A STRUCTURAL REINTERPRETATION OF THE AILLIK SERIES, LABRADOR

A. M. S. CLARK

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by

A. M. S. CLARK

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ABSTRACT

The main body of the Makkovik Peninsula, between Makkovik and Kaipokok Bays, Labrador (latitude 55°N, longitude 59°W), was mapped on a scale of 1 in. to 2000 ft., and microscopic investigation carried out on samples collected in the field, in order to determine the geological history of the Aillik Series.

The structural complexity of the Aillik Series has been shown to be considerably greater than envisaged by previous workers. It has definitely undergone three phases of deformation, and probably more. The occurrence of the first of these three deformations in some of the lithologic units, but not in others, is considered to indicate a post-first deformation age of deposition for the unaffected units. The Aillik Series is thus divided into an older and a younger sequence, both of which have undergone the second and third deformations.

The older sequence consists of very feldspathic, compositionally banded psammites of unknown origin. The younger sequence consists of feldspathic cross-bedded psammite, conglomerate, feldspathic psammite with quartz phenocrysts, and amphibolitised basic pillow lavas. These quartz phenocrysts (which may be of secondary origin) in one psammite unit indicate an association with high-level acid igneous activity. The very feldspathic nature of all of the psammites of both the older and younger sequences also suggests such an association.

The first recognisable deformation, and probably earlier deformations, produced complex compositional banding in the older sequence. The second

deformation caused the transposition of this banding in the older sequence, the production of a penetrative mineral orientation throughout the area in both sequences, and the development of mylonitic banding in some members of both sequences. A large recumbent anticline, numerous small folds, boudins, small slides, and possibly a large slide, were also developed during the second deformation. A large antiform and several minor structures were produced during the third deformation, though only occasionally occurring, imperfectly formed fabrics were developed.

The metamorphic grade during the second deformation was variable. Low amphibolite facies metamorphism affected the whole of the Aillik Series, with higher grade metamorphism occurring in parts of the older sequence.

Early dioritic orthogneiss has been intruded by a pre- or syn-second deformation granitic gneiss. Feldspar porphyritic diorite intrusions and granitic pegmatite veins show second deformation structures. Late-stage basalt, diorite and net-vein diorite intrusions show no deformational structures or fabrics.

The quartzo-feldspathic nature of the rocks, and the lack of acicular or platey minerals, makes evaluation of the structural history extremely difficult. This difficulty is compounded by the late-stage annealing recrystallisation and development of polygonal fabric, which has almost completely destroyed earlier fabrics.

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CHAPTER I

INTRODUCTION

LOCATION

The area is situated on the Labrador Coast between 55° 00' N and 55° 10' N, and 59° 14' W and 59° 25' W. It forms the main body of the peninsula between Makkovik Bay and Kaipokok Bay, (Figs. 1 and 2, and Geological Map in back pocket).

The nearest settlement is Makkovik (population ca. 350), where BRINEX (British Newfoundland Exploration Limited) maintained a supply depot and transportation center.

Makkovik is served during the summer by Canadian National Railways coastal boats which operate out of St. John's and Montreal. During the summer, BRINEX has a float-adapted DeHaviland Otter based at North West River, and a Bell G4 helicopter based at Makkovik. Small boats were hired locally when needed.

PHYSIOGRAPHY

The area has been heavily glaciated resulting in low-lying rounded hills (up to 400' above sea-level) with intervening marshes on glacial till, numerous glacial lakes and occasional higher elongated hills rising to 1000' above sea-level. Vegetation is generally sparse of tundra-type, with taller trees growing in sheltered hollows. Outcrops are abundant, though the lichen-covering and smooth rounded shape of the outcrops does not make their study easy.

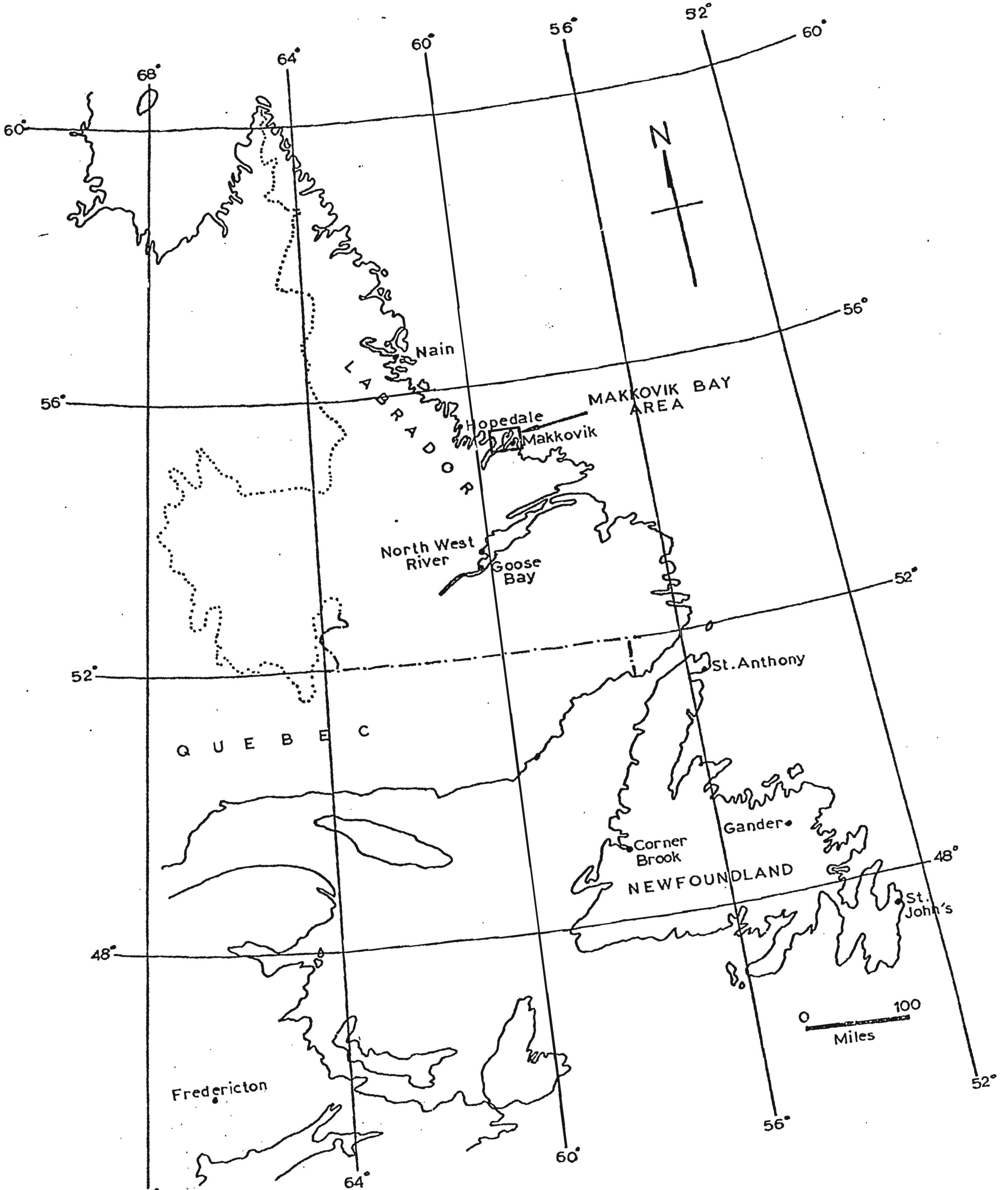


Fig 1: Location Map

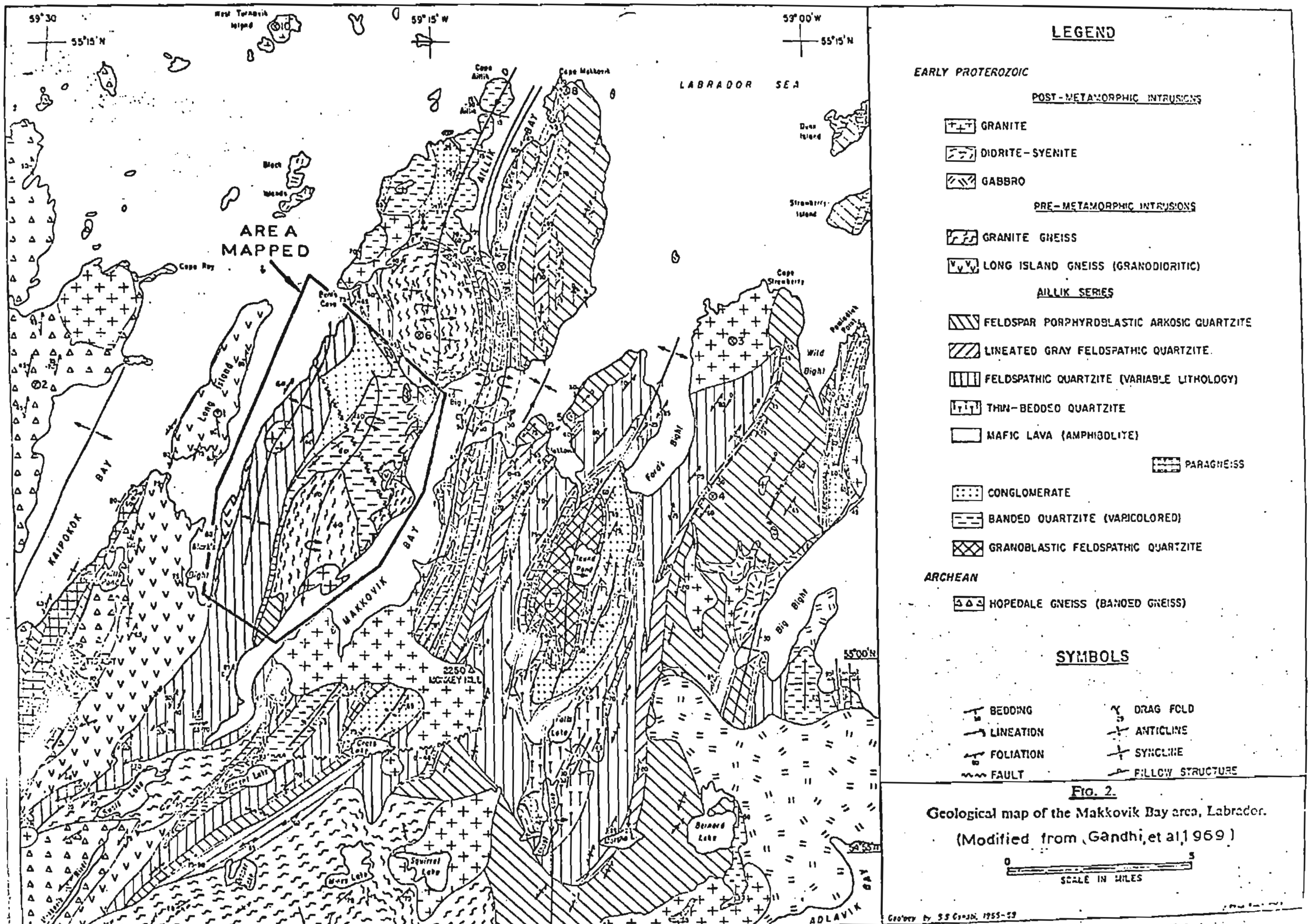


FIG. 2.

Geological map of the Makkovik Bay area, Labrador.

(Modified from Gandhi, et al 1969)

GENERAL GEOLOGY

The Aillik Series is composed of a sequence of metamorphosed psammites, conglomerates, and amphibolitised basic pillow-lavas, which overlie a complexly deformed banded gneiss basement (the Hopedale Gneiss). Structural information suggests the possibility that the Aillik Series may consist of at least two distinct sequences of similar lithologies having different structural histories, which have since been brought into juxtaposition tectonically. The rocks have undergone folding about north/south axes with the formation of a large recumbent fold in the center of the area. They have been faulted and intruded by granitic plutons and a variety of dykes, sills and veins of various ages ranging in composition from gabbroic to granitic and pegmatitic. A mantled granite gneiss dome occurs north of the area, and two intrusive granite gneiss sheets occur within the area. K/Ar age dating (Gandhi, et al, 1969) indicates a pre-Hudsonian age of approximately 1800 m.y. to 1700 m.y. for the basement Hopedale Gneiss (using Stockwell's terminology; Stockwell, 1964), and a Hudsonian age for the metamorphism of the Aillik Series and intrusion of the associated granitic rocks. This was followed by basic and intermediate dyke intrusions of Grenvillian and later age (approximately 1000 m.y. to 950 m.y., and 600 m.y. to 530 m.y.).

PREVIOUS GEOLOGICAL WORK

Early geological work was carried out as part of voyages of exploration along the Labrador Coast by Steinhauer (1814), Lieber (1860), Packard (1891), Daly (as reported by Delabarre, 1902) and others. The observations were scattered along isolated sections of the Labrador Coast and consisted of a few general descriptions of the bedrock geology. Daly's investigations included the rocks of Aillik Bay, where he noted the great number of dykes, and the wide range in composition of the dyke-rocks intruding the sedimentary sequences. The petrology of some diabase dykes was investigated by Wheeler (1933 and 1935).

Kranck (1939, 1953 and 1961) was the first geologist to investigate the Makkovik area in any detail and was responsible for the introduction of the term 'Aillik Series' for the sedimentary rocks of the Makkovik/Aillik area. He describes the structures in these sediments as gentle folding of the bedding, cut by a steep foliation varying from a fracture-cleavage to a well-developed schistosity. Later work has followed closely on Kranck's original outline of the geology.

Three graduate students from McGill University have written master's theses on the Makkovik area: Cooper (1951) investigated the petrology of some syenites and granites, Moore (1951) discussed the igneous dyke-rocks, and Riley (1951) investigated the granites, and to a lesser extent, the sediments of the area.

Large-scale regional geological maps of the Makkovik area with descriptive notes were compiled by Douglas (1953) and Christie, et al. (1953)

for the Geological Survey of Canada. Douglas describes the Aillik Series and the igneous intrusions, and suggests the possibility of the rocks forming the roof of a large batholith. He also noted a small overturned anticline on the west shore of Aillik Bay. Christie describes the whole of the Central Labrador coast very briefly and only mentions the Aillik Series.

BRINEX has been conducting mineral exploration and geological reconnaissance in the Makkovik area since 1953 (Beavan, 1958), and is continuing to do so.

King (1963) completed a master's thesis on the Cape Makkovik peninsula, in which he discusses the lithology of the sediments, their metamorphism and stratigraphic succession, and the emplacement and relative ages of the various dyke swarms of the area. Metamorphism is considered by him to be dependent on the original character of the rock, and foliation as a secondary metamorphic expression of bedding.

Geochronology and radiometric age-dating in Labrador has been carried out by Lowden (1961), Leech, et al. (1963), Stockwell (1964), and Wanless, et al. (1965 and 1967), for the Geological Survey of Canada, and by Grasty, et al. (1969). The Geological Survey reports are generally concerned with the collecting of age-data over the whole Canadian Shield, and the division of the shield into provinces based on these data. This work is well summarised by Stockwell (1968). Grasty, et al. (1969) discuss the repositioning of the Grenville Front from approximately 60 miles south to approximately 80 miles south of Makkovik.

The latest publication on the geology of the Makkovik Bay region

(Gandhi, et al. 1969) contains a comprehensive geological map (Figure 2) and a description of the lithologies, stratigraphy and possible origin of the sedimentary rocks, as well as a description of the igneous rocks of the area. The paper also discusses the relationship of radiometric age-dates to the known geology. The age dates indicate Hudsonian metamorphism of the Aillik Series and intrusion of associated granites, followed by later Grenvillian dykes and sills. He describes the structural features of the Makkovik Bay area as being due to 'a single cycle of orogenic deformation', which produced two broad north/south trending anticlines, one through Round Pond and one through Makkovik Bay, with tight folds between. The Granite Gneiss intrusions west of Makkovik Bay are described as synkinematic core intrusions, and another similar Granite Gneiss body is postulated below the Round Pond anticline. Although S- and L-fabrics and metamorphism are mentioned, they are not considered from the point of view of sequential synkinematic and static growth phases in a series of deformational episodes.

Barua (1969) discusses the geology and mineralisation of the area immediately north of the area covered by this thesis. He suggests a very close relationship between some members of the Aillik Series and acid volcanism. One 'quartzite' unit is considered by him to be a spilitic acid lava and another an acid crystal tuff.

Present and planned research in the vicinity of Makkovik includes: major bedrock and surficial geology features of the northern Labrador coastal area south to Makkovik region (Operation Torngat, Taylor, Geological Survey of Canada); structural and metamorphic studies of the Western Nain province and surrounding rocks (Sutton, Memorial University of Newfoundland);

the relationship of the Aillik Series and the Hopedale Gneiss (Ph.D. study, Marten, Memorial University of Newfoundland); a structural, metamorphic and petrological study of the Naskaupi and older fold belts of the Grenville and Nain provinces (Ph.D. study, Williams, McGill University); anorthosites and calc-alkaline plutonism in the Grenville province (Westall, Queen's University); radioactive age-dating of diabase dykes between Seal Lake and the Labrador coast (Fahrig, Geological Survey of Canada); and a continuation of the present study by the author (Ph.D. study, Memorial University of Newfoundland).

PURPOSE OF PRESENT STUDY

During the summer of 1969, the author was engaged as a field-geologist with BRINEX to map this area on a scale of 1" to 2000', and to determine its economic potential. While engaged in this work, rock samples were collected and a structural investigation was carried out with the prime intention of indicating its structural complexity and, where possible, of evaluating the structural history and styles of deformation. Interpretation was initially based on field observations and mapping, and was continued with microscopic analysis of approximately 100 thin-sections.

CHAPTER II

LITHOLOGY

NOMENCLATURE AND TERMINOLOGY

The lithologic units of the area are similar to those described by Gandhi (1969). (Fig. 2). However, most of the names have been changed since the term 'quartzite' is shown, on microscopic examination, to be incorrect as none of these rocks contain more than 80% quartz (Williams, et al., 1958). The term 'arkose' implies a sedimentary origin, for which there is no evidence at present in the area. These terms are replaced by 'psammite', which is here used in the sense of a quartzo-feldspathic rock, with no genetic implications (cf. Kennedy, 1955). The correlation of these terms is given below:

Gandhi (1969)	This Thesis
Mafic Lava (Amphibolite)	Amphibolite
Feldspar Porphyroblastic Arkosic Quartzite	Porphyroclastic Psammite
Conglomerate	Conglomerate
Banded Quartzite	Cross-Bedded Psammite Banded Psammite
	Biotite-Hornblende-Feldspar Rock
Feldspathic Quartzite (Variable Lithology)	Variable Psammite

Gandhi's terms for the different intrusive rocks have been retained.

