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GEOLOGY OF THE PRECAMBRIAN RAMAH GROUP AND BASEMENT ROCKS IN THE NACHVAK FIORD–SAGLEK FIORD AREA, NORTH LABRADOR

W.C. Morgan

1975

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CONTENTS

	Page
Abstract/Résumé	
Introduction	1
General statement	1
Previous work	2
General geology	3
Basement rocks east of the Ramah Group (units 1-7): Archean	3
Acid gneiss and migmatite (unit 1)	3
Basic gneiss and pyroxene amphibolite (unit 2)	3
Metamorphic ultramafic rocks (unit 3)	5
Paragneiss (unit 4)	5
Orthogneiss (unit 5)	5
Granite and pegmatite (unit 6)	5
Basic dykes (unit 7)	6
Structure	7
Metamorphism	9
Basement rocks west of the Ramah Group (units 8-12): chiefly reworked Archean	9
Acid gneiss and migmatite (unit 8)	9
Acid pyroxene gneiss and migmatite (unit 9)	9
Basic pyroxene gneiss (unit 10)	10
Paragneiss (unit 11)	10
Basic dykes (unit 12)	10
Structure	13
Metamorphism	15
Correlation of basement rocks east and west of the Ramah Group	15
Ramah Group (units 13-21): Aphebian	15
Quartzite (unit 13)	21
Metabasalt flow (unit 14)	22
Laminated quartzite and pelite (unit 15)	23
Slate (unit 17)	24
Dolomite (unit 18)	25
Slate (unit 19)	28
Metagreywacke (unit 20)	28
Diabase (unit 21)	29
Ultramafic rocks (unit 21a)	30
Paleocurrents	30
Sedimentary environments	31
Structure	32
Metamorphism	34
Age relations	35
Field relations	35
Radiometric ages	35
Economic geology	35
Discussion	37
References	39

Tables

Table 1.	Table of formations in basement rocks east and west of the Ramah Group	16
2.	Table of formations in the Ramah Group	18
3.	K-Ar age determinations in the general Nachvak Fiord-Saglek Fiord area	36

Illustrations

Map 6-1974 Geology, Nachvak Fiord-Saglek Fiord map-area ..... in pocket

Figure 1. Archean banded gneisses with diabase dykes unconformably overlain (in foreground and on left peak) by Ramah Group quartzite. Western slopes of Blow Me Down Mountain ..... frontispiece

CONTENTS (cont'd.)

		Page
Figure 2.	Location map showing area described in the report	1
3.	North Arm, Saglek Fiord	2
4a.	Banded gneiss, composed of alternating layers of acid and basic gneiss, cut by conformable and cross-cutting veins of granite and pegmatite. Duncan Point	4
b.	Agmatite. North side of Rowsell Harbour	4
c.	Orthogneiss. One mile east of Naksaluk Cove, Nachvak Fiord	4
5.	Swarm of feldsparphyric diabase dykes exposed on 400-foot cliff. ½ mile south of the west end of Bell Inlet	7
6.	Macroscopic subisoclinal folds exposed on the 2000 feet high north wall of Bell Inlet. Note the diabase dyke swarm, and Ramah Group in the left background	8
7a.	Migmatite (unit 8). 3 miles southeast of Tinutyarvik Cove, Nachvak Fiord	8
b.	Banded pyroxene gneisses. 11 miles west southwest of the south end of Little Ramah Bay	8
8.	Foliated amphibolite dyke (left) cuts across granulite facies gneisses (right) from which it is separated by a shear zone, parallel to the dyke contact, containing amphibolite facies mylonitized gneisses. 2 miles northwest of the west end of Ramah Bay	11
9.	Deformed basic dykes on 2000 feet high cliff. 5 miles south of the west end of Ramah Bay	11
10a.	Weakly foliated feldsparphyric diabase dyke. Approximately 4½ miles west of the west end of Ramah Bay	12
b.	Feldsparphyrix diabase dyke cut by thin shear zones. Same locality as 10a	12
11.	Isoclinal and rootless intrafolial folds outlined by basic horizons in leucocratic pyroxene gneiss. 11 miles west southwest of the south end of Little Ramah Bay	13
12.	Reworked Archean gneisses thrust to the east over Ramah Group metasediments. North slope of Quartzite Mountain south of Adams Lake	14
13.	Thrust planes exposed on 3000 feet high mountain wall, one mile west of Quartzite Mountain	14
14.	Map showing the extension of the Ramah Group south from Saglek Fiord to Hebron Fiord	17
15.	View east across Little Ramah Bay (south end visible) showing the Ramah Group (right and foreground) unconformably overlying Archean rocks	19
16.	High angle angular unconformity separating rocks of the Ramah Group (units 13 and 15) from underlying Archean gneisses. North side of Rowsell Harbour	20
17.	Unconformity between Ramah Group and Archean gneisses, exposed on mountains 4 miles north of the west end of Bears Gut. Note the planar nature of the unconformity surface, with only local minor irregularities	20
18.	View north across Ramah Bay showing inclined mountain tops, underlain by Archean rocks, that are located east of the Ramah Group	21
19a.	Deformed pebbly meta-sandstone with stretched clasts. 2 miles north northwest of Quartzite Mountain	22
b.	Trough cross-bedding in quartzite outlined by magnetite-rich laminae. Same locality as 19a	22
c.	Dyke, presumed to be a feeder to the metabasalt flow (unit 14), cutting quartzite 3½ miles southwest of Bears Gut	23
d.	Soft sediment folding and slumping in meta-sandstone of unit 15. Northeast side of Ramah Bay	23

Page

Figure 20. Load structures in laminated quartzite (unit 15). Northeast side of Ramah Bay 24
21a. Soft-sediment boudinage structure in dolomite (unit 18). ½ mile north of Ramah 25
b. Clastic dyke in argillaceous dolomite. Same locality as 21a 25
22a. Intraformational breccias in dolomite, exposed on cliff immediately north of Ramah. Typical breccia showing partial replacement of intraclasts by white calcite 26
b. Intraformational breccia beds alternating with cleaved, laminated argillaceous dolomite beds 26
c. Breccia, showing fragments with highly folded laminations, caused by soft-sediment slumping. Intraclasts are extensively replaced by white calcite 27
d. Intraformational breccia, composed of tabular intraclasts, with evidence of soft-sediment deformation and poorly graded fragments 27
23a. Well graded dolomite breccia deposited by turbidity currents. 1½ miles northeast of the west end of Ramah Bay 28
b. Flame structures and ripple-drift cross-lamination in dolomite beds associated with meta-sandstone and quartzite. Same locality as 23a 28
24. Openly folded diabase sills (unit 21), cut by fan-shaped fracture cleavage, enclose intensely contorted isoclines of slate (unit 19) in which radiating slaty cleavage is developed. Note the diapiric-like intrusions of slate through the diabase sill in the anticline core. ¾ mile north of Ramah 29
25. Mega-ripple marks in quartzite exposed on bedding planes. 3 miles southwest of the west end of Bears Gut 30
26. Cross-bedding in the quartzite formation (unit 13) of the Ramah Group . 30
27. Open folds in Ramah Group quartzite, pelite and diabase (units 16 and 21) exposed on the 3000 feet high north wall of Saglek Fiord. The regolith, unconformably surface and Archean basement rocks (right) are folded with the Ramah Group 32
28. Intensely folded Ramah Group quartzite on the west side of the belt. Two miles south of Quartzite Mountain 33
29. Folded and faulted outlier of Ramah Group quartzite and pelite (unit 16) exposed at base of 4000-foot-high mountain of Archean gneisses (unit 1) and diabase dykes. 3½ miles north northwest of Branagin Island 34
30. Highly contorted amphibolite facies Ramah Group pelite (unit 16) with gneissic banding caused by quartzofeldspathic segregation. 11 miles south of the south side of Saglek Fiord 34

Abstract

This report describes an area, in the Torngat Mountains, straddling the Nain-Churchill Structural Province boundary.

