carlsbad, mannebach and pericline twins are common in the plagioclase feldspar which are of composition of An 15%. It is interesting to note an amphibole, with some peculiar optical properties, on which studies will be made at a later date. On preliminary examination this mineral has a dark green color, with absorption in light and dark green. It is either a uniaxial positive mineral or one with an optic angle that is sensibly zero. It also exhibits strong dispersion. Alteration minerals with the exception of minor quantities of kaolin and sericite are absent and the rock is exceedingly fresh in appearance.

Minerals found in the Strawberry granite are present in the Makkovik Bay and Waterfall granites. Similarity of description exists between these granites although the Strawberry granite has the largest grain size, and its quartz crystals have deformation characteristics which are intermediate between those of the Waterfall and Makkovik Bay granites. Alteration of the Strawberry granite is less intense than that of the Makkovik Bay granite with epidote and zoisite related to the alteration of the plagioclase feldspars.

CONCLUSION

From a review of this thesis, it is evident that the relationships of the granites to the other rocks plays an important part in the interpretation of the geological history of the district.

At least five granites, with varying mineralogical composition having somewhat similar chemical compositions, have been found. It has been stated previously that the Waterfall, Strawberry, and younger Kaipokok granites are intrusive. It is thought by the author that most intrusive granites have been formed by anatexis. This point will not be discussed; however, the problems concerning the origin of the Makkovik Bay granites need explanation.

Many of the granites grade into the gneisses and the sediments. A gradation also was traced from the granite to the granite gneiss, through the quartzite gneiss and finally into the quartzite. Where this gradual change occurs it is hard to distinguish the granites from the sediments from the appearance of the rock alone.

Occasionally structures in the sediments may be traced into the granites. Some structures present in the gneisses may be followed into both the sediments and the granites. It is not uncommon to find a granitic-looking rock that has a ghost outline of bedding.

A chemical analysis calculated from a Rosiwal analysis of the granites compared with one obtained from the quartzites shows a marked similarity, as follows:

Columns 1 and 3.- Analysis by Rosiwal method.
Column 2.- Analysis by Quantitative Chemical methods. (by N. Sahlbom, Stockholm).

	Quartzite (1)	Quartzite (2)	Granite (3)
SiO_2	72.0	75.69	77.5
Al_2O_3	14.8	13.60	14.2
Fe_2O_3	0.2	0.49	0.3
FeO	0.3	0.22	0.1
K_2O	8.2	2.68	6.2
Na_2O	1.9	5.80	2.8
CaO	0.4	0.92	1.7
MgO	2.6	0.01	0.5
P_2O_5	+	+	+
TiO_2	+	+	0.1

It is interesting to note the presence of fluorite in all three rocks while allanite, which is less mobile, is confined to the granite and granite gneiss.

Even though the granites have allotriomorphic-hypidiomorphic, medium-grained textures and the quartzites have fine-grained, granulose texture (Plate 18, Figs. 1, 2), the progressive change of one to the other may be traced under the microscope. This study was made of the rocks in the gradational contact area between the granite, granite

Plate 18

Fig. 1. Texture of Quartzite Low Power crossed nicols x 20.

Fig. 2. Texture of Granite Low Power crossed, nicols x 20.

gneiss, and quartzite greiss near Tern Island. The grey quartzite gneiss is predominantly composed of quartz and albite. The percentage of quartz and plagioclase feldspar decreases in the granite gneiss and the percentage of potash feldspar increases. The mineralogical composition of the granite is similar to that of the granite gneiss. Quartzite gneiss consists of an unequigranular fine-grained granulose aggregate of leucocratic grains. The granite gneiss is coarser-grained and has metacrysts of anti-perthite set in a granulose crystalline groundmass. The granite is slightly porphyroblastic and large feldspar crystals have rims of a more sodic feldspar.