'Amphibolite' is reserved for metamorphosed (amphibolitic) basic lavas. Other amphibolitic basic rocks are specified, e.g. amphibolite dyke.

HOPEDALE GNEISS

The Hopedale Gneiss does not outcrop in the area mapped but is extensive west of it (Fig. 2). It appears to form the basement to the Aillik Series, and is a black and white banded (2 ins. to 4 ins.) gneiss (Fig. 3), showing at least three stages of deformation since the formation of the banding. Refolding of this banding has formed interference patterns of Types 1 and 3 (Ramsay, 1967), as well as other simpler folds.

The dark bands are composed primarily of medium-grained biotite imparting a schistosity parallel to the banding. A later S-fabric of quartz stringers and biotite is incipiently developed at the hinges of folds (Fig. 4). The light bands are composed of medium to coarse-grained quartz, microcline and plagioclase. The bulk composition of the gneiss is approximately 20% quartz, 25% microcline microperthite, 45% plagioclase (oligoclase/andesine), and 10% biotite, with minor opaque minerals, apatite and chlorite (after biotite), (see Appendix). Myrmekitic intergrowth is common.

AILLIK SERIES

The Aillik Series is divided into an older and a younger sequence. This division is based on the occurrence of early fabrics and structures in the older sequence and the absence of these fabrics and structures in the younger sequence (Chapter III).

Figure 3: Hopedale Gneiss, Kaipokok Bay coast near Kitts Pond.

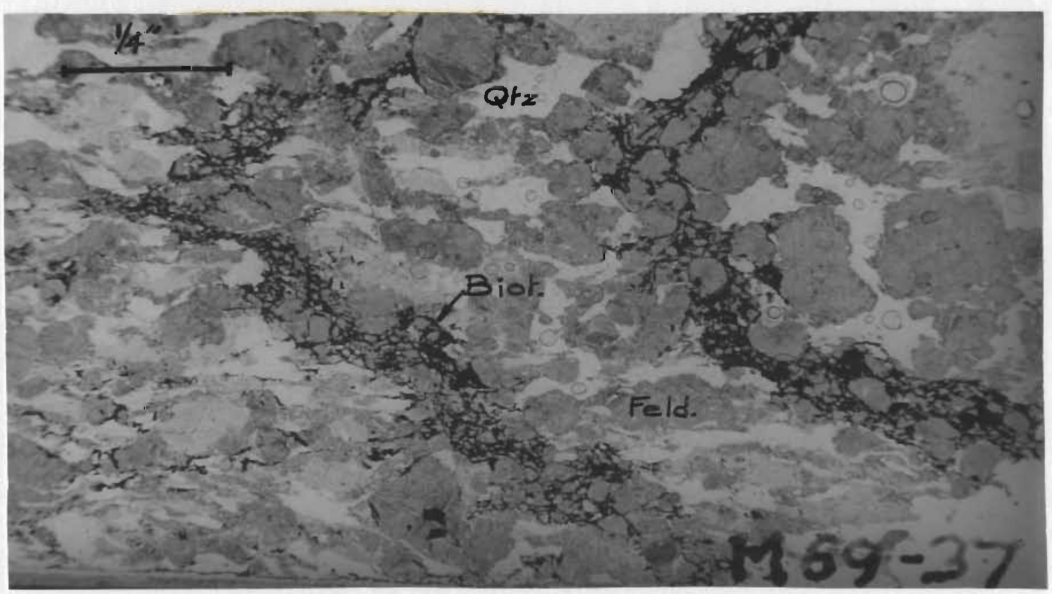


Figure 4: Hopedale Gneiss. Note axial plane orientation of quartz stringers and some biotite flakes. (Stained section, unpolarised light). (Quartz - white; Feldspar - grey; Biotite - black).

Older Sequence

The stratigraphic order of the older sequence is not known. However, the Banded Psammite appears to occur at a higher structural level than the Biotite-Hornblende-Feldspar rock, which structurally overlies the Variable Psammite.

Unit	Sub-Division	Approx. Thickness
Banded Psammite	Black and white banded psammite	20 ft.
	Grey-green banded psammite	30 ft.
	Grey biotite psammite	50 ft.
	Dark grey banded psammite	10 ft.
Biotite-Hornblende-Feldspar Rock		500 ft.
Variable Psammite		1400 ft.

Banded Psammite

Between Kennedy's Cove and Big Head, banded psammites are exposed that show no sign of sedimentary features, though 1/4 in. banding is well developed. These psammites are interleaved with a conglomerate unit.

Four different types of psammite are found within a distance of 500 feet, and because of the different mineralogical and structural types, will be considered individually:

(a) Black and white banded psammite.

Within the conglomerate a bed of fine-grained black and white to grey 1/4 in. banded psammite occurs. The banding is formed of quartz-microcline rich layers and chlorite-epidote-muscovite rich layers. The rock does not contain any plagioclase (see Appendix). Some of the microcline is weakly perthitic. Orthite (yellow brown, Bx-ve, 2nd. order bir.) occurs as cores to the epidote (Figure 5), and chlorite is derived from biotite. Sphene, dark green hornblende and opaque minerals occur in minor amounts. Muscovite is associated with patches of sericite.

(b) Grey-green banded psammite.

On the southern edge of the conglomerate is a fine-grained grey and green banded psammite. The banding is shown by intensely saussuritised andesine-rich layers, recrystallised unaltered microcline-quartz-biotite layers in which the quartz occurs primarily as inclusions in the microcline, and quartz-albite-biotite layers (Figs. 36 and 41). The difference in alteration of the plagioclase is probably due to the difference in plagioclase composition in the different layers (see Appendix).

(c) Grey biotite psammite.

Approximately 300 feet further south, a grey fine-grained thinly-banded psammite occurs. The banding is of quartz-albite-biotite in 1/4 in. layers, separated by thinner biotite-rich layers (Figs. 35 and 46). There is no K-feldspar (see Appendix). Biotite is partially altered to chlorite.

(d) Dark grey banded psammite.

At Kennedy's Cove, and also south of Big Head, are outcrops of a dark grey banded (1/4 in.) rock composed mainly of albite (40%), with about 25% biotite, 25% microcline and 0-15% quartz (see Appendix). Very fine myrmekite is developed in places. The banding is due to an increase in microcline, biotite and opaque minerals in the dark bands. These rocks

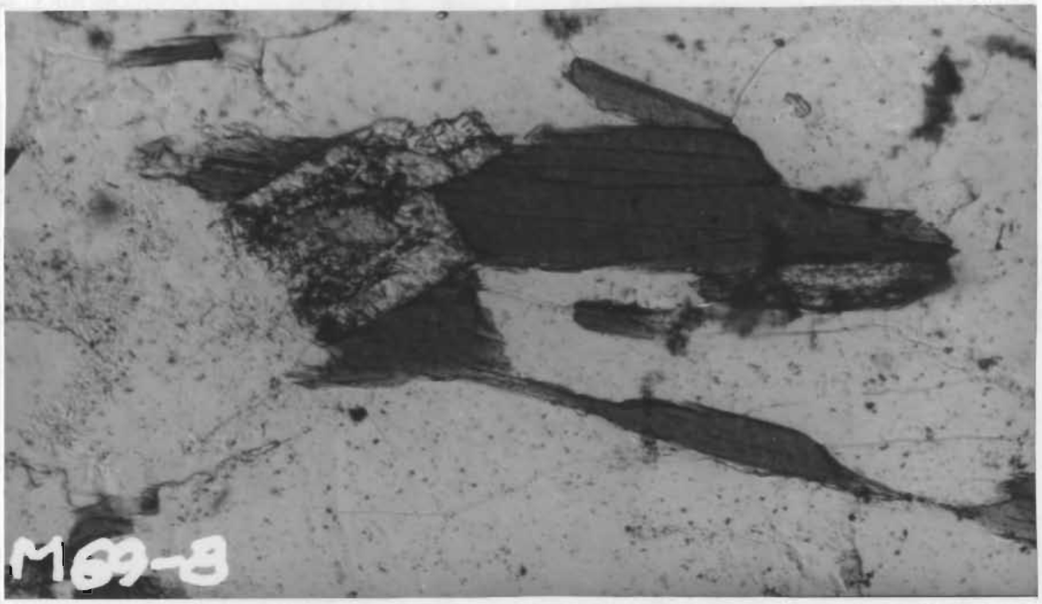


Figure 5: Orthite core in epidote, in Banded Psammite. Orthite rimmed by epidote, and set in biotite. Note euhedral epidote where protected by biotite, and corrosion of epidote where not protected. (Plane polarised light, X 192).

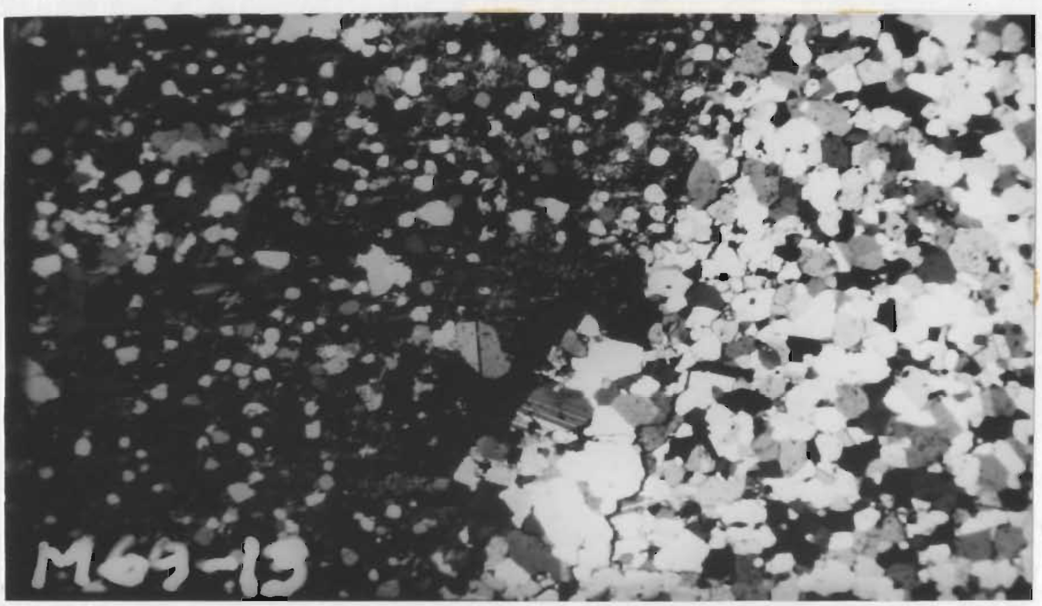


Figure 6: Microcline porphyroblast in Variable Psammite. Late stage microcline porphyroblast (left half of photo), with numerous small inclusions. (Crossed Nicols, x 12).

may represent metamorphosed diorite dykes, but because of lack of genetic evidence they are included in the Banded Psammite.

In several members of the Banded Psammite sequence (and also in the Variable Psammite), epidote rims around orthite are seen in biotite (Fig. 5). Since the orthite/epidote boundary is very sharp in almost all cases, the epidote probably formed around the orthite and is not developed from the orthite. Euhedral epidote occurs in a variety of orientations with respect to the biotite indicating the biotite is later than the epidote (i.e. epidote is not replacing biotite). Since the growth of the biotite, the epidote has started to be corroded, as shown by the retention of euhedral outline where protected by biotite, and the loss of euhedral outline where it is in contact with the matrix. Very similar orthite, epidote and biotite overgrowths are reported from granitic rocks in Maryland (Hopson, 1964), where the orthite is reported as euhedral, shows sharp contacts with the epidote rims, and both orthite and epidote are of primary igneous origin having later biotite overgrowths.

Biotite-Hornblende-Feldspar Rock

This unit is formed of 2 ins. to 6 ins. wide hornblende-rich and biotite-rich bands and occurs between the Conglomerate and the Variable Psammite due west and southwest of Astrodome Lake. It is composed of 10% biotite, 10% quartz, 25% microcline, 40% oligoclase/andesine, and 15% hornblende. The hornblende-rich bands contain up to 35% hornblende, 55% oligoclase/andesine, negligible biotite and no K-feldspar (see Appendix).

Variable Psammite

The Variable Psammite sequence consists of a variety of quartzo-feldspathic rocks. These psammites are probably of sedimentary origin though they have been intensely deformed and no sedimentary features are preserved.

The predominant rock-type is a mauve, grey or buff-yellow fine-grained indurated psammite with bands formed of pink 1/4 in. by 2 in. elongate or discoid feldspar aggregates (Fig. 43). Large (up to 1 in. diameter) late-stage microcline porphyroblasts are common and overgrow the earlier fabric (Fig. 6). The psammite is composed of approximately 20% quartz, 35% microcline and 40% plagioclase (both albite and oligoclase/andesine), and minor hornblende, (partially altered to chlorite), opaque minerals, biotite and sphene (see Appendix).

Four ft. wide fine-grained, light grey, slightly calcareous friable quartzo-feldspathic bands occur in the vicinity of Saline Lake, and also south of Bent's Cove. They contain 1 in. diameter pink microcline porphyroblasts and 1 in. diameter calcite-magnetite blebs. Smaller (1/2 in. wide) calcite-rich bands are also seen.

Occasional fine-grained black and white banded (1/4 in.) psammites showing intrafolial folding occur as 2 ft. to 4 ft. wide bands. A 4 in. wide pebble-conglomerate band with flattened pink, fine-grained quartzo-feldspathic pebbles was noted in one of these bands.

On the hill northeast of Saline Lake, 1/4 in. by 2 in. cummingtonite-calcite-microcline aggregates occur in the psammite. Also, in the vicinity, 3 ft. by 1 in. dark grey, fine-grained, platey structures occur. These structures are thought to be mud-plates and are similar in appearance to structures in the Cross-Bedded Psammite (Fig. 9).

Younger Sequence

The stratigraphic order of the younger sequence was determined from younging directions in the Cross-Bedded Psammite and Amphibolite:

Unit	Approx. Thickness
Amphibolite (youngest)	20 - 100 ft.
Porphyroclastic Psammite	100 ft.
Conglomerate	500 - 6000 ft.
Cross-Bedded Psammite (oldest)	500 - 2000 ft.

Cross-Bedded Psammite

The Cross-Bedded Psammite sequence occurs in a broad belt in the center of the area. It has been folded into a large recumbent fold, which has a core of Granite Gneiss. The base has not been seen, but the thickness down to the gneiss core is approximately 2000 feet. Good preservation of cross-bedding with no apparent distortion in most of the area suggests little deformation. However, west and south of Astrodome Lake the overlying conglomerate shows intense stretching and the thickness of the psammite unit decreases to 500 feet. Near Bent's Cove, associated conglomerates are strongly flattened.

The sequence consists, for the most part, of interlayered 1 in. to 4 ft. dark and light grey, fine-grained quartzo-feldspathic beds which locally show sedimentary features such as ripple-marks, load-casts, and flame-structures (Fig. 7).

The rock is composed of 20% quartz, 15% microcline and 50% albite, with minor pale green hornblende, phlogopite, opaque minerals, garnet and sphene, (see Appendix). In Gilbert's classification (Williams, et al., 1958), it is an arkosic arenite. However, the percentage of feldspars is very much higher than normally found in arenites, and the rock composition falls into a group of rare rocks of volcanic origin (Williams, et al., 1958), suggesting the possibility of a pre-existing volcanic terrain. The darker bands are due to a decrease in grain-size, and the concentration of opaque minerals, sphene and phlogopite. Albite and quartz porphyroblasts are developed in the darker bands. Within the sequence, especially towards the upper stratigraphic contact with the conglomerate to the west, an increase in cross-bedded members occurs. These members are usually of the order of 6 inches in thickness, but occasionally occur up to 3 feet thick (Figs. 8 and 33). These cross-bedded members are richer in calcite (up to 20%), pale green epidote (up to 5%, often with cores of yellow-brown orthite), and garnet (up to 10%).

In the vicinity of Astrodome Lake, the psammites are slightly coarser grained, and contain more microcline and sphene than further north. Biotite has almost completely altered to chlorite, and polygonal quartz and feldspar fabrics are better developed. In hand specimen, the rocks are pale pink in colour, increasing in pink and green colour and induration towards the Granite Gneiss contact at the southern edge of Astrodome Lake. This is due to an increase in fine-grained green hornblende, green biotite and garnet.

Figure 7: Load-casts and flame-structures in Cross-Bedded Psammite.

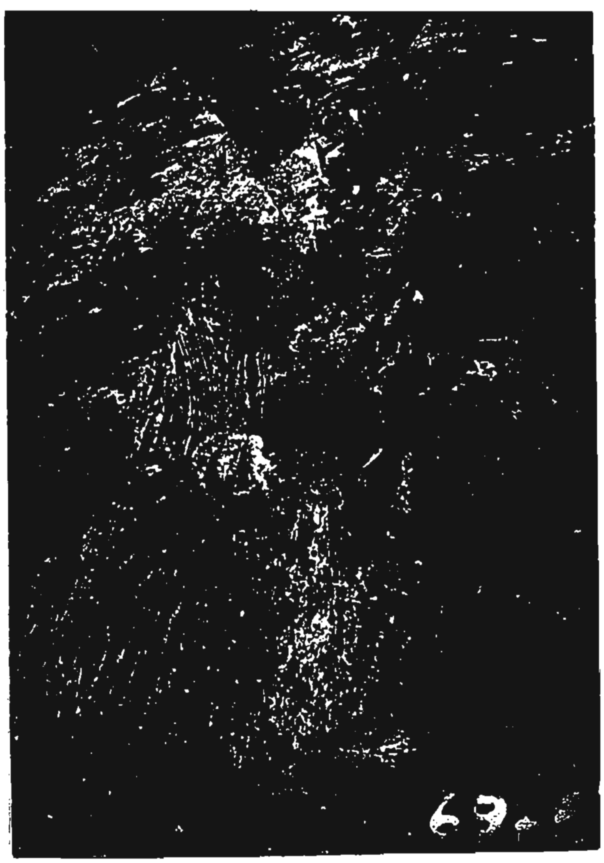


Figure 8: Cross-bedding in Cross-Bedded Psammite, near conglomerate contact southeast of Saline Lake. Youngs to the left (westward).