Nain Province to the east, part of the North Atlantic Archean craton, is chiefly amphibolite facies rocks with minor areas of granulite facies. Granitic gneisses and migmatites predominate and contain horizons of basic gneiss, paragneiss, iron-formation and ultramafic rocks. A quartz monzonitic orthogneiss body is located in the north. These rocks, deformed and metamorphosed during the Kenoran Orogeny, form a steeply inclined, linear, north-trending zone, cut by granite veins and by younger, early Aphebian, west-trending diabase dyke swarms. Uplift and erosion resulted in peneplanation of the craton.

The Ramah Group forms a linear, north-trending Hudsonian fold-belt within Churchill Province. This supracrustal Aphebian group lies unconformably on peneplaned Archean basement rocks of Nain Province and passes from slightly recrystallized platform deposits into highly deformed and metamorphosed equivalents in the west. Although metamorphic grade is chiefly greenschist and low amphibolite facies, a southern extension, traced for 26 miles from Saglek Fiord to Hebron Fiord, is high amphibolite facies. Ramah Group rocks are preserved in an asymmetrical synclinorium, bounded on the west by a west-dipping thrust and by faults. The 5000 feet of stratified rocks, predominantly of sedimentary origin with one altered tholeiitic basalt flow and several amphibolitized diabase sills, overlie a pre-Ramah regolith. Six unnamed formations mapped are, in ascending order, two lower quartzite units, two slate units separated by a dolomite unit, and a greywacke unit. Paleocurrent data indicate deposition by dominantly westward directed currents. Miogeosynclinal rocks forming the bulk of the group were probably derived from a North Atlantic Archean craton to the east.

Archean basement rocks, reworked by the Hudsonian Orogeny, form a mobile belt in Churchill Province west of the Ramah Group. The reworked zone contains lithologies similar to the Archean but is chiefly granulite facies. Fresh pre-Ramah diabase dykes that cut the Archean are metamorphosed and deformed in the mobile belt. An important cataclastic zone with extensive faults, thrusts, regional mylonites, blastomylonites, and pseudotachylyte characterizes the belt. The boundary between the Hudsonian mobile belt and stable Archean craton is obscured in the basement by the overlying Ramah Group, but represents a Labrador continuation of the Greenland Nagssugtoquidian boundary. Overthrusting of the mobile belt over the Nain Archean craton to the east and transcurrent sinistral movement took place in the boundary zone.

Although no mineral occurrences of economic importance were discovered in low-grade iron, copper, lead and zinc mineralization is present in places.

Résumé

Le présent rapport décrit une région, située dans les monts Torngat, qui chevauche la frontière de la province structurale Nain-Churchill.

A l'est de la province de Nain, une partie du craton archéen de l'Atlantique-Nord est constitué surtout d'un faciès de roches à amphibolites et de quelques zones de moindre importance qui présentent un faciès de granulites. Les gneiss et migmatites granitiques prédominent et contiennent des horizons de gneiss basiques, de paragneiss et de fer, ainsi que des roches ultramafiques. L'auteur a repéré une masse d'orthogneiss monzonitiques quartzeux dans la région du nord. Ces roches, déformées et métamorphisées au cours de l'orogenèse kénoréenne, forment une zone linéaire, orientée vers le nord et profondément inclinée, coupée par des veines de granites et par des essaims de dykes de diabase plus récentes orientés vers l'ouest et qui datent du début de l'Aphébien. Le soulèvement et l'érosion ont causé la pénéplanation du craton.

Le groupe de Ramah forme, à l'intérieur de la province de Churchill, un faisceau linéaire de plis hudsonien, orienté vers le nord. Ce groupe aphébien extra-cortical s'étent de façon discordant sur les roches du socle archéen aplani de la province de Nain et passe de dépôts légèrement recristallisés de la plate-forme à des équivalents grandement déformés et métamorphisés dans la partie ouest. Même si le métamorphisme donne lieu à un faciès constitué surtout de schistes verts et d'un peu d'amphibolites, une extension méridionale de 26 milles de longueur qui s'étend du fiord Saglek au fiord Hebron, montre un faciès à forte concentration d'amphibolites. Les roches du groupe de Ramah

sont groupées dans un synclinorium asymétrique et sont bornées à l'ouest par une poussée inclinée vers l'ouest et par des failles. Composées surtout de roches d'origine sédimentaire avec un écoulement de basalte tholéitique et de plusieurs sills de diabase transformés en amphibolites, les 5000 pieds de roches stratifiées s'étendent sur un sol pré-Ramah. Les six formations innommées qui se trouvent sur la carte sont, en ordre ascendant, deux unités inférieures de quartzites, deux unités d'ardoises séparées par une unité de dolomies, et une unité de grauwackes. Les données sur les paléocourants indiquent des dépôts laissés par des courants dirigés surtout vers l'ouest. Les roches miogéosynclinales qui forment la masse du groupe proviennent probablement d'un craton archéen nord-atlantique situé à l'est.

Les roches du socle archéen, remaniées par l'orogenèse hudsonienne, forment une zone mobile dans la province de Churchill à l'ouest du groupe de Ramah. La zone remaniée possède une lithologie similaire à celle de l'Archéen, mais son faciès est composé surtout de granulites. Les dykes de diabase frais du pré-Ramah qui traversent l'Archéen sont métamorphisés et déformés dans la zone mobile. Une zone cataclastique importante comprenant des failles, des poussées, des mylonites régionaux, des blastomylonites et des pseudotachylytes prononcés, caractérise cette zone. La limite entre la zone mobile hudsonienne et le craton archéen stable est cachée par le groupe de Ramah susjacent, mais constitue une suite, dans le Labrador, à la limite nagssugtoquidienne du Groenland. Dans la zone frontière, il s'est produit un chevauchement de la zone mobile sur le craton archéen de Nain à l'est et un mouvement de décrochement vers la gauche.

Quoiqu'on n'ait découvert aucune concentration minérale économiquement rentable, il se produit malgré tout un phénomène de minéralisation à faible teneur en fer, cuivre, plomb et zinc.

Figure 1. Archean banded gneisses with diabase dykes unconformably overlain (in foreground and on left peak) by Ramah Group quartzite. Western slopes of Blow Me Down Mountain. (C.K. Bell). GSC Photo No. 202571.

GEOLOGY OF THE PRECAMBRIAN RAMAH GROUP AND BASEMENT ROCKS IN THE NACHVAK FIORD - SAGLEK FIORD AREA, NORTH LABRADOR

INTRODUCTION

General Statement

The Precambrian Ramah Group is a narrow linear belt of north-trending, chiefly metasedimentary, rocks that lies along part of the bounding zone between Nain and Churchill Structural Provinces, as defined by Taylor (1971), in north Labrador. In the area studied (Fig. 2) the Ramah Group extends north from Saglek Fiord for about 40 miles to Nachvak Fiord, and separates Archean basement rocks to the east from Archean basement rocks reworked in the Proterozoic to the west.

The region is in the Torngat Mountains, has alpine topography with numerous summits that range in elevation from 2,500 to 4,500 feet, and has spectacular well-defined fiords (Fig. 3). Alpine peaks and sharp arêtes, common in the coastal area underlain by Archean rocks, are less common in the belt of Ramah Group rocks, and are rare in the mountain country to the west. Outcrop is abundant, but is less plentiful where the topography is not sharply incised. Rubble or felsenmeer occurs on flat mountain tops particularly west of the Ramah Group. The area is devoid of trees.