A theory of origin for the Makkovik Bay granites will be proposed forthwith. From observation obtained throughout the whole district, it is thought that the region underwent a long period of regional metamorphism. According to Turner, temperatures of this type of metamorphism may rise " ... as high as 800 °C in deep-seated granulite provinces of the Pre-Cambrian [1]. He also states that the temperature may be as low as 200 °C. The rocks of the present day surface are thought to have been subjected to metamorphic processes at a temperature usually below the melting point of quartz and albite feldspar. The conditions at this level are those that give rise to the amphibolite

[1] F. J. Turner. - Mem. 30 G. S. A. p. 285.

facies of Turner.[1] Liquids and volatile material present in the original formation, become active due to increased temperature and pressure. According to Wahlstrom if " ... 10 to 15 percent of the interstitial material is converted to liquid by solution or melting the aggregate may become sufficiently mobile to flow in response to stress."[2]

If, at any one locality, the physical chemical conditions change sufficiently to permit recrystallization or refusion of a given rock mass, then this rock may be endowed with many of the properties of an igneous rock. It is thought that the solutions present within the formation played an active part in disturbing the equilibrium of certain areas. A temperature rise is thought to have taken place in conjunction with the reactions caused by these solutions. This rise may be derived mechanically in the course of rock deformation and by the evolution of heat caused by palingenetic magmas at a lower depth.

It is thought that the Makkovik Bay granites have formed from a sedimentary series subjected to the previously outlined conditions. These granites were emplaced in a semi-plastic or plastic state into an already heated country rock. This explains the lack of intrusive contacts between the Makkovik Bay granites and other rocks. Due to the emplacement, in situ, the surrounding rocks absorbed some heat and the heat generated during the formation of the

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1 F. J. Turner.- Mem. 30 G.S.A. p. 285.

2 E. E. Wahlstrom.- Introduction to Theoretical Petrology. p. 238.

granites would be dispersed outwards. This process in conjunction with directed stress, may account for the formational, textural, and gradational features of the granite gneiss and quartzite gneiss. It also shows why allanite is not found in the quartzites but is confined to the gneisses.

The relations between the three areas of Kaipokok, Aillik and Makkovik are still obscure. Deep levels of erosion are evident at Kaipokok and Makkovik, while at Aillik, this level may be shallower. In a similar manner, deformation is more pronounced in the first two localities than at Aillik. It is interesting to note the fault that is found on the south shore of Kaipokok Bay. To the north of this fault, outcrops of Hopedale gneiss are found. The presence of this gneiss suggests a very deep level of erosion. To the south, sediments and related granites are located as previously explained. The lack of information concerning this fault prohibits a dogmatic statement of any specific directional movement on this fault; however, it is hoped that it will receive further investigation.

It is thought that the area between Kaipokok and Makkovik represents a section of a sedimentary series that has been subjected to several periods of igneous activity as well as to related periods of folding and metamorphism.

A third conclusion arose from the petrological study of the granites, gneisses and sediments of the Makkovik district. Some potash and soda feldspars of these rocks exhibit optical properties that are not in accord with those listed for such feldspars by Larsen, Winchell and Wahlstrom. This fact definitely warrants further investigation of the optical and chemical properties of the feldspars found in Pre-Cambrian granites and granitic rocks.

The limitations brought about by the nature of reconnaissance geology must be emphasized. Further detailed investigations are indeed a necessity.

In conclusion it is hoped that this thesis may be of help to those geologists who will some day continue the investigations "along the Labrador".