At the outlet to Kidney Lake, a grey psammite unit contains darker grey to black hornblendic plate-like shapes approximately 6 ins. to 1 ft. long and 1/2 in. to 1 in. wide which appear to be broken mud-plates incorporated in a sandstone bed on slumping (Fig. 9). Similar 'plates' occur on the ridge between Kidney Lake and High Point.

Conglomerate

The Cross-Bedded Psammite is apparently conformably overlain by Conglomerate, and they interfinger in the vicinity of the contact.

The boulders in the Conglomerate range in size from approximately 1 in. to 4 ft. in diameter, with the commonest size-range from 4 ins. to 1 ft. The boulders are sub-rounded, though platey blocks occur. They are poorly packed, and often completely surrounded by fine-grained grey quartzo-feldspathic matrix (Fig. 10). Though no definite size grading was seen, pebble-beds are frequent in the vicinity of the contact with the Cross-Bedded Psammite, the pebbles being sub-rounded to rounded and approximately 1 in. in diameter.

The conglomerate is composed of the following pebbles and boulders:

40% medium-grained psammite, slightly calcitic, with 1/4 in. banding, often showing cross-bedding and slump-features (Figs. 10 and 11). These boulders appear identical to the cross-bedded units of the Cross-Bedded Psammite, and are thought to have been derived from them. There is no sign of any pre-depositional S- or L-fabric, or metamorphism in the boulders.

20% very fine-grained, dark grey pebbles similar in appearance to the dark bands in the Cross-Bedded Psammite.

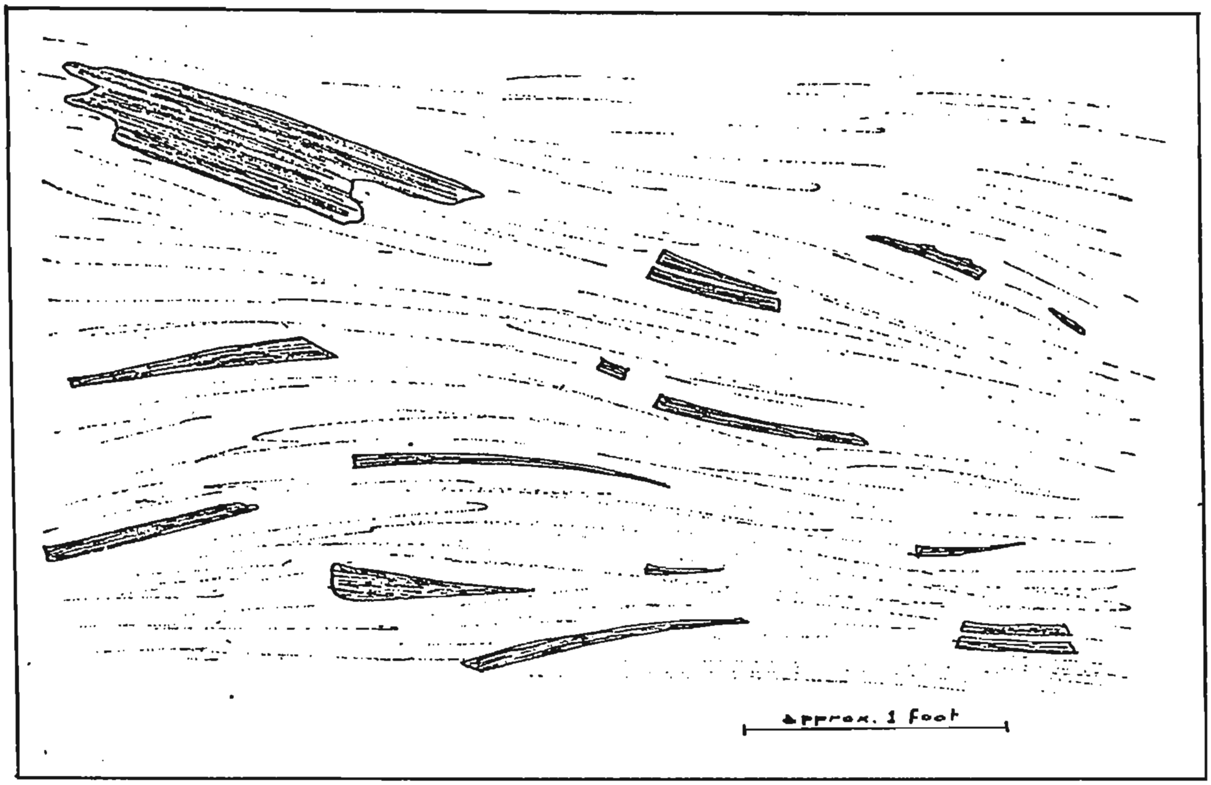


Figure 9: Mud-plates (?) in Cross-Bedded Psammite at exit from Kidney Lake. (Sketched in field).

Figure 10: Conglomerate, southeast of Saline Lake. Note cross-bedding in large boulder to right-center of photograph.

Figure 11: Conglomerate, southeast of Saline Lake. Note slump-folds in boulder to top-left of photograph.

20% white, pink, mauve and light grey fine-grained quartzo-feldspathic pebbles.

20% fine to medium-grained pink granitic pebbles with little or no mafic minerals; medium to coarse-grained pink-orange granite-gneiss with hornblende and/or biotite; medium-grained pale yellow micaceous psammite showing mineral banding and a later, cross-cutting S-fabric; fine-grained amphibolite; white quartz; red and black cherty massive and banded ironstones; and conglomerate boulders with calcitic matrix (Fig. 12). All the S- and L- fabrics in these pebbles and boulders are pre-depositional.

Towards the north, the percentage of psammite boulders decreases, and the percentage of conglomerate boulders increases.

In the vicinity of Astrodome Lake, and at Kennedy's Cove, the pebbles and boulders are smaller (2 ins. to 4 ins. diameter) and the matrix is highly hornblendic (Figs. 29 and 30). A pebble band with 1/2 in. pebbles occurs on the south side of the Kennedy's Cove conglomerate. At Bent's Cove, garnet blebs up to 1 1/2 ins. diameter occur together with aggregates of epidote and bundles of actinolite needles which appear to have formed from the matrix. Inclusions in the garnet show no preferred orientation.

The composition of the pebbles in the conglomerate indicates derivation from various quartzo-feldspathic rocks, some of which had undergone at least one deformation. Other rock-types incorporated in the conglomerate include: fine-grained amphibolite, ironstones, pebble

Figure 12: Conglomerate boulder in Conglomerate, Bent's Cove. Note flattening of smaller pebbles.

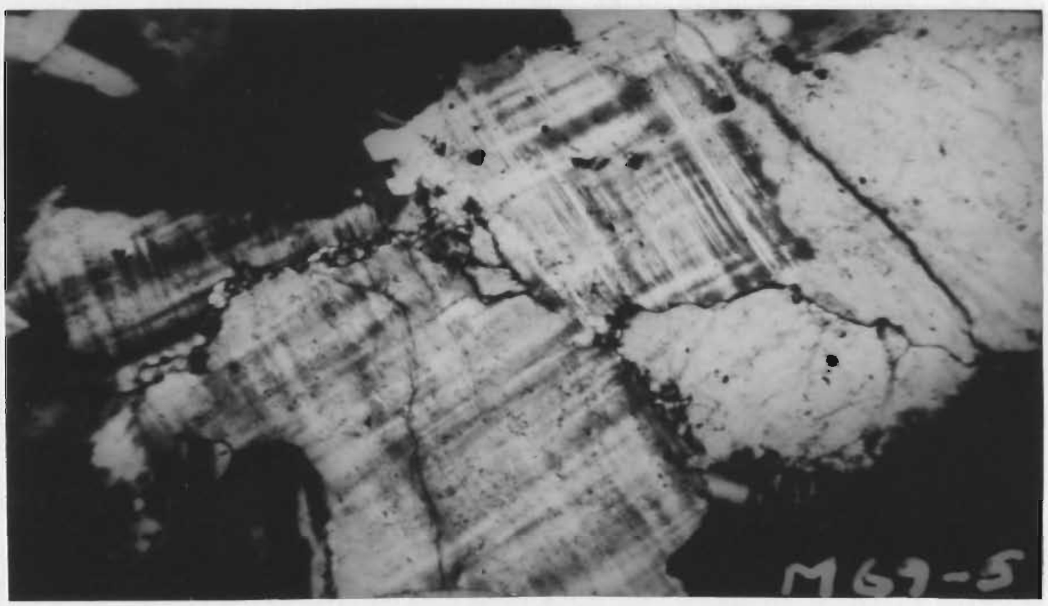


Figure 13: Crush boundaries to microcline grains in Porphyroclastic Psammite, northwest of Big Head. (Crossed Nicols, x 590).

conglomerate with calcitic matrix, granite and granite-gneiss. This variety suggests a very similar lithological assemblage to the younger rock-types of the area, and there is the possibility that some of these units have been mapped as part of the younger sequence within the Aillik Series. The dominance of boulders which closely resemble the Cross-Bedded Psammite possibly indicates a local derivation for parts of the conglomerate. The apparent complete lack of boulders of Hopedale Gneiss suggests an extensive cover to the basement prior to formation of this conglomerate.

The maximum thickness of the undeformed Conglomerate (east of Saline Lake) is 6000 ft. The Conglomerate thins out to approximately 500 ft. north towards Bent's Cove and south of Astrodome Lake. In both directions tectonic flattening and stretching are the probable main causes of thinning.

Porphyroclastic Psammite

The Porphyroclastic Psammite consists of a number of slightly different units, spacially separated and not seen in contact with one another. The units all structurally overlie the Cross-Bedded Psammite, though the contact was not seen.

North and northwest of Big Head is a pink, fine to medium-grained psammite, composed of 30% microcline, 30% quartz and 40% andesine (see Appendix). Within the unit are 1/4 in. diameter lens-like aggregates of biotite, (partially altered to chlorite), opaque minerals and sphene. Aggregates of larger microcline grains form lenses and stringers and are thought to have been formed by the breakdown of porphyroclasts. The microclines, especially the larger grains, show crushed, recrystallised boundaries (Fig. 13), and several crush-bands cut through the rock. Grain boundaries are generally serrate to interlocking, but monomineralic quartz aggregates show polygonal fabric. Small amounts of zircon, some of which is euhedral, occur in the groundmass.

Approximately 8000 ft. southwest of Big Head, a large fault zone contains a very fine-grained pale pink cataclasite(?) in which are contorted bands of opaque minerals and small slickensided surfaces. The rock is composed of very fine-grained quartz (40%), microcline (30%), and albite (20%), in which occur lenses and aggregates of larger microcline and quartz grains with interlocking and sutured boundaries. The groundmass shows well-developed polygonal fabric. The quartz aggregates often show one or two straight sides, and one shows a well-developed hexagonal outline (Figs. 14 and 15), indicating recrystallisation of phenocrysts. Fine-grained epidote (10%), and minor anthophyllite, sphene, opaque minerals and yellow-brown garnet occur in streaks and clusters. Most of the albite occurs in aggregates around epidote clusters. A rock of similar appearance and composition occurs north and northwest of Big Head and is considered to be another outcrop of the same unit.

South of Big Head, a small occurrence of grey Porphyroclastic Psammite shows a very well-developed polygonal fabric in the groundmass, in which aggregates of larger intergrown quartz grains occur. Some of the quartz aggregates have square or rhombic outlines. The rock is composed of 60% albite, 30% quartz and 10% hornblende, with negligible amounts of microcline. The small hornblende grains are arranged in long sub-parallel

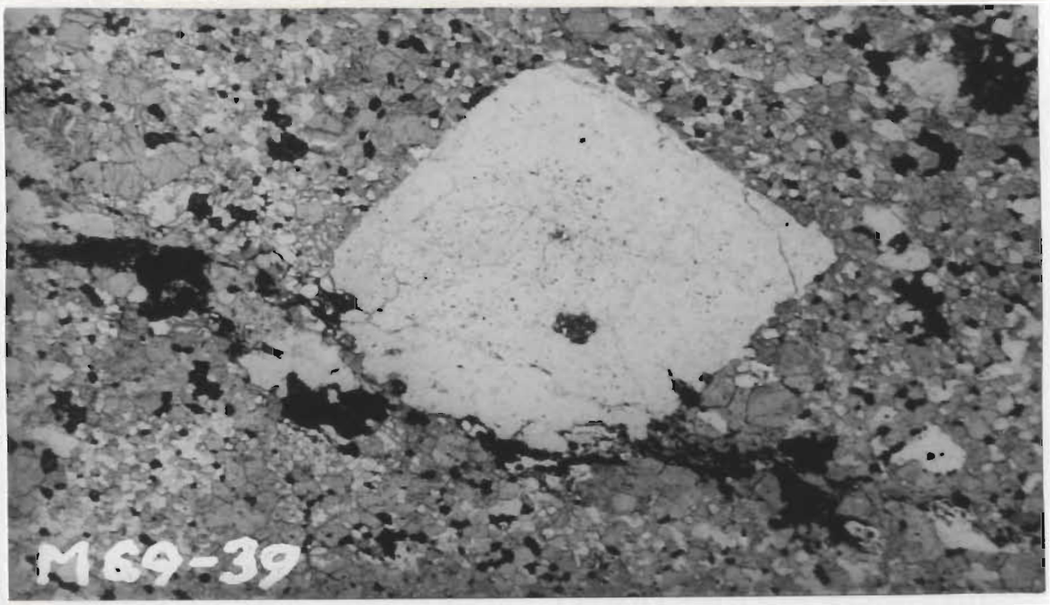
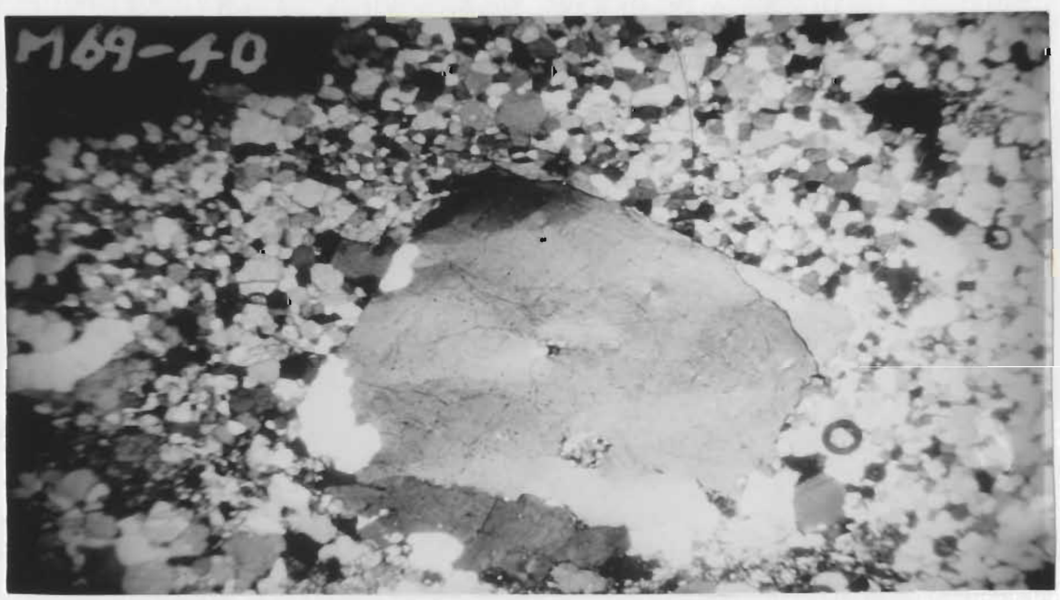


Figure 14: Recrystallised quartz phenocryst, in Porphyroclastic Psammite. (Above - Plane polarised light; Below - Crossed Nicols; Stained Section, x 30).



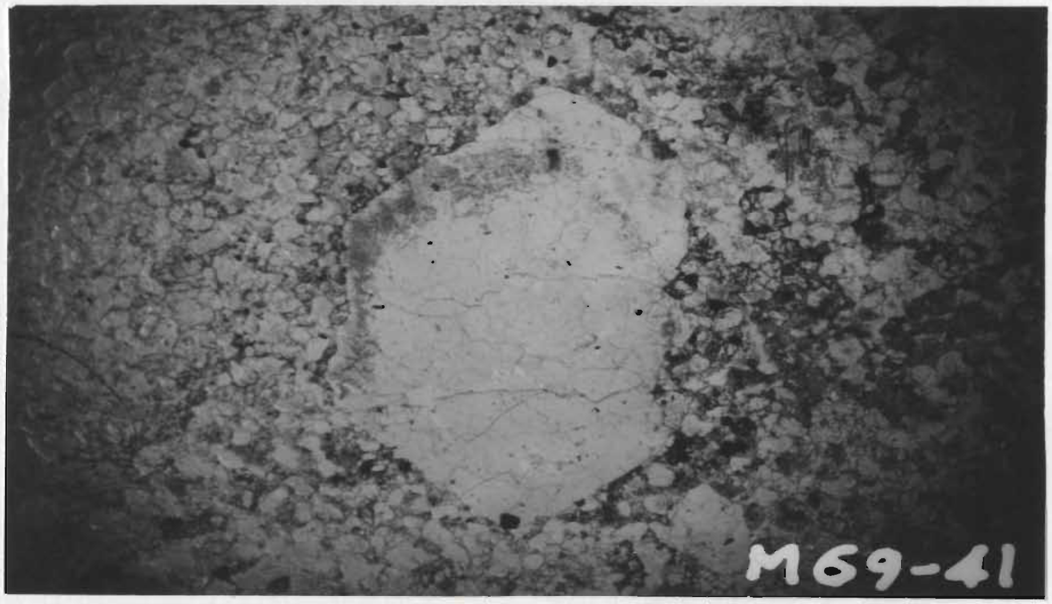


Figure 15: Recrystallised quartz phenocryst, in Porphyroclastic Psammite. (Above - Plane polarised light; Below - Crossed Nicols; Stained section; x 30).

lines along micro-fractures, and also as large aggregates. The rock is cut by a 1/4 in. quartz-rich band, possibly intrusive, in which the fine quartz grains have sutured boundaries, and are elongated parallel to one another and at a small angle to the vein walls. Late stage fractures contain fibrous chloritoid(?) as an alteration product of hornblende. A very similar lithologic unit occurs on the east flank of the hill due west of Middle Head.