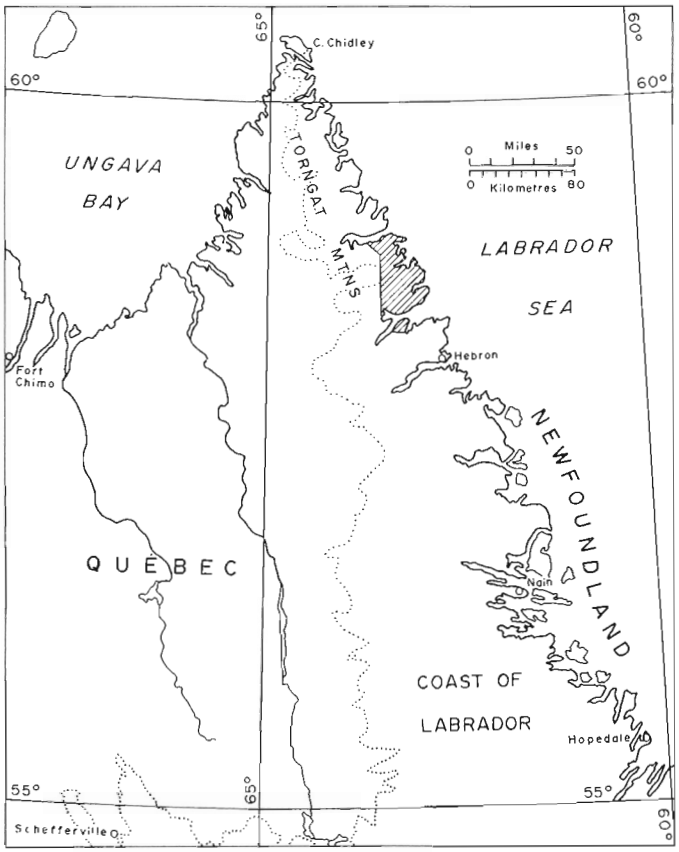

Figure 2. Location map showing area described in the report.

This report and map, based chiefly on field observations and preliminary examination of thin sections, presents results of field work undertaken in 1971 and 1972.

Saglek, a United States Air Force Base at Cape Uivak on the south shore of the entrance to Saglek Fiord was used as a starting point for access to the map-area. Prior permission has to be obtained from U.S.A.F. to enter Saglek and to use the paved airstrip and living quarters. Saglek, which is 360 miles north of Goose Bay and 300 miles northeast of Schefferville, is most easily reached by chartered aircraft and is serviced each summer by D.O.T. sealift.

Base camp during both field seasons was located on the north shore of Ramah Bay at Ramah, the site of a former Moravian mission about 40 miles north of Saglek. Camp was established by a float-equipped Otter aircraft in 1971 and by helicopter in 1972. As the sea in Ramah Bay is sheltered from the Atlantic swell and there is a gravel beach at Ramah, it is suitable for float-equipped aircraft. Saglek, however, has a rocky beach that is exposed to the Labrador Sea and can prove treacherous for a seaplane. An amphibious aircraft is ideal for operation between Saglek and Ramah and was used at the end of the 1972 field season. Service flights with all supplies and provisions were made by Otter aircraft from Goose Bay in 1971 and Schefferville in 1972.

In 1971 shoreline and foot traverses were mainly limited to parts of the area accessible by pneumatic boat. Work in 1972 was greatly facilitated by a Bell 47 G4A helicopter which provided a means of access to the entire area. The helicopter was used for traversing along irregular flight lines, for mapping areas of difficult access, for putting out foot traversing parties inland, and for setting up mobile two-men field camps that were commonly boat-supported.

North Labrador is justly noted for inclement weather and a short summer. Dense fog, rain, low cloud, high winds and snow can occur throughout the field season, and high winds are persistent from mid-August onward. The weather was extremely bad in 1971, and Saglek Fiord and Ramah Bay were not free of sea-ice until 13th July. The following season, although break-up was complete in those fiords by 5th July, bad ice conditions persisted on the coast until the end of July and prevented the use of pneumatic boats. A heavy snowfall in late August 1972 covered the Torngats to sea level and stopped work for one week. Temperatures in July and August, however, can reach 80°F, and 23 days were workable in July, 1972.

Eskimo families from Nain, a community 140 miles south of Saglek, travel to the Torngats by small boat each summer to fish for char in Saglek Fiord, Ramah Bay and Nachvak Fiord. With the exception of Saglek there are no permanent settlements in the map-area. Hudson's Bay Company posts were, however, formerly located at Nachvak Fiord and Saglek Fiord, and at

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Author's address:
6th Floor, Sun Building,
100 West Pender Street,
Vancouver, B.C. V6B 1R8

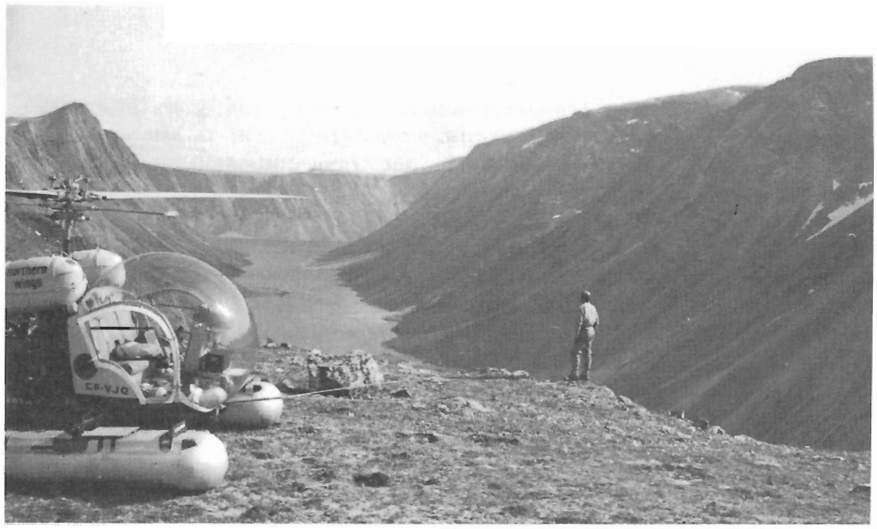

Figure 3.

North Arm, Saglek Fiord. (J.J. Capron). GSC Photo No. 162175

Ramah where accommodation was leased from the Moravian Mission. Only foundations now remain of these buildings.

The writer was ably assisted by R.J. Buchanan in 1971 and 1972, by I. Knight in 1971, and by M.P. Cecile in 1972. M.E. Cherry assisted for 3 weeks and G.D. Jackson for 4 weeks in 1972. J.J. Igloliorte, C.D. Martin and J.H. Maley served as traversing assistants in 1971. A.G. Harris, C.W. Jefferson and J.H. Maley in 1972. Thanks go to Peter Drummond, a competent radio operator in 1972, and to Carl Wheaton, a diligent cook during both field seasons. A helicopter, available for 2 weeks in 1971, was supplied by Viking Helicopters Limited and piloted by R. Watson. The helicopter in 1972 was provided by Northern Wings Helicopters Limited and piloted in turn by J. Patcha, J.J. Capron and A. Gosselet. Laurentian Air Services Limited supplied fixed-wing aircraft in 1972 and contributed to the successful accomplishment of the field work. The co-operation of Canadian Marconi Company, particularly of D. Davies, base manager at Saglek, greatly facilitated work in the area. Drs. G.D. Jackson and F.C. Taylor are acknowledged for numerous discussions with the writer and for their constructive criticism of the manuscript. Dr. F.W. Chandler provided advice on sedimentary rocks and critically read the section on the Ramah Group.

Previous Work

The earliest reference to the geology of the map-area is in a report by Steinhauer (1814) on observations made by two Moravian missionaries who journeyed along the Labrador coast from Okak to Ungava Bay in 1813. Prior to the establishment of the mission at Ramah in 1871, Ramah Bay was known as Nulletartok Bay and Slate Bay. Bell (1884, 1895) noted that the slaty rocks that occur at Ramah extend to Nachvak Fiord. Daly (1902), who was a member of the Brown-Harvard expedition in the year 1900, named the Ramah Group (Ramah Sedimentary Series) and described coastal geology particularly near Nachvak Fiord. Another member of the expedition, Delabarre (1902), walked overland with companions from Hebron Fiord to Nachvak Fiord and recorded the extent of the Ramah Group.