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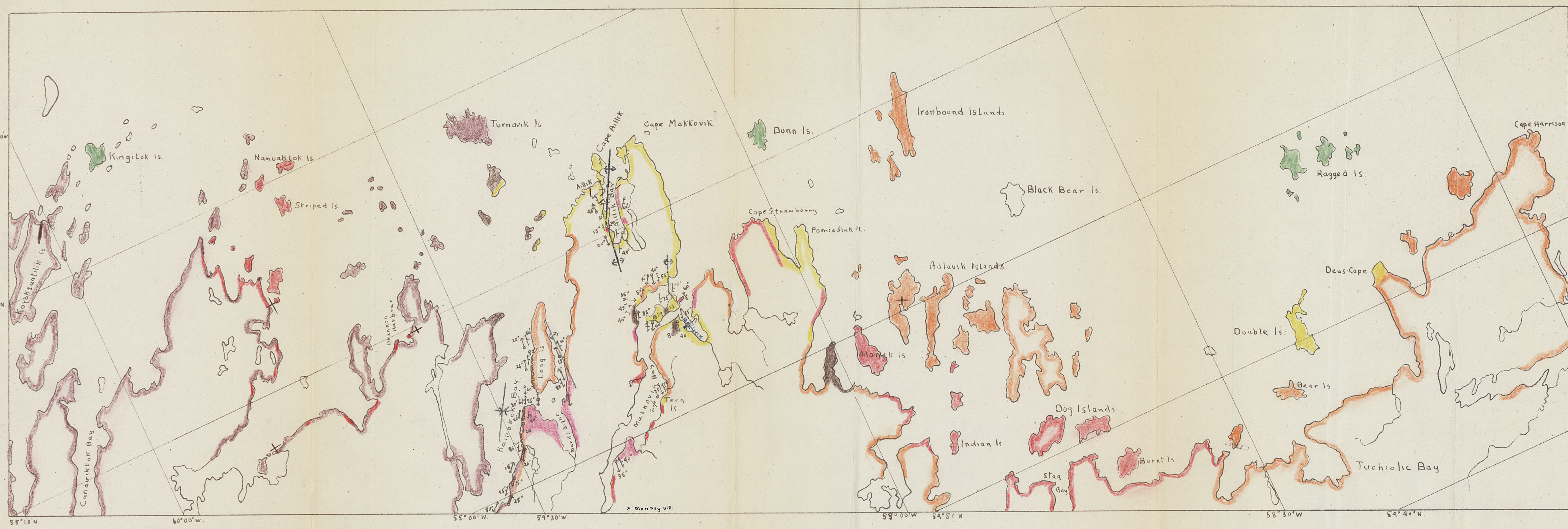


LEGEND

BEDDING	DRAG FOLD
SCHISTOSITY	FAULT
LINEATION	FOLD AXIS

BASIC DYKES AILLIKITE, DIABASE, LAMPROPHYRE, AMPHIBOLITE

STRAWBERRY TYPE GRANITE

SYENITE

MAKKOVIK BAY TYPE GRANITE

HOPEDALE GNEISS

GRANITE GNEISS AND QUARTZITE GNEISS

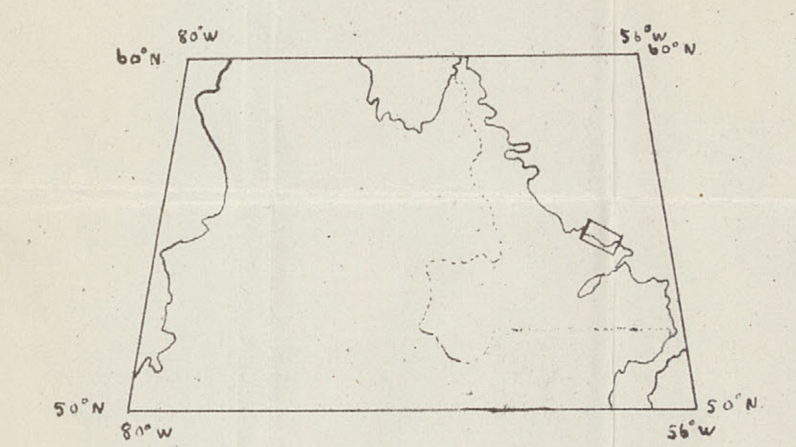
AILLIK SERIES

CAPE HARRISON — KINGITOK ISLAND SECTION

EAST COAST OF LABRADOR

SCALE 4 MILES TO 1 INCH

4 0 4 8 12 16



INDEX MAP

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