Pure white fine-grained psammite with larger (1 mm.) quartz aggregates occurs immediately below the amphibolite north of Long Point Cove and at the outlet of Kidney Lake. The rock is composed of quartz (40%), microcline (30%), and oligoclase (25%). Some of the quartz aggregates have a square to rhombic outline. A large amount of sphene (5%) and garnet (5%) occurs as very fine grains. Aggregates of sphene appear to have acted as nuclei for the formation of garnet which often completely surrounds sphene cores. Garnet has also nucleated on quartz/quartz grain boundaries (Fig. 16). The outer edges of the larger garnets are free of inclusions indicating slower growth and concomitant expulsion or absorption of inclusions (Fig. 17), possibly due to a decrease in available material to form the garnets (Sturt et al., 1961).

Most of the above units contain square to rhombic outlined quartz aggregates, and one hexagonal outlined quartz aggregate was seen. These are euhedral quartz crystals that have recrystallised in response to strain. Since quartz only forms euhedral crystals under magmatic conditions they must have been phenocrysts. However, whether these rocks are high-level intrusives or extrusives, or whether they are sediments derived from a nearby igneous

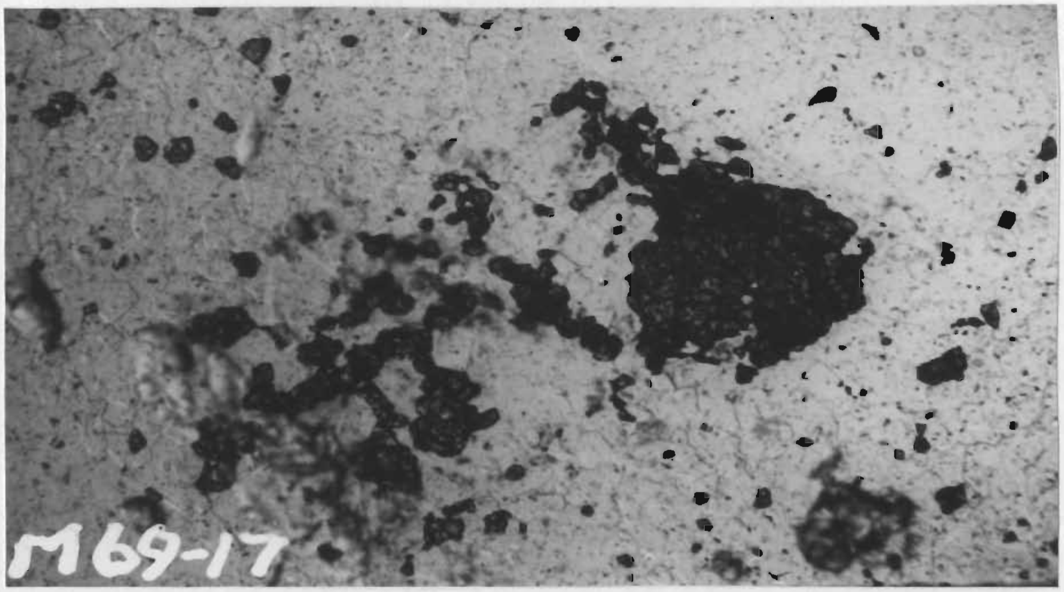


Figure 16: Skeletal garnet in Porphyroclastic Psammite. Garnet growing at quartz intersections. (Plane polarised light, x 285).

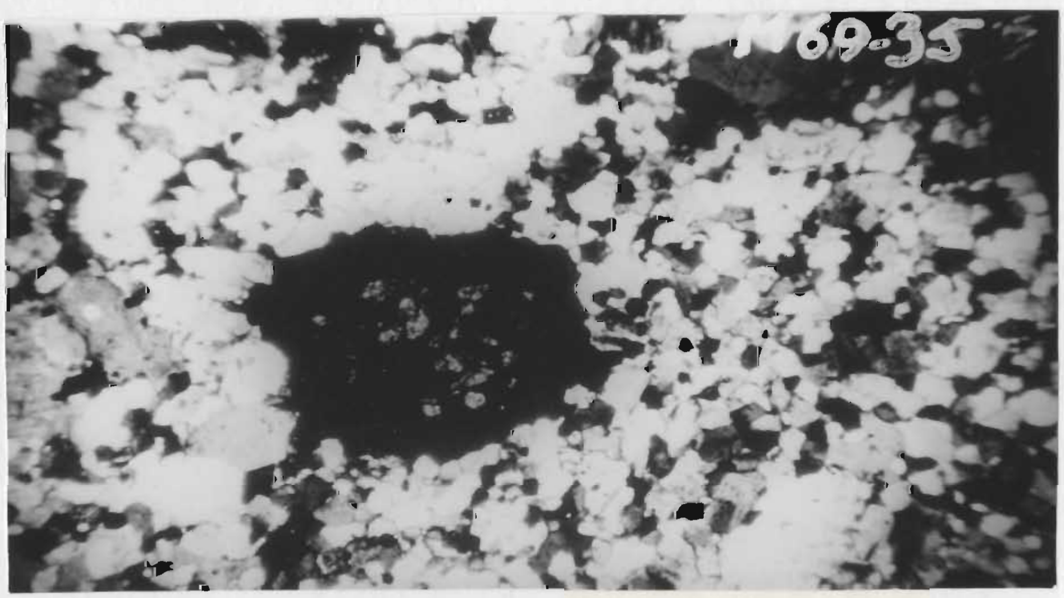


Figure 17: Garnet aggregate around sphene core in Porphyroclastic Psammite. (Crossed Nicols, x 114).

terrain cannot at present be determined. They do indicate, though, that there was an early stage of high-level acidic igneous activity, possibly with associated volcanism.

Amphibolite

Overlying, and possibly interbedded with, the Porphyroclastic Psammite and Cross-Bedded Psammite in the east is a series of amphibolitised basic pillow-lavas (Fig. 18). The Amphibolite is fine to medium-grained and is composed of 50% to 60% dark green hornblende, 40% oligoclase/andesine and up to 10% biotite. The interstices between pillows are filled with fine-grained light green epidote-rich material. On Long Point hill, the pillows show a very well-developed chilled margin. They are generally not noticeably deformed, though a weakly to strongly developed penetrative S- and L-fabric is seen. The fabric becomes very strongly developed towards Big Head and Kennedy's Cove, where the pillows are flattened to approximately half their normal thickness.

On the northwest flank of Long Point hill, pillows lie directly on Cross-Bedded Psammite. The pillows are approximately 1 ft. long by 6 ins. thick at the contact, and are very much smaller and more flattened than higher up in the unit.

A 4 ft. wide unit of dark grey, fine-grained psammite containing approximately 1 in. diameter elongate flattened hornblende blebs occurs immediately below pillow-lavas and above the Cross-Bedded Psammite on top of Long Point hill. As the blebs are not interconnected, they are thought to be lapilli (Figs. 19 & 20). In this vicinity, in between the pillows, are several 1 ft. long spindle-shaped epidote-rich blebs, which may be volcanic bombs.

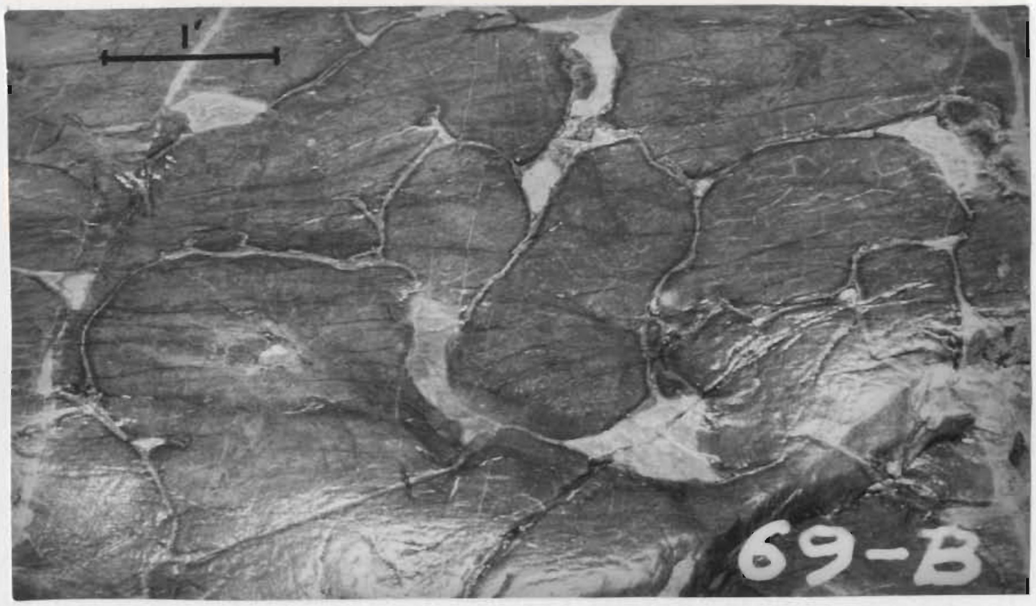


Figure 18: Amphibolitized pillow-lavas, on coast south of Big Head. Note tops facing towards top of photograph, epidote-rich material in pillow interstices, and poorly developed S-fabric across photograph.

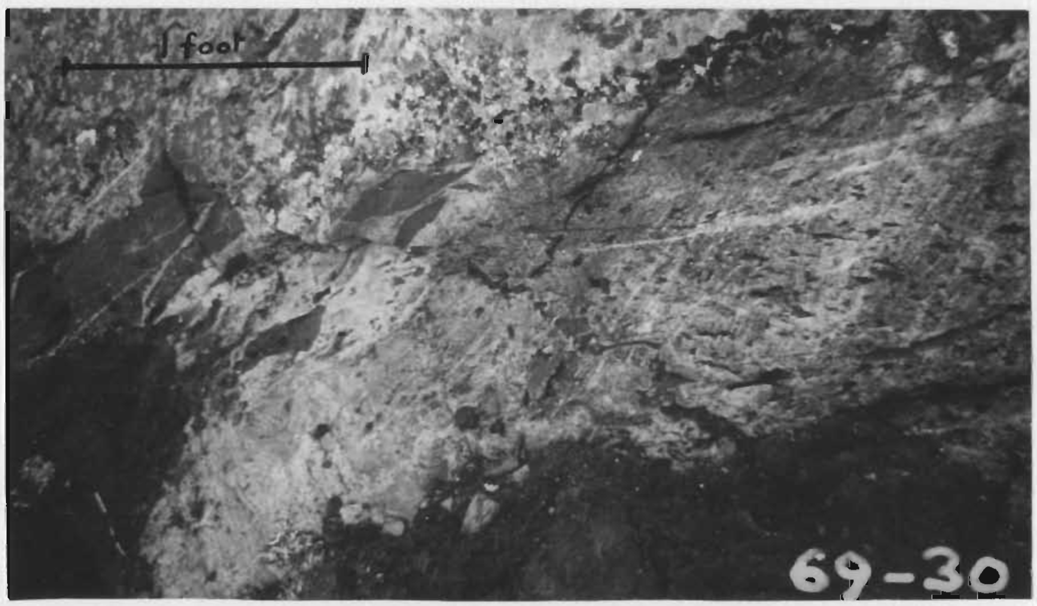


Figure 19: Lapilli deposit (to right hand side of photograph), overlain by pillow-lavas (extreme left of photograph), and intruded by Granite Gneiss (top left of photo). Top of Long Point hill.

Figure 20: Lapilli deposit. Hand-specimen, coin is approximately 1/2 in. diameter.

Figure 21: Hopedale Gneiss (?) xenoliths in Long Island Gneiss, Mark's Bight.

INTRUSIVE ROCKS

Long Island Gneiss

The Long Island Gneiss is a medium-grained grey to white hornblendic gneiss of quartz-monzonitic composition, and usually contains small (up to 4 ins.) amphibolitic inclusions. The gneiss is primarily grey with 1/4 in. to 1/2 in. hornblende needles, and is formed of approximately 20% microcline, 40% oligoclase and 20% quartz, with 5% blue-green (possibly sodic) hornblende, 10% brown-green biotite, and minor sphene and opaque minerals. The microcline is perthitic. The oligoclase occurs as groundmass and as aggregates of larger grains which show weakly developed normal and reverse zoning. The only alteration is saussuritisation of the cores of plagioclase crystals. In the vicinity of Mark's Bight, the Long Island Gneiss contains 4 ft. xenoliths similar to the Hopedale Gneiss (Fig. 21).

South of the area, at Swell Lake, the Long Island Gneiss is finer grained and white to pale buff coloured with stubby, poorly aligned hornblende crystals and many small (1 in.) hornblendic inclusions. It is intruded by Granite Gneiss. On Long Point hill a gneiss of similar appearance is also intruded by Granite Gneiss and is considered to be a variant of Long Island Gneiss. Northwest of Long Point Cove, Long Island Gneiss is seen to intrude Amphibolite.

The gneiss from Long Point hill shows crushing between grains and serrate grain boundaries, while the gneiss from the Kaipokok Bay coast shows fairly well-developed polygonal fabric of both the groundmass and larger aggregates. The gneiss has the uniform composition of an intrusive igneous rock, and is here considered as an orthogneiss.

The main body of Long Island Gneiss on the Kaipokok Bay coast is in contact with a flattened highly hornblendic pebble (?) band, composed of black hornblendic pebbles (?) in a lighter grey, very fine-grained quartzitic matrix, (Fig. 22). The origin of the band is not known. However, it is closely related to the Long Island Gneiss as it occurs on the eastern side of the gneiss throughout its length in Kaipokok Bay, and regardless of the rock-type to the east.

Granite Gneiss

The Granite Gneiss occurs in two major bodies, as an apparent sheet-like structure in the core of the recumbent fold, dipping approximately 20° eastward, and as another sheet-like structure forming Long Point hill, and dipping approximately 30° eastward.

The Granite Gneiss forming the core of the fold is a coarse-grained pink to orange quartz-feldspar-biotite gneiss of granitic composition (Figs. 24 and 49), which is structurally underlain to the west of Astrodome Lake by overturned Cross-Bedded Psammite. It is composed of approximately 40% quartz, 35% microcline and 15% plagioclase (albite/oligoclase), with between 10% and 20% brown biotite and/or dark green hornblende. Towards the Makkovik Bay coast hornblende increases and biotite decreases in amount. Accessory minerals include euhedral zircons and opaque minerals. Alteration is generally slight, but towards the Makkovik Bay coast alteration increases. Chlorite, actinolite, and opaque minerals are developed from biotite and hornblende, and plagioclase is saussuritised. Microcline is perthitic.

Cross-Bedded Psammite to the west of Long Point hill dips eastwards at approximately 70° into the Granite Gneiss, which cross-cuts the beds.

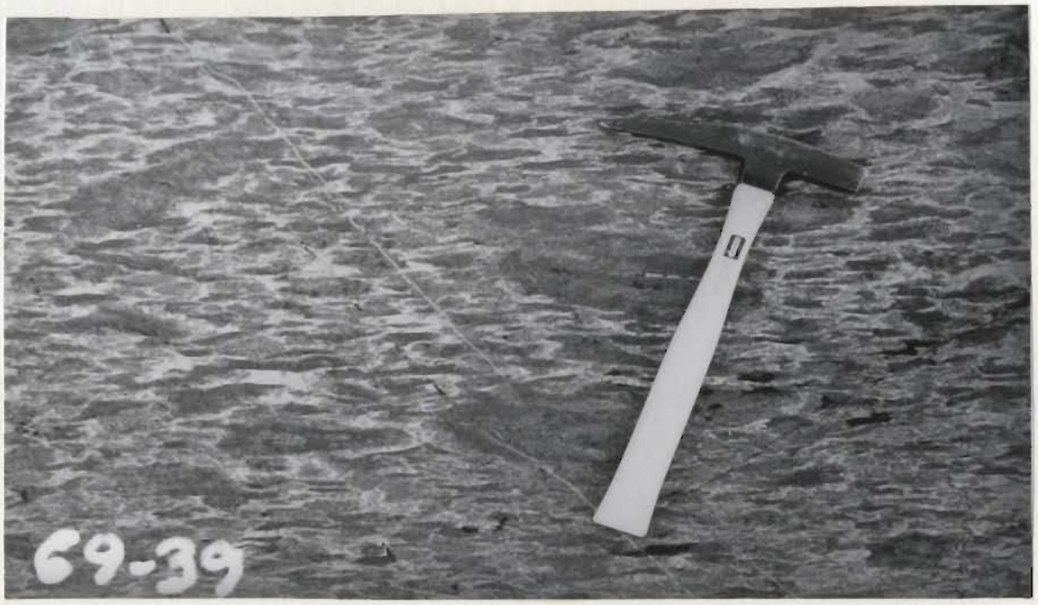


Figure 22: Hornblendic pebble (?) band, northwest of Bent's Cove.

Figure 23: Granite Gneiss intruded into Amphibolite pillows, Long Point hill. Note stoping of Amphibolite by Granite Gneiss.

The gneiss contains many large xenoliths of Cross-Bedded Psammite and Amphibolite, (Fig. 23), as remnants of the roof of the intrusion. This gneiss is probably an intrusive off-shoot of the gneiss in the core of the recumbent fold. Both gneisses are very much more homogeneous and generally less well foliated than the gneiss forming the Aillik Dome north of the area. The mode of emplacement of the gneisses within the area was primarily magmatic stoping, as shown by large xenoliths of country rock and off-shoot veins, whereas the Aillik Gneiss Dome appears to have been emplaced as a less fluid body as evidenced by the mantling of the dome by the country-rock (Fig. 2).

Monkey Hill Granite

The Monkey Hill Granite is a fine to medium-grained pink, or sometimes grey, hornblende granite. It is generally non-foliated, but in the vicinity of Long Point Cove shows a poorly developed lineation of short hornblende crystals. It is pink in colour and finer grained than the Long Island Gneiss of Long Point hill, but investigation of four thin-sections shows its microscopic appearance is similar and composition, including most accessories, the same as the Long Island Gneiss. However, it contains appreciable amounts of rutile associated with an opaque mineral (ilmenite?), whereas the Long Island Gneiss does not contain rutile. It is shown to be intrusive into the Granite Gneiss (Fig. 20) and between Long Point Cove and Big Head, it also intrudes Amphibolite.