More detailed work was accomplished in 1915 and 1916 by Coleman (1921) who observed a volcanic flow near the base of the Ramah Group in Ramah Bay and measured two stratigraphic sections on the south side of Nachvak Fiord. He described paragneiss, hypersthene gneiss, crystalline limestone, and occurrences of pseudotachylyte. Odell (1933, 1938), geologist on the Grenfell-Forbes northern Labrador expedition in 1931, introduced the terms granulite and charnockite to the literature of the map-area and also reported occurrences of mylonite and pseudotachylyte.

The coast was mapped in 1951 at a scale of one inch to four miles by Christie (1952) who measured a detailed stratigraphic section of the Ramah Group on the north shore of Ramah Bay. He noted that the Ramah Group extended to the south side of Saglek Fiord and considered that the west contact was probably a fault. It is interesting to note that Christie observed a marked difference in basement rocks that outcrop to the west and to the east of the Ramah Group. His maps show intermediate hypersthene and pyroxene gneisses west of the Ramah Group with granitoid gneisses to the east.

Part of the Ramah Group in the area between Ramah Bay and Rowsell Harbour was mapped in considerable detail in 1946 and 1947 by Milligan and Goodman (*in* Douglas, 1953). They produced a detailed stratigraphic column and cross-section of the Ramah Group on the north shore of Ramah Bay, mapped Archean gneisses thrust over rocks of the Ramah Group north of Rowsell Harbour, and recognized a number of other west-dipping thrust faults.

The area was mapped in the 1967 and 1969 phases of Operation Torngat (Taylor, 1969, 1970), a helicopter-assisted reconnaissance geological mapping program in northeastern Quebec and northern Labrador. Inland parts of the map-area were investigated for the first

time, and the Ramah Group was shown to be bounded to the west by a thin strip of Archean rocks, west of which lay Proterozoic granulites.

The present study aims to investigate the Ramah Group and Archean-Proterozoic basement contact, in addition to assessing the economic potential of the area. Summary accounts of progress have been published (Morgan, 1972, 1973). Stratigraphy and sedimentology of the Ramah Group are currently under detailed investigation by Knight (1973), and will form the basis of a doctoral thesis submitted by him to Memorial University of Newfoundland.

GENERAL GEOLOGY

The present map-area includes parts of Nain and Churchill Structural Provinces as defined by Taylor (1971).

For convenience it is divided into the following three regions:

Basement rocks east of Ramah Group
Basement rocks west of Ramah Group.
Ramah Group.

Formations in basement rocks both east and west of the Ramah Group are shown in Table I. Table II lists formations recognized in the Ramah Group.

Basement Rocks East of the Ramah Group (Units 1-7): Archean

Acid Gneiss and Migmatite (Unit 1)

Although this unit consists of a number of different rock types, including acid gneiss, banded gneiss, migmatite, agmatite and granulite, no subdivision has been attempted at this stage in the investigation. Thin bands of basic gneiss (unit 2), paragneiss (unit 4) and rare lime-silicate rocks are also present. Local horizons contain numerous inclusions and blocks of ultramafic rock (unit 3) that range in size from a few inches to several tens of feet.

The acid gneiss is a white or grey leucocratic rock with a characteristic granular texture and commonly ranges in composition from granite to granodiorite. It is fairly homogeneous with a mineral foliation or a compositional layering indicated by thin layers or discontinuous lenses of ferromagnesian minerals, chiefly hornblende and biotite, set in a quartzofeldspathic matrix. Quartz locally tends to be bluish while a green colour is imparted to the rock by chlorite formed as an alteration product of other minerals. Irregular conformable and crosscutting bodies of foliated granite and pegmatite are common and display poorly defined contacts with the acid gneiss. Crosscutting veins and sheets of massive late stage granite and pegmatite (unit 6) with sharp contacts also occur. In thin section the acid gneiss is found to be considerably altered. Strongly microperthitic microcline and antiperthitic plagioclase are altered to kaolin and sericite while hornblende and biotite are chloritized. Pseudomorphs, considered to be alteration products of pyroxenes and amphibole, are common. Garnet is rare as are unaltered cores of diopside and hypersthene.

Banded gneiss (Fig. 4a) consists of acid gneiss alternating with layers of amphibolite or basic gneiss (unit 2) that are commonly 1 to 10 feet thick. Thin basic bands tend to be lenticular and composed of amphibolite or hornblende gneiss. Thicker bands form well-defined layers that may be continuous for considerable distances and contain hypersthene, diopside and garnet.

The gneisses are commonly strongly migmatized with irregular bands or blocks of basic gneiss and paragneiss separated by acid gneiss and irregularly cut by granitic veins. Nebulitic migmatite, consisting of indistinct veined inclusions in a granitic matrix, is also present. Minor structures are apparently chaotic, but provide evidence of mobilization. Where the migmatite has a brecciated appearance with blocks enclosed in and veined by a granitic matrix, it has been mapped as agmatite (Fig. 4b).

Granulites occur sporadically throughout this unit, particularly in the north between Delabarre Bay and Nachvak Fiord.

Locally the acid gneiss and migmatite grade into paragneiss, and much of this unit is possibly of metasedimentary origin. A few discordant amphibolite bodies that were observed in migmatite may represent an early phase of basic dyke intrusion.

Basic Gneiss (Unit 2)

Basic gneiss is an important lithological marker horizon by means of which the structure of parts of the basement rocks east of the Ramah Group can be determined. The basic gneiss forms elongated conformable bands that differ greatly in thickness but commonly range from mappable horizons 500 feet or more thick to bands a few feet across. Between Bears Gut and Kangalasiorvik Bay, a concentration of basic gneiss outlines an open synform, a structure erroneously interpreted as a syncline of the Ramah Group by Odell (1938).

The basic rocks are rusty or brown weathering, and are black or dark grey on fresh surfaces. Individual horizons commonly have a strong mineral foliation and are massive, gneissic or compositionally banded on a large scale. Veins and lenses of quartz, granite, and pegmatite commonly occur parallel to the gneissic banding, and much of the basic gneiss is migmatized. These rocks differ in composition but are chiefly pyroxene-bearing hornblende gneisses and amphibolites that may contain various amounts of garnet and/or biotite. Presence of hypersthene or diopside or both minerals is a characteristic feature. Irregular conformable or crosscutting veins of quartzofeldspathic pegmatite with hypersthene and diopside are present at several localities. Some basic rocks also contain bands of quartz-rich silicate-oxide iron-formation that range from 30 feet to 100 feet thick. Locally basic gneiss grades laterally and along strike into paragneiss (unit 4). Numerous small bodies of metamorphosed

Figure 4a.

Banded gneiss, composed of alternating layers of acid and basic gneiss, cut by conformable and cross-cutting veins of granite and pegmatite. Duncan Point. (G.D. Jackson). GSC Photo No. 162572

Figure 4b.

Agmatite. North side of Rowsell Harbour. (G.D. Jackson). GSC Photo No. 162542

Figure 4c.

Orthogneiss. One mile east of Naksaluk Cove, Nachvak Fiord. (M.P. Cecile). GSC Photo No. 162484

ultramafic rocks (unit 3) are present within many basic horizons. Several large elongated ultramafics terminate along strike in pyroxene amphibolite bands.

In some thin sections pyroxenes are extensively altered and are rimmed and replaced by green hornblende. Other thin sections contain apparently stable mineral assemblages that include hypersthene, diopside and brown hornblende.

There is no evidence of the original nature of the mappable bands of basic rocks. Although some may be derived from sedimentary rocks the majority are probably metamorphosed igneous rocks.

Metamorphosed Ultramafic Rocks (Unit 3)

Ultramafic rocks are fairly common and occur within leucocratic gneiss (unit 1) or associated with horizons of pyroxene amphibolite (unit 2). They form stumpy lenticular bodies with a maximum size of $\frac{3}{4}$ mile by $\frac{1}{4}$ mile or occur as elongated horizons up to $1\frac{3}{4}$ miles long and 200 feet thick. All are conformable and are elongated parallel to the foliation or composite banding in surrounding gneisses. The frequent occurrence along strike of several mappable bodies or of trails of small discontinuous lenses and blocks probably indicates that the ultramafic rocks are remains of original sheet-like bodies.