Along the coast of North Head the granite shows two phases, a yellow-grey fine-grained granite with 1 in. to 2 ins. hornblendic inclusions, and a fine-grained pink granite. The yellow-grey phase appears to be slightly earlier than the pink phase (Fig. 25).

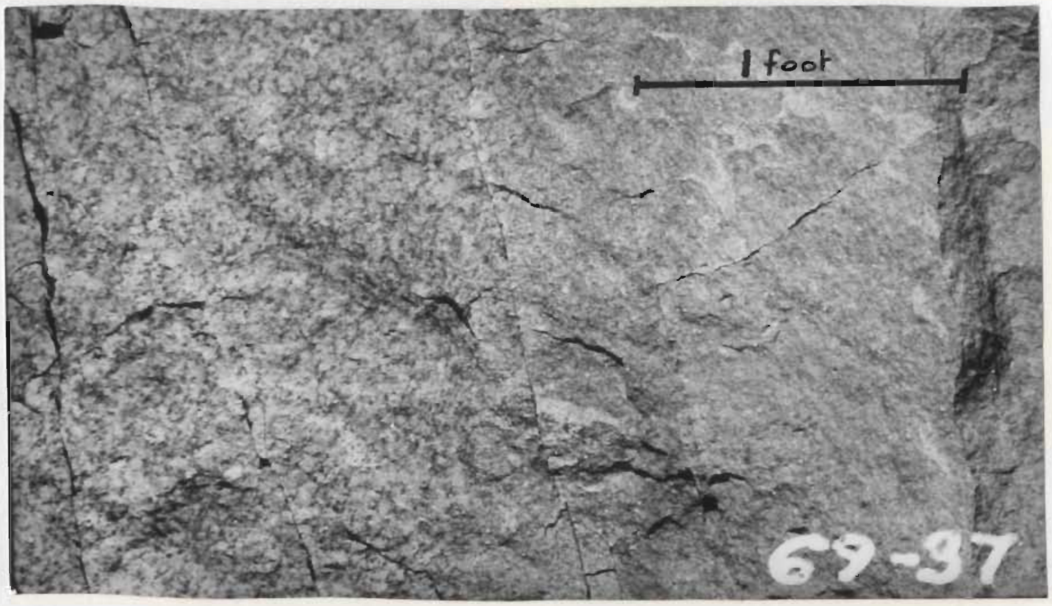


Figure 24: Granite Gneiss (left side of photograph) intruded by Monkey Hill Granite (right side of photograph). Lower North Head Cove. Note chill margin to Monkey Hill Granite.

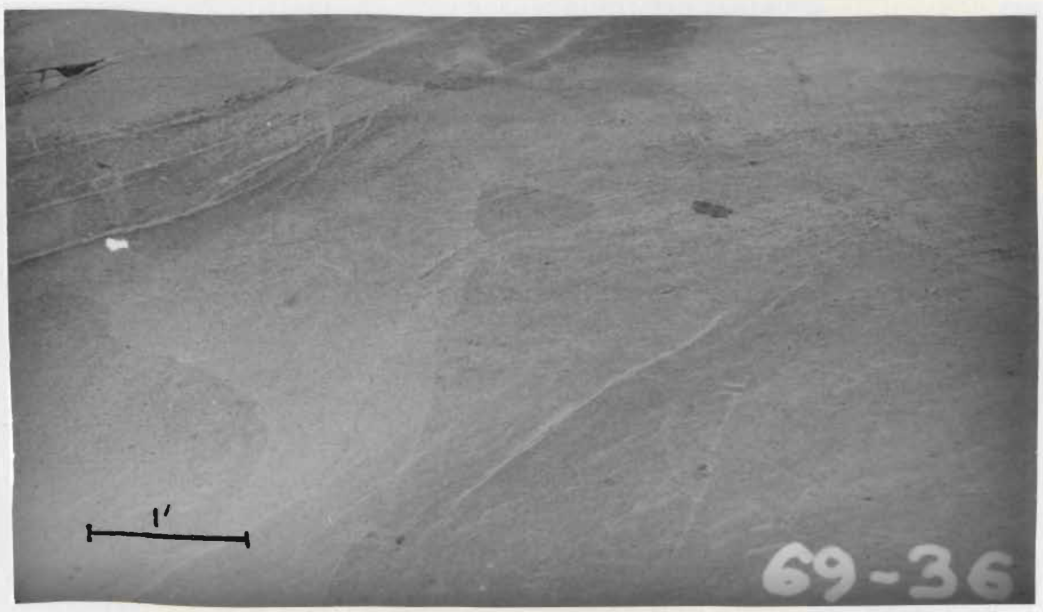


Figure 25: Grey and Pink Monkey Hill Granite, North Head. The grey (darker) phase appears to be earlier than the pink (lighter) phase.

Graphic Granite

A single graphic granite plug occurs in the Variable Psammite opposite the southern end of Long Island. It is a pure pink quartz-feldspar granite, with occasional minor muscovite flakes, showing coarse and fine graphic intergrowth of quartz and microcline, and is surrounded by many off-shoot veins of graphic granite. Its composition is approximately 55% microcline microperthite, 40% quartz and 5% albite, with negligible amounts of muscovite.

Due east of the southern end of Mark's Bight many graphic granite veins occur in Variable Psammite, suggesting the possibility of another small plug below the surface.

Dykes, Sills and Veins

In the vicinity of Big Head many coarse-grained amphibolitic dykes are seen. They show a penetrative L- and S-fabric indicating an early intrusion.

South of Saline Lake to Mark's Bight a few feldspar porphyry dykes of intermediate composition occur in the Variable Psammite. A penetrative S-fabric is developed in these dykes, and is continuous with the banding in the surrounding psammite.

Pegmatite veins occur in abundance in the Variable Psammite along the Kaipokok Bay coast, and have been ptygmatically folded and boudinised (Figs. 37, 38, 42, and 43). The veins are usually quartz-microcline pegmatites, but occasionally magnetite was seen (Fig. 26), and one occurrence of muscovite in pegmatite was seen south of Saline Lake.

Although cross-cutting relationships between pegmatites are occasionally seen, they can probably be considered as belonging to a single intrusive phase.

Intrusions of lamprophyre (not seen in the area), basalt, diorite and net-vein diorite (Fig. 27) have either near vertical or near horizontal attitudes. Their cross-cutting relationships indicate that they are the latest intrusions.

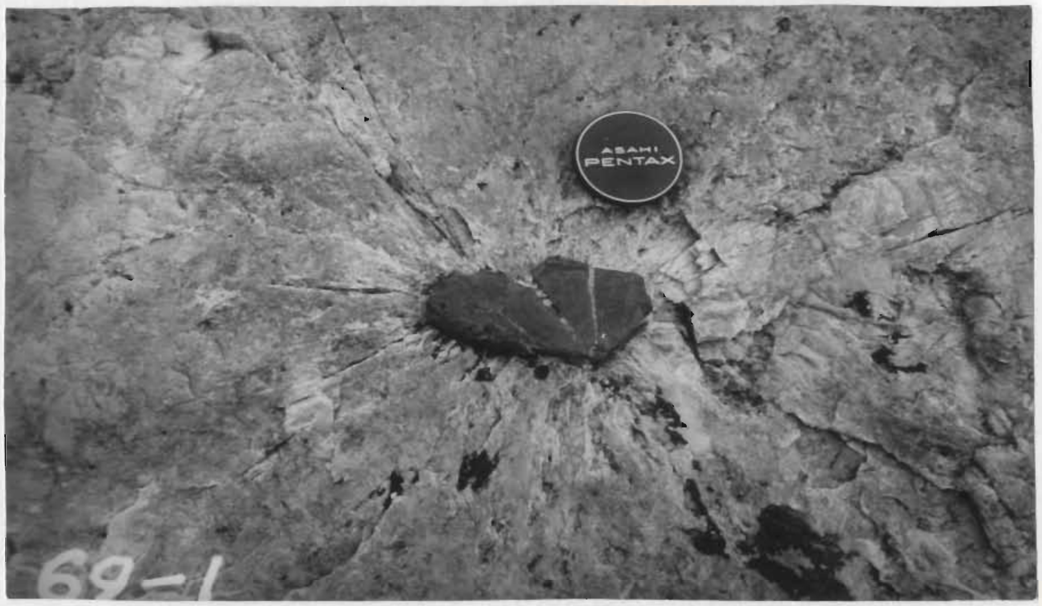


Figure 26: Magnetite crystal in Pegmatite, Saline Lake. Lens-cap is 2 ins. diameter.

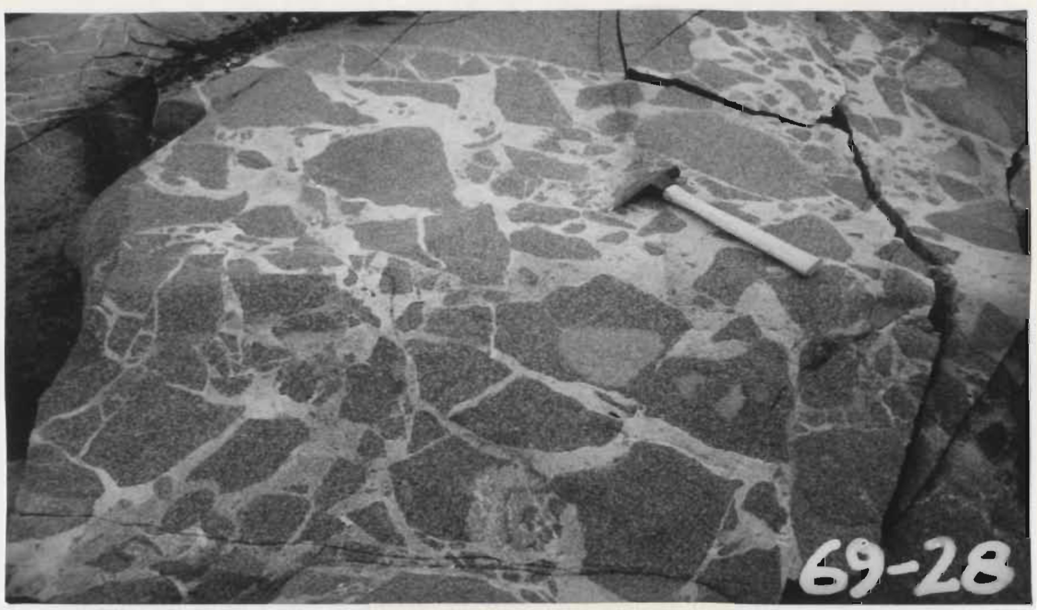


Figure 27: Net-vein diorite, Big Island.

CHAPTER III

STRUCTURE AND METAMORPHISM

TERMINOLOGY

In this discussion the different phases of deformation (Sturt, et al., 1961), folding, S- and L-fabric development and metamorphic mineral growth will be referred to by the following abbreviations and suffixes:

Bedding	S_o
First Deformation:	D_1
Folding	F_1
S-fabrics	S_1
L-fabrics	L_1
Mineral growth syn-D_1 (after Sturt et al., 1961)	Ms_1
Mineral growth post-D_1	Mp_1

Second Deformation:

Above terminology applied with subscript 2 replacing subscript 1, e.g. Mp_2.

Similarly for third and subsequent deformations -- D_3, D_4, etc.

The terminology used in describing deformation axes and principle directions is as follows (Flinn, 1962):

X -- Short axis of the deformation ellipsoid, maximum strain.

Y -- Intermediate axis of the deformation ellipsoid, intermediate strain.

Z -- Long axis of the deformation ellipsoid, minimum strain.

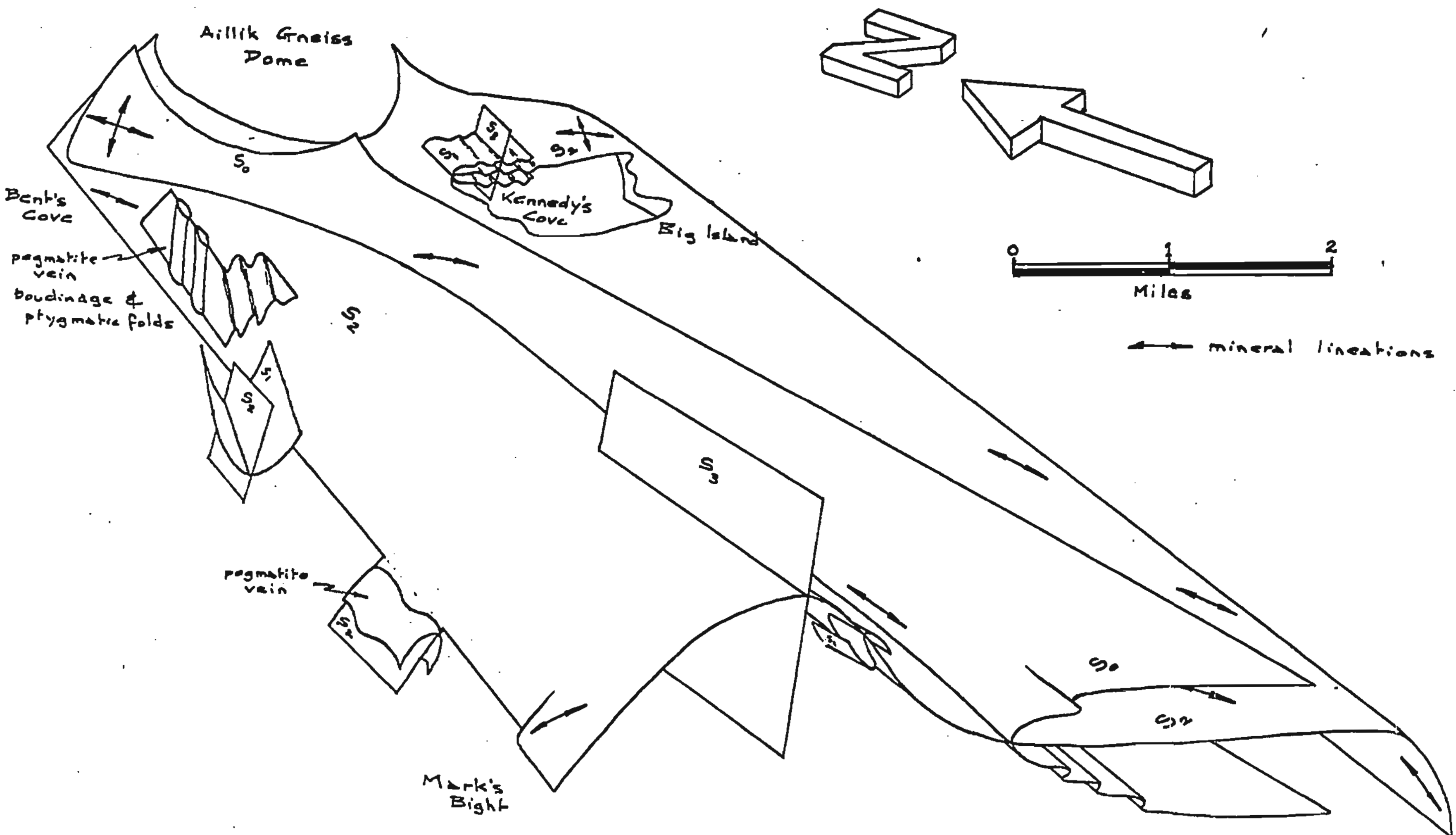


Figure 28: Structural Surface Diagram.

INTRODUCTION

A penetrative S- and L-fabric of biotite, actinolite and hornblende is developed throughout the area. The contacts between the older and younger sequences are not exposed, but the penetrative fabric is similarly oriented on either side of these contacts and is therefore considered as the same fabric. The sequence of deformations has been determined using this main penetrative (D_2) fabric as a structural reference datum.

Late-stage annealing recrystallisation (Turner, et al., 1963) under static conditions has produced well-developed polygonal fabrics throughout almost all the rocks in the area. This recrystallisation has almost completely destroyed all evidence of earlier fabrics in most of the rocks, and especially in those with high quartz and feldspar contents.

A pronounced compositional banding is developed in the older sequence and provides the key to understanding the D_2 and earlier structures in these rocks. This is dependent on an understanding of the nature and origin of the different types of banding and their relationship to the fabrics within the rocks.

ORIGIN AND SIGNIFICANCE OF NON-SEDIMENTARY BANDING

Non-sedimentary banding may be produced by several processes acting separately or together:

a. Translational Mylonite Banding.
A localised cataclastic banding related to simple shear is often developed along fault-zones, the most important of which, in this connection, is probably that related to slides (Fleuty, 1964).

b. Non-Translational Mylonite Banding.

Mylonite banding may be produced by the flattening and lateral extension of certain units with no related simple shear movement (Johnson, 1967).

c. Transposition of Earlier Banded Features.

Earlier banding, whether bedding or a compositional banding, may be transposed into a later banding by tight folding, and attenuation of fold-limbs (Whitten, 1966).

d. Transposition and Recrystallisation of Earlier S-Fabrics.

Kink banding and crenulation of pelitic and amphibolitic rocks to produce strain-slip fabric leads to the production of compositional bands (Rast, 1965; Patterson et al., 1966; Dewey, 1969). The banding may be enhanced by the migration of minerals to the hinges or limbs of the folds.

THE MAIN PENETRATIVE DEFORMATION (D_2)

Biotite, hornblende and actinolite S- and L-fabrics are seen throughout the area. Their continuity of orientation across lithologic contacts suggests that they are related to a single deformation.

At least one earlier fabric in the rocks of the older sequence was folded during this penetrative deformation, indicating that it is D_2 or later. It will be considered as D_2 here. The division of the Aillik Series into older and younger sequences is based on the occurrence of pre-D_2 structures and fabrics in the former, and the presence of S_2 as the earliest recognisable fabric in the latter.

Younger Sequence

a. S- and L-Fabrics.

Scarcity and small grain size of platy and acicular minerals in the younger sequence has resulted in the S_2 and L_2 fabrics being poorly defined. The fabrics are generally defined by hornblende and biotite, but phlogopite and actinolite are the main oriented minerals in the Cross-Bedded Psammite.

The Conglomerate bed west of the Cross-Bedded Psammite shows an increase in deformation from east of Saline Lake northwards, and from north of Astrodome Lake southwards, with the central section being almost completely undeformed (Figs. 10 and 11). Towards Bent's Cove the deformation is indicated by flattening of the pebbles (X:Y:Z = 1:5:5, k = 0; Flinn, 1962), and this is also seen in the conglomerate at Kennedy's Cove (X:Y:Z = 1:3:3, k = 0; Fig. 29). West and south of Astrodome Lake the pebbles are stretched, with no flattening (X:Y:Z = 1:1:3 1/2, k = ∞ ; Fig. 30). (See Appendix).

The causes of this variation in pebble deformation are not known. However, similar gradational variation is reported from Norway (Oftedahl, 1948), and also from Shetland (Flinn, 1956). The variation in deformation recorded in Norway is related to position within the orogen. The Funzie Conglomerate of Shetland is associated with a thrust-plane, the movement on which was caused by the deformation. A thrust-plane may occur between the Conglomerate and the Variable Psammite, placing the older rock unit (the Variable Psammite) in the higher structural position, and it is possible that this thrust-plane is genetically related to the deformation in the Conglomerate.

Figure 29: Flattened Conglomerate, Kennedy's Cove.

Figure 30: Stretched Conglomerate, Astrodome Lake. Coin is approximately 1/2 in. diameter.

b. Banding.

Lens-shaped aggregates of microcline and plagioclase in the Porphyroclastic Psammite are probably derived from phenocrysts, indicating a stage of non-translational mylonitisation. Euhedral quartz phenocrysts show straining and recrystallisation to give sutured aggregates (Figs. 14 and 15).

c. Folds.

Small folds seen in the Cross-Bedded Psammite northwest of Astrodome Lake indicate the beds turn up to the west (Fig. 32). The axial-planes of these folds dip gently southeast and the axes plunge moderately southwest. Stratigraphic tops indicate that this is the lower limb of a large eastward facing recumbent anticline (Figs. 31 and 33). This recumbent fold was traced for an axial length of approximately 5 miles, and has a known limb length of approximately 3000 ft.- The core of the fold is occupied by Granite Gneiss, and west of Astrodome Lake the overturned lower limb is overlain by this gneiss. No other F_2 folds were encountered in the younger sequence.

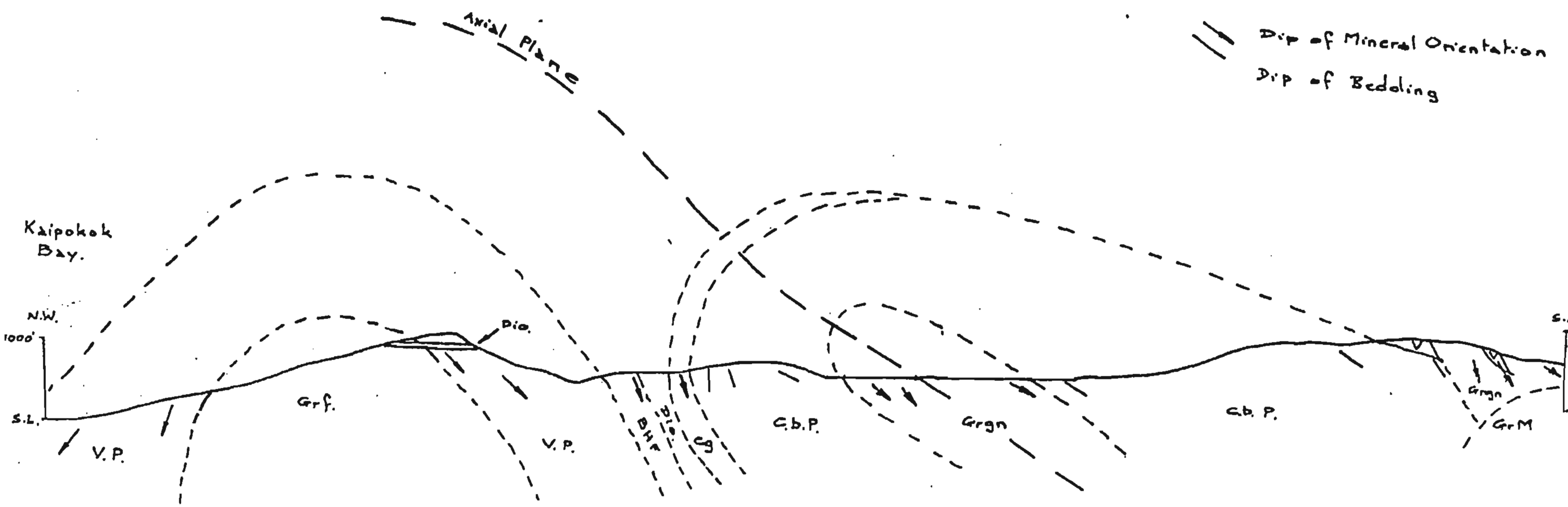
d. Other Structures.

No boudinage or other structures were seen in the younger sequence.

Older Sequence

a. S- and L-Fabrics.

The S-fabric is best developed in the Banded Psammites, where a higher concentration of biotite and muscovite than is normally seen in the Aillik Series shows a well-developed orientation. A few grains of biotite, phlogopite and hornblende in the Variable Psammite show S_2 and L_2 orientations,



V	Amphibolite	Dio.	Diorite
Cg	Conglomerate	Grf	Graphic Granite
CbP	Cross-Bedded Psammite	GrM	Monkey Hill Granite
BHF	Biotite-Hornblende-Feldspar Rock	Grgn.	Granite Gneiss
V.P.	Variable Psammite		

Figure 31: Cross-Section

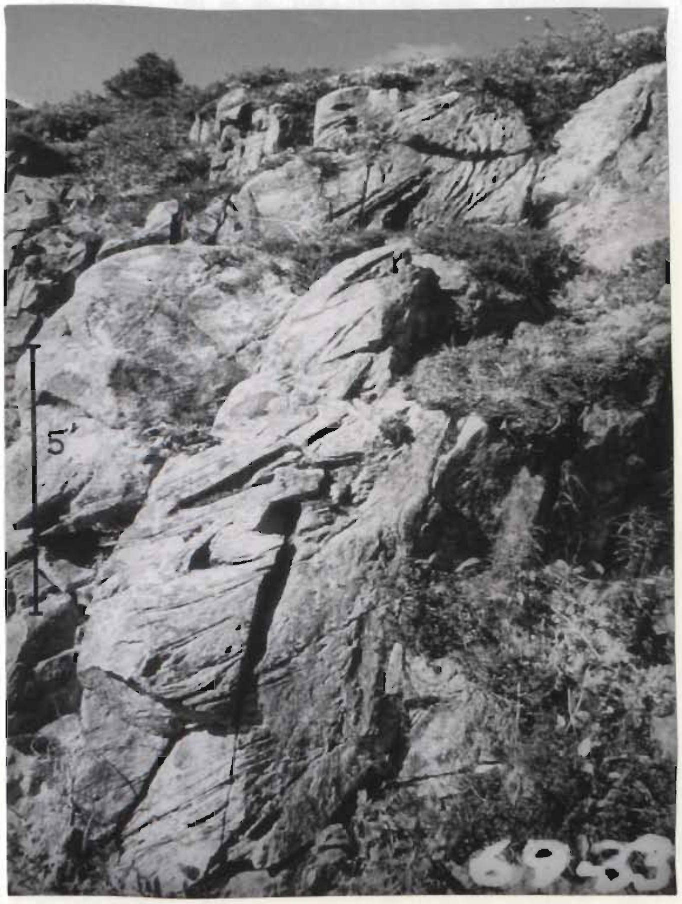


Figure 32: Minor folds in Cross-Bedded Psammite. Near hinge of recumbent anticline, north of Astrodome Lake. The folds indicate that this is the lower limb of the anticline, which closes up to the right (northwest). (Photograph facing southwest).

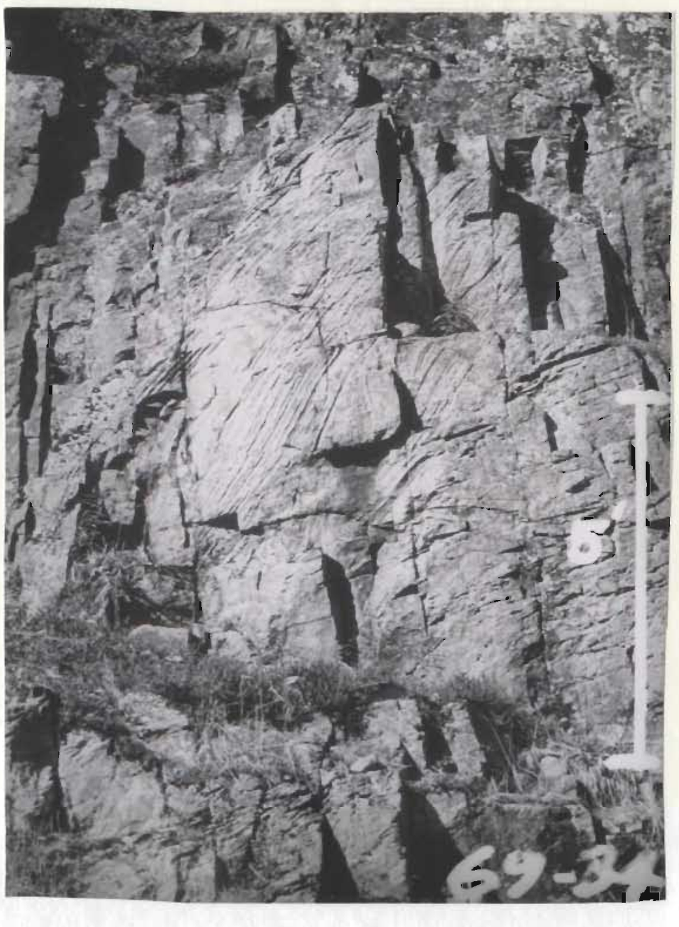


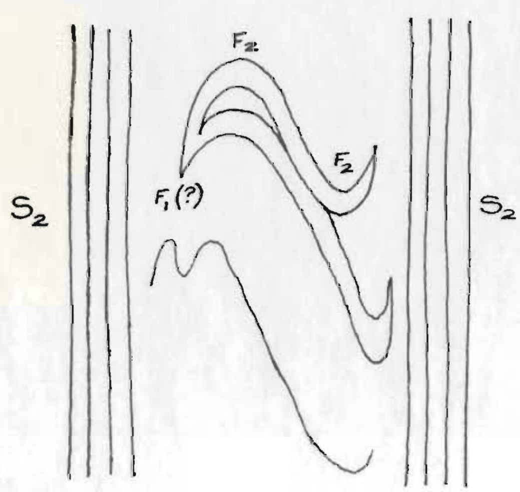
Figure 33: Overturned beds in Cross-Bedded Psammite. Cross-bedding youngs down towards the right. Lower limb of the recumbent anticline, near the axis northwest of Astrodome Lake. (Photograph facing southwest).

and the pebble-bands associated with the psammite are flattened in the S_2 plane. The Biotite-Hornblende-Feldspar Rock has very well developed S_2 and L_2 fabrics in biotite and hornblende.

b. Banding.

On Big Island, just east of the area, bedding or well-developed S_1 banding has been folded and transposed into the S_2 orientation (Fig. 34). The grey biotite psammite at Kennedy's Cove, shows F_2 folding of a well-developed S_1 biotite banding and fabric associated with mineral orientation (Fig. 35). The S_1 banding and fabric often pinches out or merges forming a composite penetrative fabric, and this appears to be the normal expression of the F_2 folding. The banding in the black and white banded psammite is primarily between quartz-microcline and chlorite-epidote layers. This banding is discontinuous over a strike length of approximately 2 ft., and, by analogy with the grey biotite psammite, this is considered as being structural discontinuity formed by complete attenuation of the limbs of isoclinal F_2 folds forming an S_2 transpositional banding. The Variable Psammite shows a well developed compositional banding of microcline and plagioclase (Figs. 42 and 43). The banding is discontinuous and is formed of lens-shaped aggregates of microcline and plagioclase grains in a finer grained plagioclase-quartz groundmass. Because the aggregates are generally monomineralic, they are thought to have been derived from larger grains, during the formation of non-translational mylonitic banding. A black biotite-rich unit at Mark's Bight has biotite in S_2 orientation both within the aggregates and augened around them indicating syn-deformational regrowth of plagioclase. The Biotite-Hornblende-Feldspar Rock shows

Figure 34: Intrafolial folds in Banded Psammite, Big Island. Light coloured band indicated by arrow to left of hammer (see also sketch below), possibly indicates F_1 fold, refolded to give F_2, with the axial plane parallel to S_2 outside the folded section.



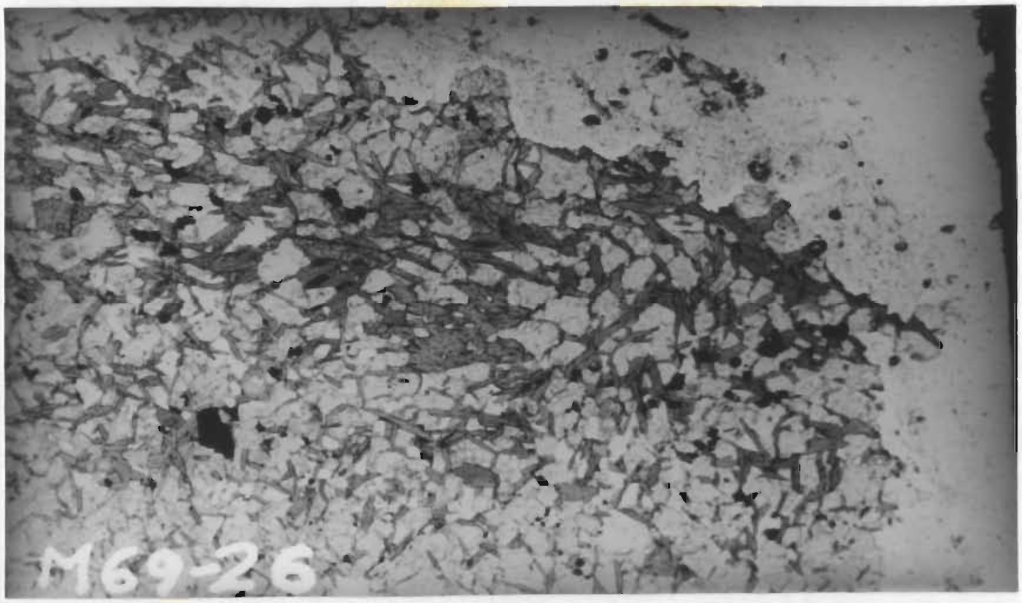


Figure 35: F_2 fold in grey biotite psammite, Kennedy's Cove. Fold closes to right. Note both banding and fabric being folded around hinge. (Plane polarised light, x12).

Figure 36: Banding and slide in grey-green banded psammite, Kennedy's Cove. Note slide truncates S-fabric. (Unpolarised light, stained section).

crushing and lensing of large feldspar crystals, augened by hornblende (which may indicate the initial phases of non-translational mylonitisation), and 1/4 in. spaced biotite-rich bands. The banding in the grey-green psammite at Kennedy's Cove is complex. It is formed of plagioclase-rich and microcline-rich layers, with a few coarse-grained muscovite layers. The origin of these bands is not known. Sharp contacts between bands tend to truncate the main banding and S-fabric at a low angle (Fig. 36), suggesting sliding (Fleuty, 1964). 1/4 in. coarse-grained muscovite bands are often developed at such cross-cutting contacts. It is assumed, for the present, that this sliding is D_2, related to the penetrative S_2 fabric.

c. Folds.

Well developed ptygmatic folds occur near Saline Lake (Figs. 37 and 38). The horizontal trace of the axial planes of these folds is parallel to the banding. A single dubious axial plane attitude was measured which is considerably different in orientation to the banding (the ZY plane, Fig. 39). Folding could be produced on a plane lying between 0° and 45° to X (Flinn, 1962), but the axial planes of folds develop parallel (or nearly parallel) to the ZY plane (Ramsay, 1967), whereas this axial plane is at 45° to the ZY plane. If the axial plane measurement is correct, this suggests that the fold may have been in existence prior to the D_2 deformation, i.e. that the pegmatites were possibly intruded prior to or during D_1.

Considering the bulk shortening of the pegmatites as negligible, the bulk shortening of the enclosing Variable Psammite can be determined from comparison of the arc-length of the ptygmatic folds with the limb-to-

Figure 37: Ptygmatic folding of pegmatite vein in Variable Psammite, Saline Lake.

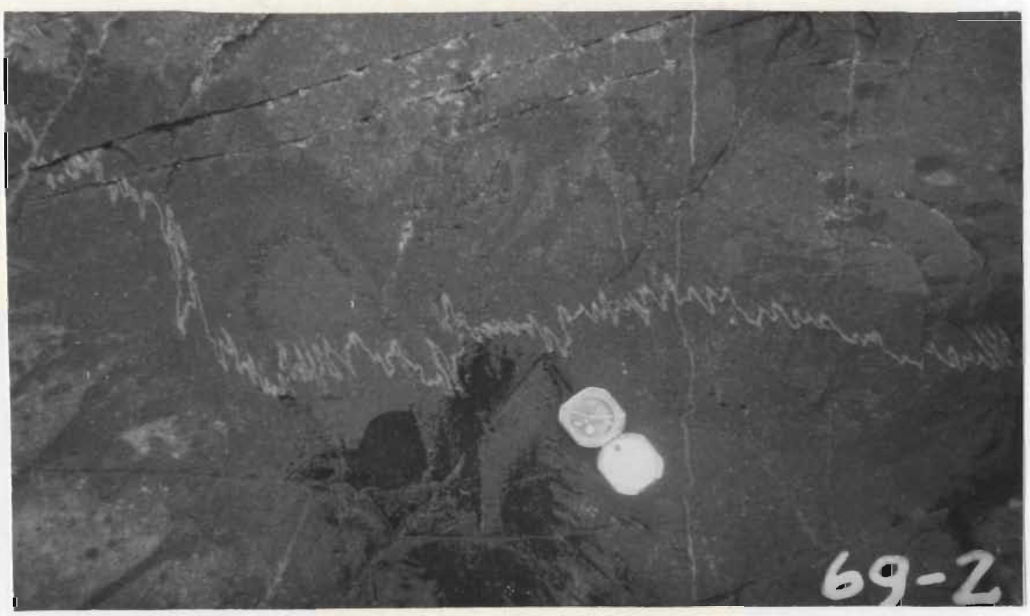


Figure 38: Ptygmatic folding of pegmatite vein in Variable Psammite, Saline Lake.