In the field ultramafic rocks are readily recognized by a distinctive rusty, brown or green weathered surface. The bodies display foliation parallel to the regional trend and a rare compositional variation that may represent primary layering. They are chiefly peridotites that have been extensively serpentinized but pyroxenites, hornblendites and amphibolites are also represented. Individual bodies are commonly variable in composition. Some contain hypersthene while others are cut by quartzofeldspathic hypersthene-bearing pegmatites. Many are intruded by quartz and quartzofeldspathic veins. Irregular zones and lenticular veins containing serpentine, talc, mica, chlorite or asbestos are common. Small amounts of soapstone are present in a number of bodies.

Paragneiss (Unit 4)

Several bands of paragneiss have been mapped in the area south of Ramah Bay, the largest being $\frac{1}{2}$-mile-wide conformable horizon that extends for 7 miles from northwest of Reichel Head to Bears Gut. Numerous small bands of paragneiss are, however, present throughout the area east of the Ramah Group.

The paragneiss is characterized by a very deeply weathered rusty brown surface but as the rock has a distinctive compositional banding it is readily distinguished at a distance from ultramafics (unit 3) and all other rock types present in the area. Some horizons have a marginal zone of pyroxene amphibolite (unit 2) while others grade along strike into basic gneiss (unit 2), and most are considerably varied in composition across strike. The paragneiss is commonly migmatized and contains conformable and irregular veins and patches of quartz, granite and pegmatite.

Fresh surfaces of paragneiss are chiefly white but range to a dark grey colour. Typically the rock is fine to medium grained, composed of essential quartz and feldspar, and contains minor amounts of biotite and pale pink garnet. Within an individual paragneiss band there are commonly local layers of feldspathic quartzite and quartzite up to a few feet thick. Pelitic horizons rich in biotite with or without garnet are also present and may contain graphite and/or sillimanite. Hornblende, diopside, hypersthene, chlorite, pyrite and chalcopyrite have been noted within paragneisses of this map-unit. Narrow zones of thinly banded silicate-oxide iron-formation composed of magnetite, hornblende, garnet and quartz are also interbanded with paragneiss at some localities.

Orthogneiss (Unit 5)

This distinctive map-unit which occurs in the northern part of the area forms a stock-like body that underlies about 4 square miles near Kammarsuit Mountain and Naksaluk Cove on the south side of Nachvak Fiord. Small conformable bodies and veins are also present in the acid gneiss and granulite (unit 1) and are well exposed along the coast between Kammarsuit Mountain and Bigelow Bay.

Characteristically the orthogneiss (Fig. 4c) contains subhedral or augen-shaped feldspar megacrysts. Foliation within the intrusion is subparallel to the contact, varies from weak to pronounced, and is outlined by parallel alignment of megacrysts, by different concentrations of feldspar, and by variations in composition. Several thin bands of basic gneiss and garnet-pyroxene amphibolite (unit 2) occur within the orthogneiss. Marginal parts of the intrusion are migmatitic, or highly sheared and mylonitized, or are interbanded with acid gneiss (unit 1).

The orthogneiss, a mottled white and dark grey to black rock, is medium to coarse grained with composite megacrysts of potash feldspar up to 2 inches, and is composed of essential quartz, potash feldspar, plagioclase and biotite. Composition chiefly ranges from quartz monzonite to granodiorite although quartz diorite is also present. Quartz commonly has a blue tinge, and locally the gneiss is yellow-green due to high epidote content.

In thin section the feldspars, strongly microperthitic microcline and plagioclase (An_{26}), are cloudy and altered, particularly the plagioclase which contains much sericite and epidote. Biotite forms aggregates of small crystals that are possibly pseudomorphs after pyroxenes and amphiboles, relict crystals of which are rare. Apatite, zircon, and opaques rimmed by sphene are accessory minerals.

Granite and Pegmatite (Unit 6)

Coarse-grained white granite and pegmatite occur throughout basement rocks east of the Ramah Group

but are numerous only between The Muzzle and Saglek Fiord. They form crosscutting veins and sheets, roughly conformable to the regional foliation, that range up to tens of feet across. A few intrusions, however, are thicker, but only one forms a small mappable body. These rocks are particularly well developed on the coast south of Reichel Head where they form an anastomosing network of dyke and sill-like veins.

Rocks of this map-unit intrude all rock types described above (units 1 to 5) and commonly exhibit sharp contacts. The granite and pegmatite are massive or weakly foliated and show little evidence of strong deformation or folding. They are readily distinguished from the lenticular, folded pegmatites and granitic sweats that are an inherent component of the acid gneiss and migmatite (unit 1).

The most common rock type is a medium- to coarse-grained, massive, well-jointed white leucocratic biotite granite that grades into pegmatite. Locally, particularly outside the map-area in the vicinity of Saglek Base at Cape Uivak, this unit is pink and forms a large-scale stockwork. Thin sill-like bodies separated by rafts of gneiss are widely exposed at that locality and appear to be the dominant rock type where the gneiss is flat lying.

Minor amounts of garnet, hypersthene, diopside and amphibole have been recorded in these rocks. Commonly, however, the rocks have an altered appearance and the original mafic minerals are replaced by aggregates of biotite and chlorite. Plagioclase (An_{30}) is altered and sericitized, microcline is strongly microperthitic, and minor amounts of epidote, sphene and zircon are present.

Basic Dykes (Unit 7)

A characteristic feature of basement rocks east of the Ramah Group is the occurrence of swarms of basic dykes of more than one age. In the 40-mile north-south distance between Nachvak Fiord and Saglek Fiord there are at least three hundred subparallel, almost vertical, roughly east-trending basic dykes. Only a few are shown on the accompanying preliminary map (in pocket). Although the majority have a crude east trend, several trend northwest, north, or northeast. The east-trending dykes can be traced for a maximum distance of 12 miles, from the Labrador Sea to the Ramah Group contact. The dykes range greatly in thickness but are commonly up to 200 feet wide.

The following generations of basic dyke emplacement have been recognized in the present study: -

(a) Remnant discordant amphibolites
(b) Post-migmatization amphibolite dykes
(c) Nonporphyritic diabase
(d) Feldsparphyric diabase
(e) Thin nonporphyritic diabase.

Remnant discordant amphibolites. The earliest basic intrusions recognized in the area consist of identifiable remnants of discordant dykes that are present in the acid gneiss and migmatite (unit 1). These remnants are composed of amphibolite and pyroxene amphibolite, are folded, ruptured, cut by granitic veins, migmatized, agmatized, and metasomatically replaced. The remnants are usually only a few feet or tens of feet thick.

Post-migmatization amphibolite dykes. An early phase of post-migmatization basic dyke intrusion is possibly indicated by the presence of several sheared, foliated, metamorphosed dykes, a few of which appear to be folded. These dykes are now granoblastic-textured amphibolites. They have been noted at only a few localities and knowledge of their distribution and age relationships with other dykes in the study area is at present fragmentary. Although a late syntectonic Kenoran intrusive origin is possible, the dykes may have been deformed and metamorphosed by the post-Ramah Group orogeny.

Nonporphyritic diabase. The majority of the dykes mapped are black or brown weathering diabases that sharply truncate the regional foliation and structures in the basement gneissic rocks. They branch into numerous interconnected off-shoots that commonly tend to converge after some distance. The dykes are essentially massive and nonfoliated but are locally slightly deformed and metamorphosed. Some dykes have one or both contacts sheared, others are cut by faults, and a few are openly folded. Original contacts are, however, chiefly sharp, chilled and fine grained. Numerous wedge-like penetration tongues and very thin hair-like veins of diabase a few inches or less in thickness terminate in the country rocks and commonly show no evidence of folding or deformation. Where nonporphyritic dykes within this swarm intersect there is commonly no evidence of chilling of one dyke against another. The relative chronologies of the nonporphyritic and feldsparphyric dykes of generations (c) and (d) was not definitely established.