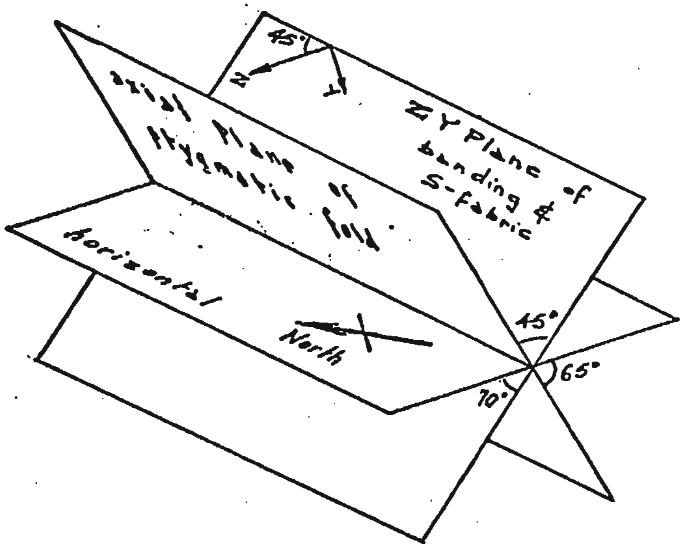


Figure 39: Block Diagram of Structures in Variable Psammite.

limb distance perpendicular to the axial plane (Ramsay, 1967). As the plunge of the folds is not known, this determination gives a maximum amount of shortening for the host rock. The amount of shortening was calculated as 50% or less.

Type 1 interference patterns (Ramsay, 1967) were seen on the Kaipokok Bay coast opposite the Graphic Granite pluton (Fig. 40). One set, seen in a 4 ins. wide conglomerate band in a banded psammite unit of the Variable Psammite, shows flattening of the pebbles parallel to the D_2 banding in the Variable Psammite. This indicates a probable D_2 origin for the structures, and a k-value of $1 < k < \infty$ (Flinn, 1962). However, D_3 effects could not be determined and may have assisted in the production of these structures.

Minor F_2 folds of banding, with an axial-planar S_2 fabric, occur in the grey-green psammite (Fig. 41). Four ft. wide calcite-rich bands in the Variable Psammite, just south of Saline Lake show an S_2 fabric which cuts across the bands. The difference in attitude is of the order of 10°, and indicates that the calcite-rich bands form a southward plunging F_2 synform to the west of the outcrop.

d. Boudinage.

A vertical face perpendicular to the strike of the S_2 banding in the Variable Psammite showed development of small (1 in. by 1/4 in.) boudins in a thin calcite-rich band. Biotite flakes in the boudins parallel the banding, indicating that the X-direction is the same as for the planar fabric. The Z-direction, determined from mineral lineation in the boudins,

Figure 40: Eye-structures in pegmatite vein in Variable Psammite, head of Mark's Bight.

Figure 41: F_2 fold hinge in grey-green banded psammite, Kennedy's Cove. Note penetrative S_2 fabric. (Unpolarised light, stained section).

plunges moderately north-northwest. Pegmatite veins in the vicinity show well developed boudinage (Figs. 42 and 43), but the boudins were only seen on a horizontal surface. These boudins are probably of D_2 age since they have been produced by stretching of a vein lying close to the S_2 banding which contains Y and Z of the deformation ellipsoid (Flinn, 1962). In some beds on Big Island boudinage is well developed (Fig. 44). The boudin axes indicate the apparent Z-direction, on the horizontal plane, to be approximately east-northeast. This orientation is similar to that of the boudins on the Kaipokok Bay coast.

D_2 Metamorphism

Certain facies indicator minerals occur in D_2 orientation. As there is no sign of replacement of or by these minerals (apart from alteration of biotite to chlorite and saussuritisation of andesine, to be discussed later), they are considered to have grown or recrystallised during the D_2 deformation. Late-stage annealing recrystallisation and development of polygonal fabric has almost completely obliterated the D_2 fabrics and textures, making estimation of metamorphic grades difficult.

a. Older Sequence.

The older sequence contains hornblende, biotite and muscovite, oriented in the S_2 plane. Both albite and oligoclase/andesine occur, and minor anorthite was seen. Cummingtonite (colourless, Bx + ve, length slow, extinction angle 19°, birefringence first order yellow) is found occasionally in the Variable Psammite. The occurrence of both albite and oligoclase/andesine probably indicates development on the boundary of the Quartz-Albite-Epidote-Almandine and the Staurolite-Almandine Subfacies (Winkler,

Figure 42: Pegmatite boudins in Variable Psammite, Saline Lake. Note D_2 banding being cross-cut by the pegmatite.

Figure 43: Pegmatite boudins in Variable Psammite, Saline Lake. Close-up of boudin neck. Note banding being cross-cut by the pegmatite and being drawn into the neck of the boudin.

Figure 44: Boudins in Variable Psammite, Big Island.

Figure 45: Polygonal (?) quartz inclusions in microcline. Grey-green banded psammite, Kennedy's Cove. (Cross Nicols, X 285).

1967). Patches of sericite in the black and white banded psammite at Kennedy's Cove suggest sericitisation of an earlier potassic feldspar prior to growth or recrystallisation of later unaltered microcline. The association of muscovite with the sericite suggests recrystallisation of muscovite from sericite. At Kennedy's Cove and at Mark's Bight, epidote shows corroded outlines (Fig. 5), and there appears to be minor anorthite developed, suggesting the attainment of higher grades of metamorphism.

b. Younger Sequence.

The Younger Sequence contains albite, epidote, biotite, and garnet. Andesine occurs in the Porphyroclastic Psammite and in the Amphibolite and actinolite in the Cross-Bedded Psammite. The biotite and actinolite are oriented in the S_2 plane. This mineral assemblage suggests metamorphism in the younger sequence during D_2 times was probably also on the boundary of the Quartz-Albite-Epidote-Almandine and Staurolite-Almandine Subfacies.

PRE-D_2 STRUCTURES AND FABRICS

Possible Pre-D_1 Structures and Fabrics

Folds on Big Island (Fig. 34) indicate that there may be a pre-D_1 banding folded by F_1 folds. However, at present, definite evidence of pre-D_1 banding is lacking.

The D_1 banding of the grey biotite psammite at Kennedy's Cove is formed of biotite-rich bands separated by 1/4 in. quartz-feldspar bands. It is thought to be tectonic in origin and to have developed from an earlier S-fabric by transposition and recrystallisation.

D_1 Structures and Fabrics

At Kennedy's Cove, small F_2 folds in the grey biotite psammite fold a 1/4 in. S_1 biotite banding (Fig. 35). S_1 compositional banding in the grey-green psammite at Kennedy's Cove is folded by F_2 folds and truncated by D_2 slides. On Big Island 2 in. wide black and grey D_1 banding has been folded and transposed into D_2 banding. Transposition and recrystallisation of a pre-D_2 S-fabric probably gave rise to the imperfectly developed 1/4 in. biotite banding in the biotite-rich portions of the Biotite-Hornblende-Feldspar Rock.

Pre-D_2 Metamorphism

Microcline in the D_2 banding in the Banded Psammite contains small quartz inclusions. Where these inclusions are in contact with one another they show straight boundaries (Fig. 45). Although slightly rounded, there is a suggestion of polygonal outline, and it is possible that there was a pre-D_2 period of annealing recrystallisation and development of polygonal fabric which has since been destroyed.

Epidote inclusions in biotite, especially in the Banded Psammite, are euhedral (Fig. 5), indicating metamorphic stability prior to D_2 deformation.

The S_2 banding of the Variable Psammite has developed by cataclastic breakdown of large microcline and plagioclase grains, probably porphyroblasts, indicating a pre-D_2 stage of feldspar growth.

The overall indications are of a post-D_1 / pre-D_2 period of static readjustment by annealing recrystallisation with development of polygonal fabric, and growth of feldspar porphyroblasts in some units. The microcline grains containing small inclusions in the Banded Psammite may possibly also be pre-D_2 in age.

POST-D_2 STRUCTURES AND FABRICS

D_3 Structures and Fabrics

The F_2 fold in the grey biotite psammite is crenulated (F_3). There is partial development of S_3 on the limbs of the crenulations (Fig. 46). The S_2 banding appears to be cut by a very weak S-fabric at 30° to the banding, but this is not distinct enough to warrant a separate classification.

The S_2 fabric in the Variable Psammite is folded into a large F_3 antiform, the axial plane of which is vertical and trends northeast (see Geological Map).

The S_2 fabric at Kennedy's Cove is upturned to the north against the Aillik Gneiss Dome. The S- and L-fabrics in the dome parallel the sedimentary cover (Fig. 2). No suggestion of a fabric axial-planar to the dome is seen in either the gneiss or the cover-rocks, suggesting that the dome may be an F_3 structure, resulting from the non-penetrative D_3 deformation. Alternatively, possible competency differences between the gneiss and the surrounding rocks may have caused the formation of a structure similar to an exceptionally large augen or boudin during the second deformation (Ramsay, 1967).

Figure 46: F_3 crenulations and S_3 fabric (vertical in photograph). Grey biotite psammite, Kennedy's Cove. (Unpolarised light, x 12).

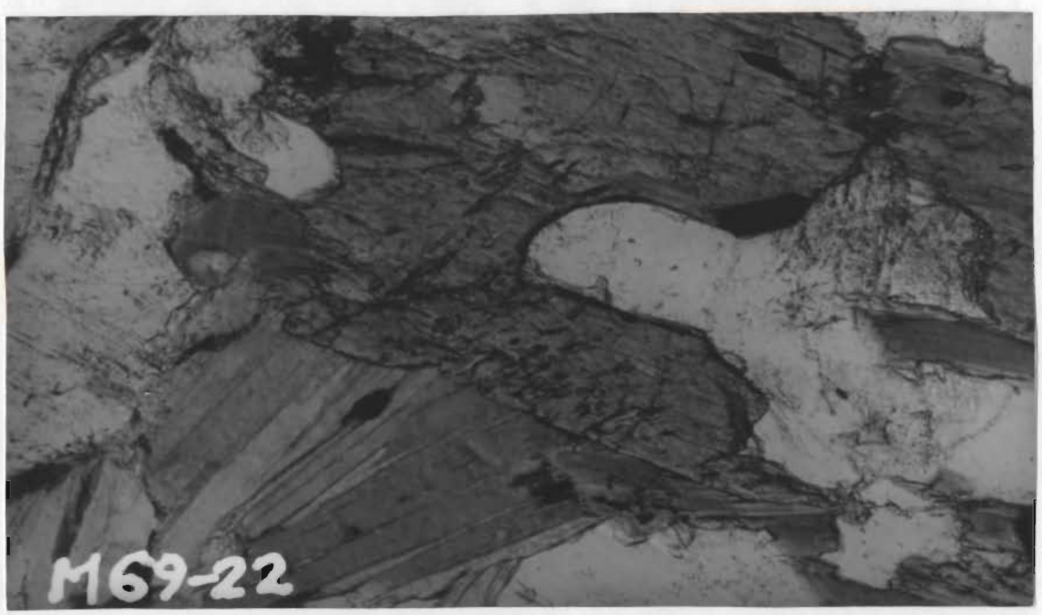


Figure 47: Inclusion trails in hornblende. Grey biotite psammite, Kennedy's Cove. (Plane polarised light, x 285).

Post-D_2 Metamorphism

In the grey biotite psammite at Kennedy's Cove, one occurrence of blue-green hornblende which has overgrown and included biotite partially oriented in the S_3 direction was seen (Fig. 47). The inclusion trails are straight or near-straight indicating a post-D_3 period of static hornblende growth (Mp_3, Sturt et al., 1961). However, there is no sign of hornblende overgrowth over D_2 hornblende crystals in the other psammites or in the Amphibolite.

Post-D_3 annealing recrystallisation with the production of well-developed polygonal fabric occurs throughout the area, and has almost completely destroyed earlier fabrics in most of the rocks of the area.

The last recognisable metamorphic events are the static growth of microcline porphyroblasts in the Variable Psammite and Cross-Bedded Psammite sequences (Fig. 6), the coarsening of the fabric outside the microcline porphyroblasts, the retrogression of biotite to chlorite, and saussuritisation of andesine in the grey-green psammite at Kennedy's Cove.

AGES OF IGNEOUS INTRUSIONS

Pre- or Syn-D_2 Intrusives

Pegmatite veins on the Kaipokok Bay coast are not intensely folded and show no signs of refolding. They are therefore probably post-D_1. The pegmatites are oblique to the composite S_2 banding in the Variable Psammite. This banding, although affected by boudinage, is not asymtotic to the pegmatite boundaries, but is truncated by them at an acute angle (Fig. 43), indicating a probable syn-D_2 age of intrusion.

The Long Island Gneiss has a well-developed L-fabric of slightly flattened xenoliths and of acicular hornblende, which parallels the Z-direction in the enclosing rocks indicating a pre- or syn-D_2 age of intrusion. The Long Island Gneiss is intruded by Granite Gneiss which also shows D_2 fabrics as do several basic and intermediate dykes. These intrusives are therefore also of pre- or syn-D_2 age.

Post-D_2 Intrusives

The Monkey Hill Granite is not schistose and is intruded into Granite Gneiss. It is therefore post-D_2 in age, and is probably pre- or syn-D_3 as in a few places it shows a very poorly-developed fabric of hornblende grains.

Since the Graphic Granite plug shows no noticeable D_2 fabric and is intruded into the core of the Variable Psammite antiform it presumably was emplaced post-D_2. Post-D_2 basalt, diorite and net-vein diorite (Fig. 27) dykes and sills, showing no fabric, occur throughout the area.

FAULTS AND ASSOCIATED STRUCTURES

Faults

A large northwest trending fault at Bent's Cove shows related drag-folding 3000 ft. southwest of Bent's Cove, indicating a sinistral displacement direction. Another fault with transverse displacement (as indicated by slickensides) occurs 6000 ft. south of Bent's Cove. The sense of displacement here could not be determined. A large fault trends north-northwest from Makkovik Bay to Kaipokok Bay and passes along the north side of Astrodome Lake. South of the fault the lower limb of the recumbent fold is overlain by Granite Gneiss, and plunges southeast. North of the fault the upper limb of the fold is seen, indicating a vertical displacement of approximately 1000 ft. down to the north. The fault pattern in the Cross-Bedded Psammite and Amphibolite due west of Big Head indicates a small northeasterly trending graben. It could not be determined whether the graben faults were normal or reverse, or whether there had been any large-scale strike-slip component, but the slickensides indicate the last phase of movement was vertical. Many smaller 1 ft. wide fault-zones having imperfect brittle sigmoidal tension-gashes are seen along the Kaipokok and Makkovik Bay coasts. They appear to form a conjugate set at approximately 90° to one another, and indicate that the maximum stress was oriented west-northwest (Anderson, 1951; Ramsay, 1967).

Kink-Bands

Approximately 7000 ft. northeast of Astrodome Lake a large imperfectly developed kink-band, about 8 ft. wide and 20 ft. long occurs in the Cross-Bedded Psammite. Although imperfectly developed this kink-band shows sinistral rotation (Fig. 48). Smaller 1 ft. wide kink-bands occur in the Granite Gneiss at North Head (Figs. 48 and 49). The maximum stress direction must have been oriented at a small angle to the foliation to produce these kink-bands (Patterson et al., 1966; Dewey, 1969). This direction is almost perpendicular to the maximum stress direction which produced the faults, indicating formation under a different stress-field.

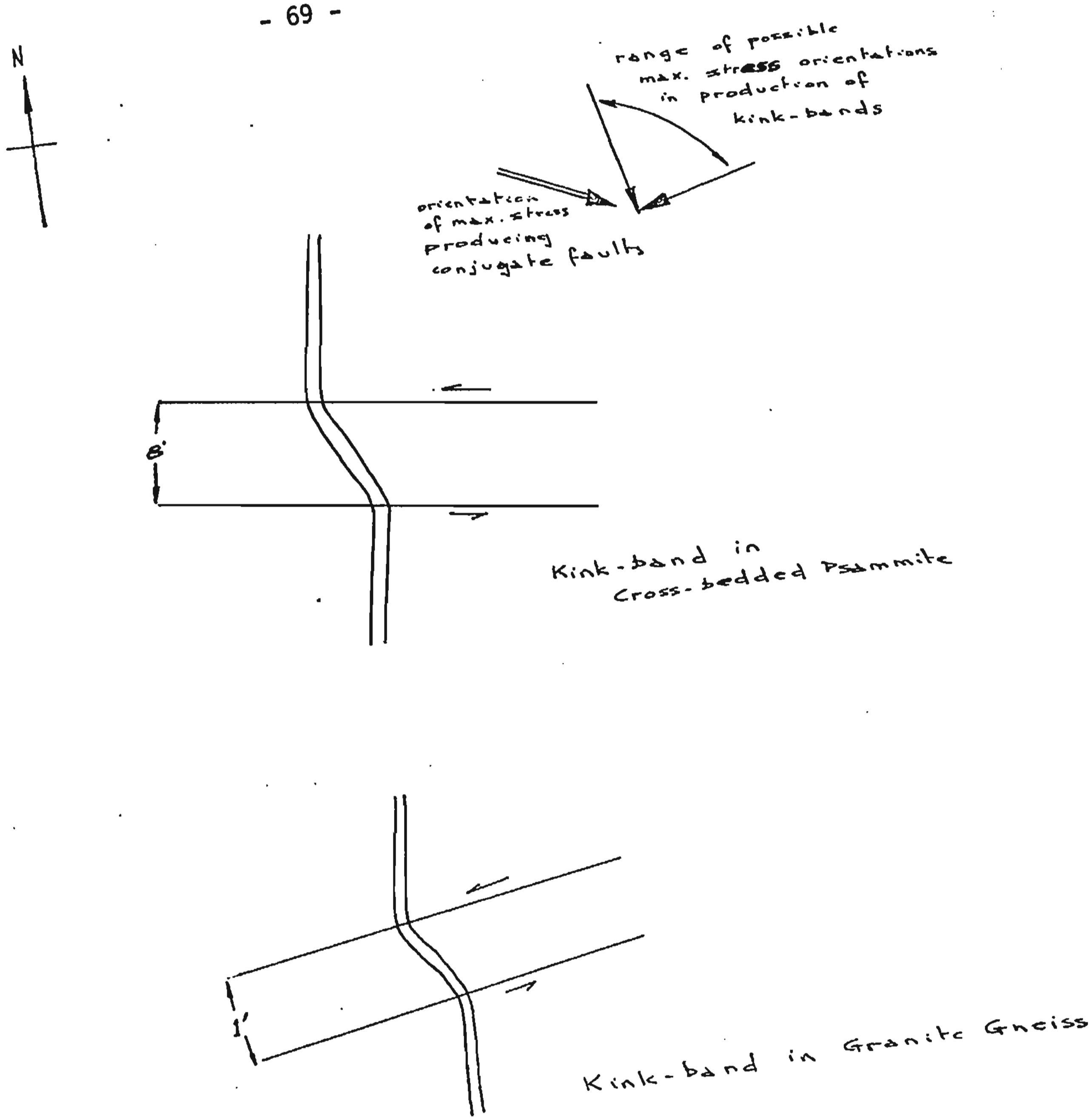


Figure 48: Kink-Bands.