Thin section study indicates that subophitic or ophitic textures are preserved. Original clinopyroxene crystals, replaced by brown and green hornblende around thin margins, and slightly altered subidiomorphic plagioclase feldspars are also present. Olivine pseudomorphed by chlorite and epidote is common in these dykes, and opaques are largely altered to sphene.

Feldsparphyric diabase. Feldsparphyric diabase dykes are widely scattered throughout the area. At a few localities they form closely spaced swarms that consist of several tens of dykes in a small area (Fig. 5). These dykes tend to be only a few feet thick, contain 1.0-cm plagioclase phenocrysts, and although altered have relict pyroxenes and igneous textures.

Thin nonporphyritic diabase. On the south side of Bell Inlet a closely spaced swarm of ten to twenty interconnected feldsparphyric dykes is cut by a 15-inch-thick black nonporphyritic diabase dyke. A different joint pattern is present in the crosscutting dyke and, although the contacts are commonly sheared local chilling was observed.

Figure 5.

Intense swarm of feldsparphyric diabase dykes exposed on 400 foot cliff. ½ mile south of the west end of Bell Inlet. GSC Photo No. 161992

Structure

Regional foliation throughout this area has a general north trend and a moderate to steep dip to the west. Local variations in attitude are however common, and foliation is irregular between Ramah Bay and Nachvak Fiord where trends range from northeast to northwest.

Minor folds have a complex apparently chaotic geometry caused by plastic deformation and flow folding. Tectonic inclusions, rootless isoclinal intrafolial folds, transposed compositional banding, décollement structures and ptygmatic structures all occur. Superposed fold structures are common, and detailed structural analysis would establish the presence of several phases of folding. In addition, basement rocks east of the Ramah Group have been involved in at least two periods of deformation, the Kenoran Orogeny and a later orogeny that affected the Ramah Group. Folds in the Archean basement caused by the post-Ramah Group orogeny are, however, generally difficult to d-detect. They are conspicuous at the east contact of the group in the vicinity of Saglek Fiord. There the folded unconformity surface between the Ramah Group and Archean basement (Fig. 27) is magnificently exposed.

Macroscopic inclined and overturned isoclinal to subisoclinal folds, with amplitudes of 2,000 feet, marked by pyroxene amphibolite bands are well exposed on fiord walls and mountain faces (Fig. 6). These folds commonly have axes that plunge north and south at low to moderate angles, and have axial planes that dip west at about 70 degrees. Individual folds cannot be traced far, as even the thicker basic gneiss marker horizons tend to die out after a few miles. Locally there is some evidence of crossfolding, for example near Bears Gut where many folds have north-

Figure 6. Macroscopic sub-isoclinal folds exposed on the 2,000 feet high north wall of Bell Inlet. Note the diabase dyke swarm, and Ramah Group in the left background. GSC Photo Nos. 161959-161962-161963

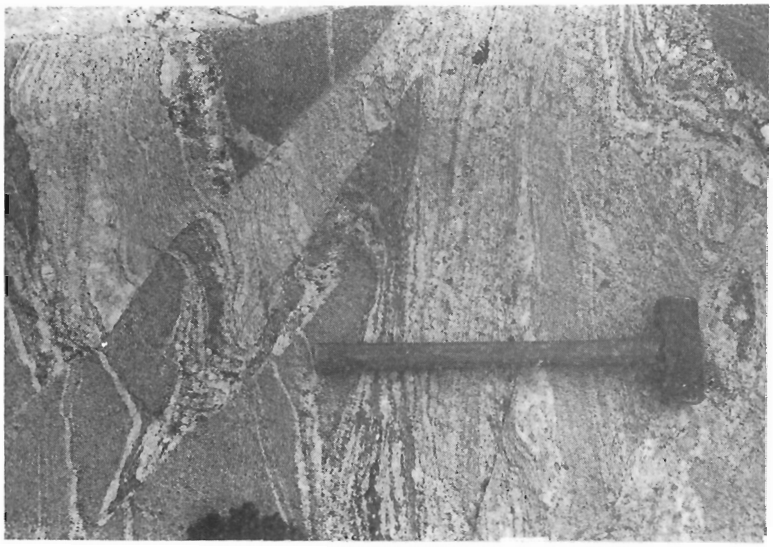

Figure 7a. Migmatite (unit 8). 3 miles southeast of Tinutyarvik Cove, Nachvak Fiord. (M.E. Cherry). GSC Photo No. 162675

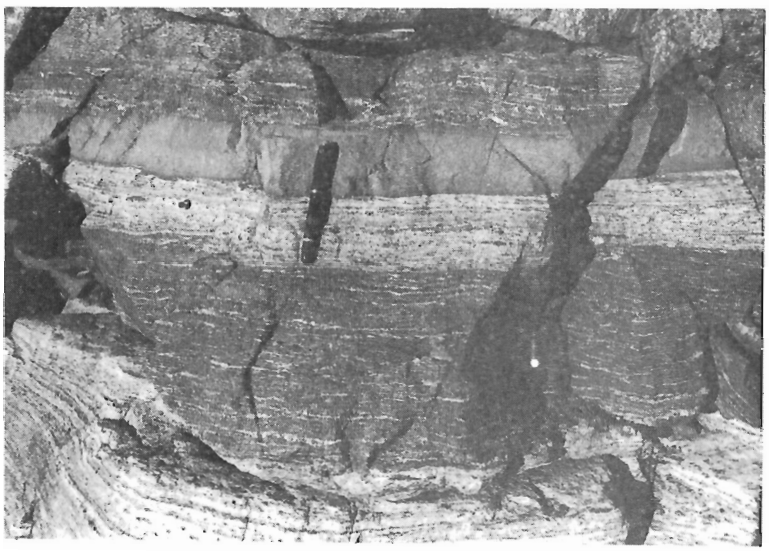

Figure 7b. Banded pyroxene gneisses. 11 miles west southwest of the south end of Little Ramah Bay. (M.E. Cherry). GSC Photo No. 162654

west and northeast trends. A large-scale open synformal structure outlined by basic gneiss (unit 2) north of Kangalasiorvik Bay is possibly later than the isoclinal folding.

Faults are common and mainly trend north, northeast and northwest. Relative ages between the various fault trends were not established, but some predate and others postdate deposition of the Ramah Group. Brecciation, shearing and slickensiding are associated with the faults. There are no extensive areas or regional development of mylonitized rocks in the basement east of the Ramah Group.

North-trending subvertical strike faults are well exposed east of Little Ramah Bay. Although the amount

of vertical movement is not known, most of these show a slight sinistral strike-slip displacement relative to basic dykes. Both sinistral and dextral movements, seldom greater than 1,000 feet, were observed on faults with northwest and northeast trends.

Several north-trending west-dipping thin crush zones occur in the area between Delabarre Bay and Nachvak Fiord, on the east side of Kammarsuit Mountain. They are probably extensions of west-dipping thrust faults that cut the Ramah Group and basement rocks between Delabarre Bay and Rowsell Harbour.

Metamorphism

The occurrence in the acid gneiss and migmatite (unit 1) of granular textures, of strongly microperthitic feldspars, of rare unaltered cores of hypersthene, and of local areas of granulite facies rocks has been described above. Because of these and other features the acid gneiss, in general, is considered to represent granulite facies rocks that to a large extent have undergone retrogressive metamorphism to amphibolite facies. Basic rocks of unit 2, however, commonly contain hypersthene and are largely of granulite facies, having survived the retrogressive metamorphism. The altered appearance of the orthogneiss (unit 5) in hand specimen is verified by textures and mineralogy observed in thin section and is considered to indicate retrogression, possibly of an original charnockitic rock.

Occurrences of partly retrogressed granulite facies relicts in the present map-area were first described by Bridgwater (1970). Similar retrogression of Precambrian basement rocks in southern West Greenland has been described in detail by Windley (1969a, 1969b).