Figure 49:   Kink-bands in Granite Gneiss, North Head.

CHAPTER IV

SUMMARY AND DISCUSSION

Summary

The Aillik Series has been divided into an older and a younger sequence, based on the occurrence of pre-D_2 deformation in the older sequence, whereas D_2 is the earliest deformation seen in the younger sequence.

The older sequence consists of a variety of psammites which have undergone at least two deformations with the production of compositional banding (D_1 banding).

The exceptionally high feldspar content of these psammites suggests a close relationship to acid volcanism (Williams, et al., 1958).

The deposition of the younger sequence occurred after D_1 times. The younger sequence was initiated by the deposition of a cross-bedded psammite of arkosic composition, followed by a boulder-conglomerate. Later high-level acid volcanic activity is evidenced by remnant quartz-phenocrysts in the Porphyroclastic Psammite. However, it cannot be determined whether the Porphyroclastic Psammite represents an intrusive or extrusive acidic rock, or a sedimentary rock derived from an igneous terrain. The Porphyroclastic Psammite was followed by basic volcanism and the deposition of pillow-lavas.

After deposition of the younger sequence, tight F_2 folding transposed banding in the older sequence, produced the recumbent fold in the younger sequence, and initiated sliding. A penetrative fabric was produced, and this fabric was used as a structural reference datum. Banding of a non-translational mylonitic nature was produced in the Variable Psammite and the Porphyroclastic Psammite. The metamorphic grade, during D_2 times, was at the boundary of the Staurolite-Almandine and Quartz-Albite-Epidote-Almandine Subfacies (Winkler, 1967).

Later folding, with partial production of a weakly developed fabric, produced the large antiform in the Variable Psammite and also possibly formed the Aillik Gneiss Dome. The metamorphic grade was lowered in post-D_2 times as evidenced by the formation of chlorite from biotite. Intense post-D_2 annealing recrystallisation has almost completely destroyed the earlier fabrics. The radioactive age-dating of Gandhi, et al. (1969) suggests that these phases of deformation are all related to a single orogenic cycle of Hudsonian age.

Discussion

The present interpretation rests on a considerable amount of circumstantial evidence. However, it has been shown that the structural history is considerably more complex than was envisaged by previous workers. Rather than a gentle folding cut by steep foliation varying from a fracture cleavage to a well-developed schistosity (Kranck, 1953), or 'a single cycle of orogenic deformation' (Gandhi, 1969), the structures and structural history are shown to be extremely complex and of several ages and styles of deformation.

The overall structural history has been based on the assumption that the penetrative fabrics are of the same age (D_2). The similarity of orientation of fabrics on either side of the lithologic contacts makes this assumption appear reasonable, though in no case could the fabric be traced directly across a contact.

The division into older and younger sequences is based on the non-occurrence of pre-D_2 fabrics in the younger sequence. However, it is possible that pre-D_2 fabrics may not have developed in this area, but may be developed elsewhere (Flinn, 1956; Ramsay, 1963).

The D_2 banding developed in the Banded Psammite is the result of transposition of the D_1 banding. The D_1 banding appears to be the result of refolding of a pre-D_1 S-fabric, or possibly a pre-D_1 banding. If there was a pre-D_1 banding, this banding itself may be the result of earlier deformations. The origin of the Banded Psammite structures may thus be very complex. The character and origin of the banding in both the older and younger sequences should be investigated more fully.

The slides in the Banded Psammite cut across the D_2 banding and the S_2 fabric at a low angle. They may represent a different deformation, though no other evidence is available at present.

Further information is needed on the character and possible origin of the Porphyroclastic Psammite, especially as several occurrences of mineralisation occur in a similar rock-type from Aillik Bay (Fig. 2) to approximately 50 miles southwest along strike. The possible relationship to acid volcanism of other units should also be investigated. A member of the Variable Psammite unit occurring northeast of the area, is considered by Barua (1969) to be a spilitic acid lava because of the high sodium content and high Na_2O/K_2O ratio. Gandhi's (1969) Lineated Grey Feldspathic Quartzite (Fig. 2), which does not occur in the area covered by this thesis, is divided by Barua into a crystal tuff unit and an acid volcanic quartzite, based on fabric. Both are described as being highly sodic and are considered to be related to acid volcanism for this reason.

Investigation should be carried out in the Makkovik vicinity to determine other occurrences of older and younger sequences, and to differentiate between them. At present the only other known occurrence of younger sequence rocks is at Pomiadluk Point (Gandhi, 1969), though Big Island appears to consist of both older and younger sequences.

A similar assemblage of rocks, including acid and basic volcanics, (but also including red-beds, limestones and shales), occurs between Kaipokok Bay and Seal Lake, 100 miles southwest of the area, along strike (Moore, 1952; Hansuld, 1958). This assemblage is divided into a lower marine series, which is disconformably (?) overlain by an upper (presumably younger) red continental series, and F_1 folds face westward as does the recumbent fold in the area of this thesis (Kennedy, 1970, personal communication). Williams (1970, personal communication) has divided the rocks of the upper Kaipokok River area (50 miles southwest) into a younger and an older sequence. Williams' older sequence consists of argillaceous and calcareous rocks overlain disconformably (?) by basic volcanics and interbedded quartzite and conglomerate. His younger sequence consists of arkose, feldspathic quartzites, and acid and intermediate volcanic tuffs and flows, which are often porphyritic. There is, thus, a strong resemblance among the geological occurrences along strike for a considerable distance.

The structural complexity of the area and the lack of clearly defined fabrics has made the full evaluation of the structural history impossible in the short time available. A considerable amount of further work is necessary to determine the geological history of the Aillik Series.

The occurrence of uranium and molybdenum mineralisation in some of these lithologic units outside the area, and the lack of understanding of the origin of this mineralisation makes the full understanding of the petrology and history of the host-rocks extremely important.

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APPENDIX

MODAL ANALYSES

Modal analyses were carried out on stained thin-sections. The thin-sections were stained for K-feldspar (yellow) and plagioclase (red) after the method described by Bailey, et al. (1960). Plagioclase composition was determined from measurement of refractive index, 2V and Albite-twin extinction angles (Slemmons, 1962).

1. Hopedale Gneiss. Sample No. AMSC-69-51, collected as a beach boulder on Kaipokok Bay coast.

2. Black and white banded psammite. Sample No. AMSC-69-4, from Kennedy's Cove. Whole rock analysis.

3. Ditto. Analysis of microcline-rich bands.

4. Ditto. Analysis of quartz-rich bands.

5. Ditto. Analysis of biotite-rich bands.

6. Grey-green banded psammite. Sample No. AMSC-69-3, from Kennedy's Cove. Whole rock analysis.

7. Ditto. Analysis of saussuritised bands.

8. Ditto. Analysis of microcline-rich bands.

9. Ditto. Analysis of plagioclase-rich bands.

10. Grey biotite psammite. Sample No. AMSC-69-72, from Kennedy's Cove.

11. Dark grey banded psammite. Sample No. AMSC-69-25, from south of Big Head.

12. Variable Psammite. Sample No. AMSC-69-26, from Saline Lake.

13. Biotite-Hornblende-Feldspar Rock. Sample No. AMSC-69-46, from south of Astrodome Lake. Whole rock analysis.

14. Ditto. Analysis of hornblende-rich bands.

15. Ditto. Analysis of biotite-rich bands.

16. Cross-Bedded Psammite. Sample No. AMSC-69-16, from northeast of Astrodome Lake.

17. Porphyroclastic Psammite. Sample No. AMSC-69-81, from north of Big Head.

MODAL ANALYSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Quartz	20	30	25	70	25	20	2	40	50	15	2	20	10	10	15	20	30
Microcline	25	35	55	--	--	25	--	45	--	--	25	35	25	--	30	15	30
Plagioclase	45	--	--	--	--	15	20	--	40	60	40	40	40	55	35	50	40
Plag. Comp.	01/ And	--	--	--	--	--	And	--	Ab	Ab	Ab	Ab & And	01/ And	01/ And	01/ And	Ab	And
Hornblende	--	x	x	x	x	--	--	--	--	2	--	x	15	35	x	x	--
Biotite	10	20	15	5	50	5	5	10	10	20	25	5	10	x	15	x	x
Muscovite	--	5	x)	20)	10	5	5	5	--	--	--	--	--	--	--	--	--
Sericite	--	5	x)	)		25	65	--	--	--	--	--	--	--	--	--	--
Epidote	--	3	x	x	10	x	x	--	--	x	--	--	--	--	--	x	--
Chlorite	x	x	x	x	x	2	x	--	--	x	--	x	x	--	--	x	x
Orthite	--	x	x	x	x	--	--	--	--	x	--	--	--	--	--	x	--
Sphene	--	x	x	x	x	--	--	--	--	--	--	x	--	x	x	x	x
Opaque	x	x	x	x	x	--	--	--	--	3	5	x	x	x	x	x	x
Garnet	--	--	--	--	--	--	--	--	--	--	--	--	--	--	---	x	--
Actinolite	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	--
Zircon	--	--	--	--	--	x	x	--	--	--	--	x	--	x	x	--	x
Fluorite	--	--	--	--	--	--	--	--	--	x	x	x	--	--	--	--	--
Phlogopite	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--

"x" indicates minor amounts.

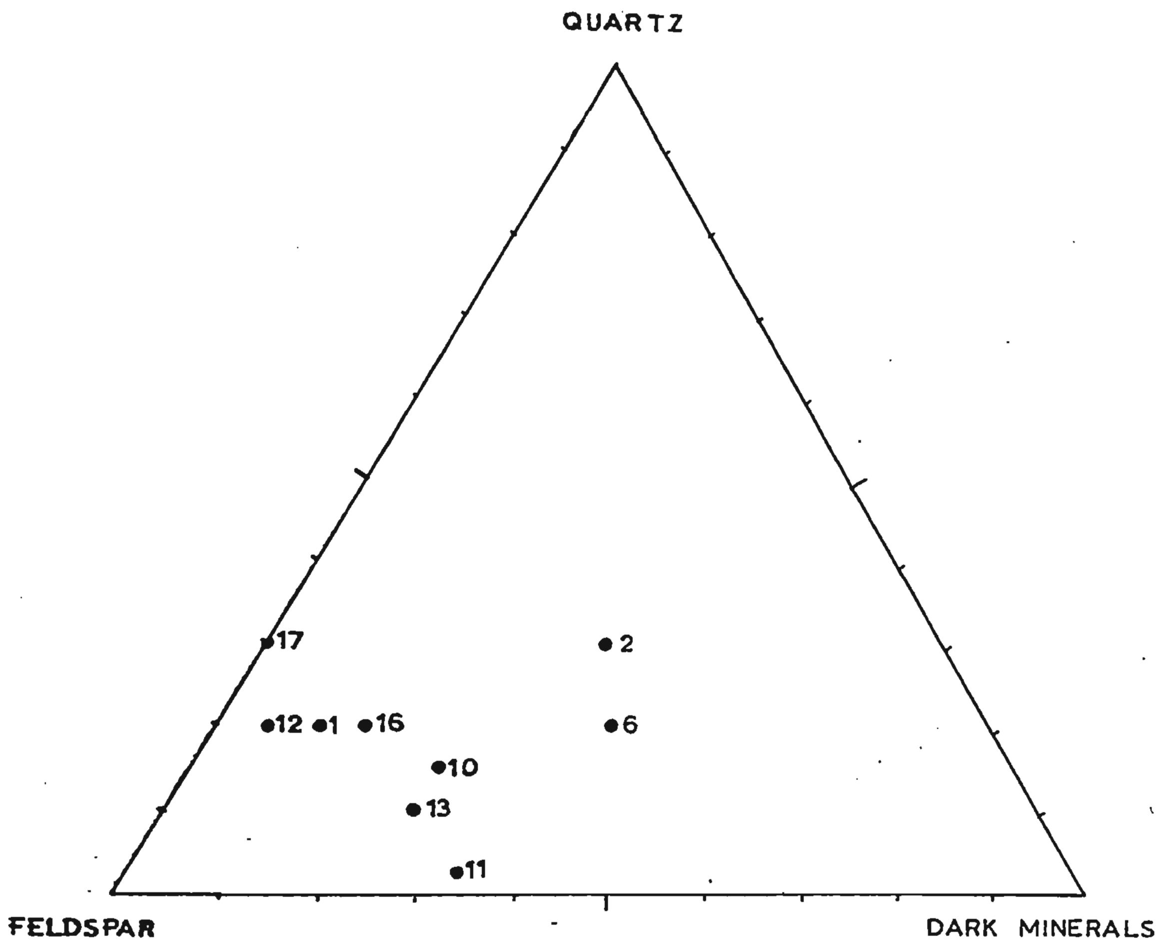

Figure 50: Triangular Diagram — Quartz/Feldspar/Dark Minerals

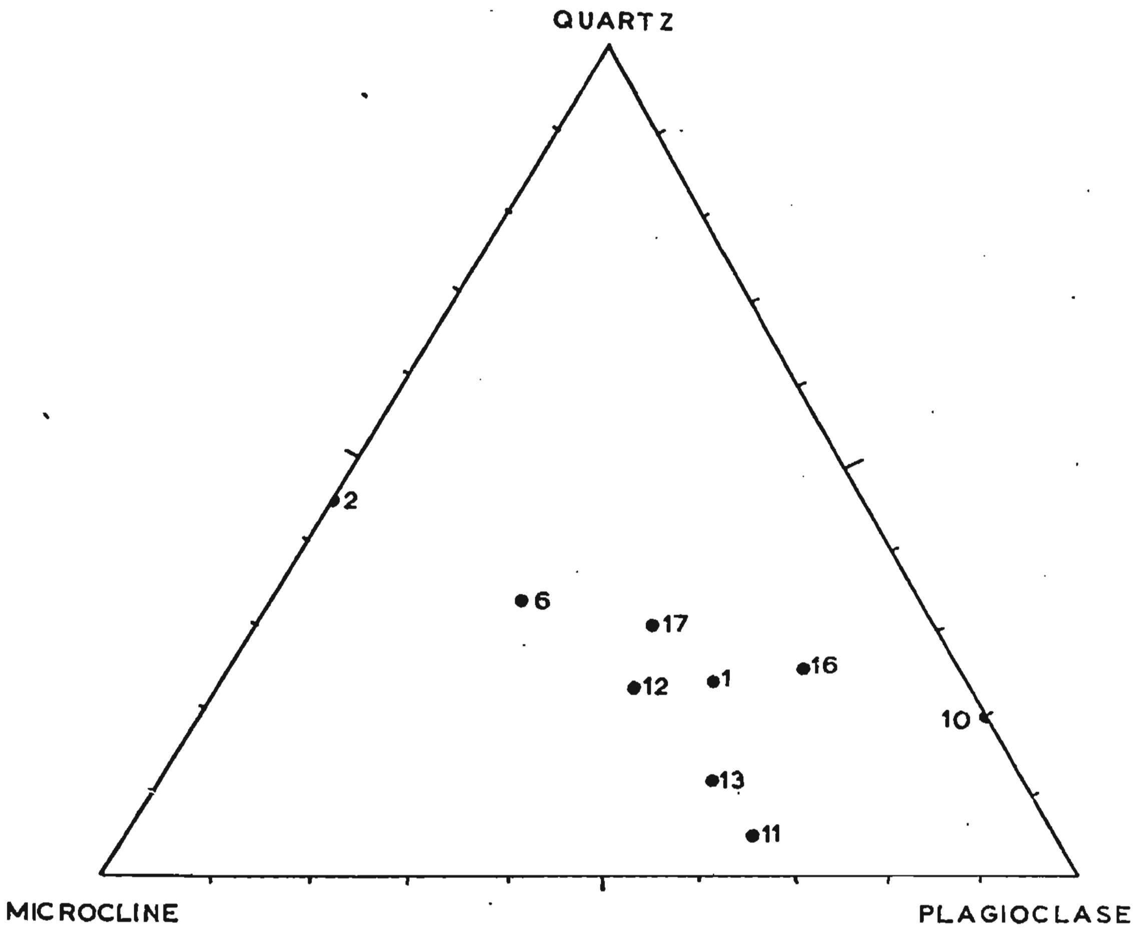

Figure 51 : Triangular Diagram — Quartz / Microcline / Plagioclase

DETERMINATION OF K-VALUES

K-values (Flinn, 1962) could only be determined for the conglomerates, and not for any of the other rock types in the area. Measurements were taken of approximately twenty to thirty small to medium sized pebbles of all compositions represented. As it was not possible to remove the pebbles from the matrix, measurements of X and Y were made for each pebble shown on a face cut perpendicular to Z, and the average X/Y ratio calculated. Similarly, for X and Z on a face cut perpendicular to Y. X, Y and Z values were calculated from these ratios. Variations between measurements were large, up to 50% in the extreme cases, but the majority of measurements fell within a range of approximately 20%.

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