Basement Rocks West of the Ramah Group (Units 8-12): chiefly reworked

Archean

Acid Gneiss and Migmatite (Unit 8)

This map-unit forms a one- to three-mile-wide strip immediately west of the Ramah Group and extends from Nachvak Fiord to south of Saglek Fiord. Continuity of this strip is broken at two places, northwest of the west end of Ramah Bay and west of the south end of Little Ramah Bay.

Unit 8 consists of grey weathering leucocratic gneiss and migmatite (Fig. 7a). The gneisses have granular textures and locally contain relict pyroxenes, but the mafic minerals are considerably altered and chloritized. Garnet is rare in these rocks as are basic gneiss bands. Small bodies of ultramafic rocks are present but are not shown on the accompanying map.

Unit 8 is characterized by pronounced cataclasis. The classification of cataclastic rocks used here is based on that summarized by Spry (1969). Most of the cataclastic rocks are foliated and are commonly lineated, so that cataclasites are rare. Zones of protomylonite several feet to several hundreds of feet thick occur throughout this unit. Mylonite is less common, tends to occur in thinner zones, and can be observed to grade into protomylonite or ultramylonite. Tectonic breccias are common, particularly in the strip of gneiss and migmatite that extends north for about 15 miles from Saglek Fiord. Bright brick red deeply weathered zones are a conspicuous feature of outcrops there, particularly on the east side of Nakvak Brook near the fiord. Conformable, crosscutting and network veins of pseudotachylyte are present at several localities.

In the southern part of the map-area, the contact between the acid gneiss and migmatite (unit 8) and the acid pyroxene gneiss to the west (unit 9) is faulted for a distance of about 15 miles. From 5 miles south of the west end of Ramah Bay north to Nachvak Fiord, however, fault contacts are essentially absent, although there is local mylonitization.

Some granulites (unit 9) that have been subjected to intense retrograde metamorphism and cataclasis associated with faulting, may be included in the western part of map-unit 8.

Acid Pyroxene Gneiss and Migmatite (Unit 9)

This map-unit, characterized by occurrence of hypersthene in quartzofeldspathic rocks, is located in general west of the acid gneiss and migmatite (unit 8) and can be traced continuously from Nachvak Fiord to Saglek Fiord. These rocks are less well exposed than basement rocks east of the Ramah Group. Thin bands of basic granulite (unit 10) paragneiss (unit 11) and a few small ultramafic bodies are included in this map-unit. Paragneiss bands are more common in the south, and are virtually confined to the granulite area west of Nakvak Brook. Bands of silicate-oxide iron-formation, a few inches thick, occur in granulites 2 miles northeast of the north end of North Arm. Zones of leucocratic gneiss and migmatite that do not contain hypersthene are also present. Mappable sub-units were not recognized in this area of high grade gneisses and migmatites.

Typical outcrops are dark brown or dark grey brown and are locally deeply weathered. Some massive outcrops that consist of more homogeneous pyroxene gneiss tend to be resistant and weather very pale grey to white. Fresh surfaces vary in colour and may be yellow, green, brown or blue grey; all have a characteristic waxy or resinous appearance.

The main rock-type is a fine- to medium-grained leucocratic granulite that consists dominantly of quartz and feldspar with minor hypersthene. Small amounts of other minerals including diopside, garnet, hornblende and biotite may, however, be present. Bands of basic pyroxene gneiss that range in thickness from a few feet to several tens of feet are common (Fig. 7b), but mappable bands of pyroxene amphibolite (unit 10) are rare, possibly in part due to the type of exposure, and are not comparable in number to those present in unit 1 east of the Ramah Group. Rocks of intermediate composition are abundant and are also included in unit 9. Garnet is more common in portions with mafic or intermediate composition.

Foliation in these rocks is indicated by alternations of basic and acid material, commonly one inch or less thick. Textures are variable and may be equigranular but commonly have a streaky foliation due to parallel orientation of platy quartz and feldspar grains. The finely laminated granulites possess blastomylonitic textures similar to those described in granulites by Watznauer (1969) and Spry (1969, p. 294) and have strong mineral lineations.

Where unit 9 is in gradational contact with unit 8 parts of unit 9, within the hypersthene zone, are highly migmatitic. They contain all the structures, rock-types, and interrelationships typical of migmatite (unit 8) and described above under unit 1. Migmatite is not confined to the gradational contact zone, but is conspicuous at localities several miles west of the contact where all component lithologies contain hypersthene and where the rocks are clearly granulite. Migmatite structures are complex and are sheared and smeared out so that individual horizons terminate rapidly along strike. Rocks that can be termed migmatite do not, however, occur throughout the unit and are, for instance, not evident in the area west of Nakvak Brook.

Laminated granulites that possess a mylonitic appearance and are considered to be recrystallized mylonites (blastomylonites) are very common throughout the area underlain by unit 9. Zones of later cataclasis are also common throughout this area, and several occurrences of pseudotachylyte have been observed.

Basic Pyroxene Gneiss (Unit 10)

A few mappable bands of basic pyroxene gneiss and pyroxene amphibolite up to 2 miles long and 500 feet thick occur in unit 9, mainly west and southwest of Ramah Bay. Unit 10 is deeply weathered and outcrops have crumbly brown surfaces. The rocks tend to be coarse-grained with garnet poeciloblasts several inches across and large conspicuous hypersthene, diopside and hornblende crystals.

Paragneiss (Unit 11)

A 4-mile-wide strip of paragneiss has been mapped in the southwest part of the area in the vicinity of North Arm, Saglek Fiord. Thin interbands with gradational contacts also occur within the acid granulite of unit 9 particularly towards its western contact with unit 11.

Unit 11 is commonly a rusty weathering white to grey, fine- to medium-grained quartzofeldspathic rock that contains biotite, garnet, graphite and local sillimanite. Parts grade into feldspathic quartzite that may be garnetiferous. Local veins of quartz and pegmatite are present.

Although some localities show no evidence of cataclasis, this unit as a whole is characterized by blastomylonitic textures. The paragneiss has a platy appearance due to parallel alignment of thin elongated lenticular aggregates of medium- to coarse-grained grey quartz. The lenticular quartz aggregates are extremely elongated and outline strong mineral lineations described as "ribbon texture" by Spry (1969, p. 294). Feldspars and some granular aggregates of garnet are also drawn out into ribbons. Individual inch-sized garnets may form augen, or rotated porphyroclasts, or may be rounded or subidioblastic.

Effects of later cataclasis are also present in the paragneiss. Tectonic breccias, cataclasites, mylonites and pseudotachylyte veins occur locally.

Basic Dykes (Unit 12)

The occurrence in basement rocks west of the Ramah Group of swarms of basic dykes of more than one intrusive age was established. They are as numerous in this area as in basement rocks east of the Ramah Group. Crosscutting dykes are rare in the acid granulite (unit 9) block west of Nakvak Brook and were not observed in the blastomylonitic paragneiss (unit 11), but are abundant elsewhere. On air photographs the dykes show up well against a background of light weathering acid gneiss and migmatite (unit 8), but are commonly difficult to observe where they cut the darker brown-weathering granulites (units 9 and 10).

Most dykes are subvertical but some are subhorizontal and others are folded. Thicknesses range from a few inches to a maximum of about 200 feet. No distinction has been made between dykes of different intrusive ages on the map (in pocket) on which only a few dykes are shown.

Dykes west of the Ramah Group have an overall northeast trend. There are, however, considerable variations and all trends in the quadrant between east and north are represented. Some local dykes, for instance 10 miles south-southwest of the west end of Ramah Bay, have a northwest trend.

At the present stage in the investigation only a rough classification of the dykes is possible into:

Older dykes. These are metamorphosed, deformed, and are now amphibolites. Although both nonporphyritic and feldsparphyric varieties can be recognized, the relative order of emplacement is not known.

Younger dykes. These are fresh to slightly altered ophitic diabases that postdate the amphibolite dykes. Two ages of these younger dykes are known.

Older dykes. These are common throughout the area. Many branch and converge without exhibiting chilled relationships at intersections. Their trend, in general, is rotated from east or east-northeast, where they cut unit 8 and parts of unit 9, adjacent to the Ramah Group contact, to northeast or north on being traced west away from this contact. As a result the angular discordance between crosscutting amphibolite dykes and foliation in the gneisses and granulites becomes less to the west. Deformation has destroyed evidence of crosscutting relations so that basic dykes

Figure 8.

Foliated amphibolite dyke (left) cuts across granulite facies gneisses (right) from which it is separated by a shear zone, parallel to the dyke contact, containing amphibolite facies mylonitized gneisses. 2 miles northwest of the west end of Ramah Bay. (M.P. Cecile). GSC Photo No. 162353

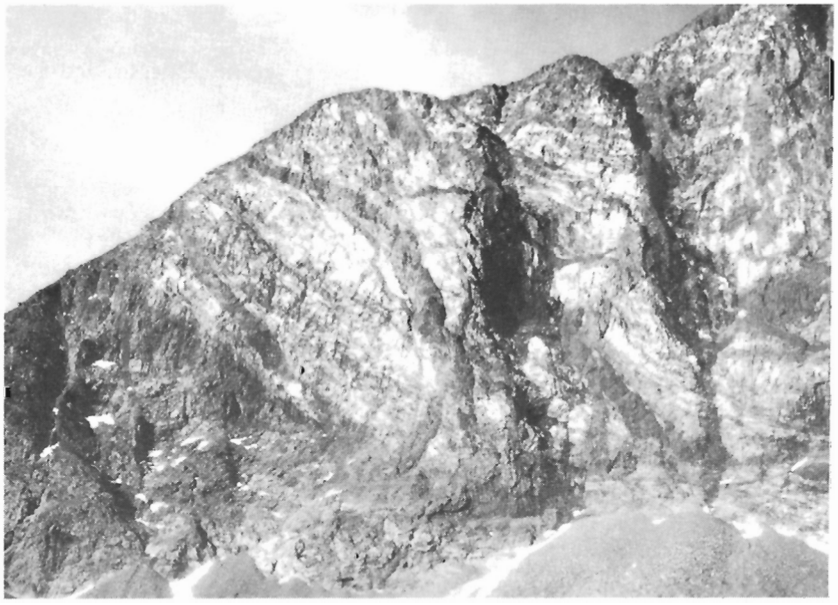

Figure 9.

Deformed basic dykes on 2,000 feet high cliff. 5 miles south of the west end of Ramah Bay. GSC Photo No. 202531-G

appear conformable. Crosscutting relationships are, however, locally preserved (Fig. 8).

The older dykes are well exposed on 1,000-foot to 3,000-foot cliffs near Stecker River, west of Quartzite Mountain and along the 8-mile scarp that runs south from the west end of Ramah Bay (Fig. 9). Subvertical crosscutting dykes turn into sills conformable with the regional foliation; have highly irregular thicknesses; pinch and swell along their lengths; and are isoclinally folded.

A 200-foot-thick east-trending amphibolite band that cuts across acid granulite 2 miles southwest of the west end of Ramah Bay is fairly representative of the nonporphyritic older dykes. Foliation in the granulite facies country rocks, which are commonly amphibolite facies adjacent to the dyke, trends roughly east parallel to the contact near the dyke, but has the regional north trend away from the contact. The amphibolite dyke is also foliated, parallel to its margins, throughout its width. Foliation in the acid granulite adjacent to, and in the marginal parts of, the dyke is of a cataclastic nature (protomylonite and mylonite) and has developed along shear zones that postdate dyke intrusion. Two ages of foliations are therefore present in the country rocks. Detailed examination of the dyke contact shows local cross-

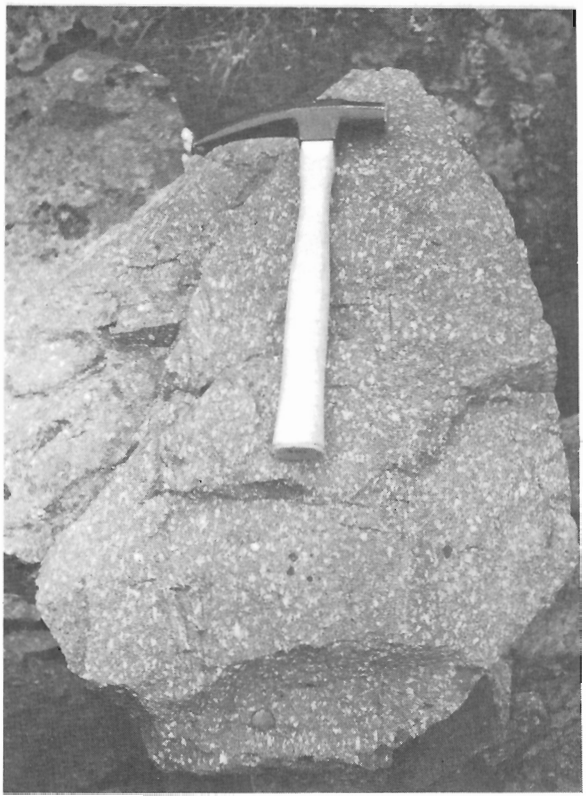

Figure 10a. Weakly foliated feldsparphyric diabase dyke. Approximately 4½ miles west of the west end of Ramah Bay. GSC Photo No. 162218

replaced by hornblende and biotite. The centre of the dyke is a medium- to coarse-grained, mottled dark green, weakly foliated amphibolite consisting mainly of hornblende, biotite and plagioclase. In thin section the rock is seen to have a granoblastic to schistose texture with little trace of ophitic relations. Original plagioclase crystals are, however, hazily outlined and occupied by granular plagioclase aggregates that include some biotite.

Some amphibolites have a strong foliation, defined by alternating hornblende-rich and plagioclase-rich layers, subparallel to dyke margins. This foliation may occur only in the centre bounded by schistose margins, or may occur across the dyke. Streaky hornblende and plagioclase mineral lineations are present in some amphibolites. A decrease in grain size commonly occurs towards the margins.

The extent of deformation and metamorphism of the feldsparphyric dykes also varies considerably and thin chilled offshoots may be preserved. Locally these amphibolites are characterized by preservation of relict igneous textures and 1.0-cm long plagioclase phenocrysts (Fig. 10a). In the vicinity of shear zones that roughly parallel dyke contacts feldspars are granulated and drawn out (Fig. 10b). Highly sheared dykes are strongly foliated and have blastoporphyritic textures.

Younger dykes. Younger, ophitic, fresh, diabase dykes occur throughout the same area as the older amphibolite dykes but are much less numerous and tend to be thin, in the order of a few feet or tens of feet. They trend both parallel and at high angles to the amphibolite dykes, but always show clear crosscutting relationships with the country rocks. Although the

Figure 10b.

Feldsparphyric diabase dyke cut by thin shear zones. Same locality as 10a. GSC Photo No. 162215

cutting relationships and small offshoots. Although the very fine grained contacts appear to be chilled, they are probably chiefly the result of shearing. The marginal phase of this dyke is black, massive, fine grained, and contains 2.0-mm plagioclase laths. Slightly corroded subhedral plagioclase crystals and opaques are seen in thin section to be surrounded by very fine grained anhedral hornblende and biotite. The texture is essentially ophitic with primary pyroxene diabases are massive, the margins of a few are sheared and weakly foliated. At several localities younger dykes and their aphanitic apophyses have been observed to crosscut, and chill against, foliated amphibolite dykes.

More than one age of younger dyke intrusion is present, and this is illustrated by relationships exposed 4 miles south-southwest of the west end of Ramah Bay. A 40-foot-thick north-trending dark grey-green, mas-

sive, ophitic diabase exhibits chilled contacts and crosscutting relationships with acid granulites (unit 9) there. This dyke is sharply crosscut by a 3-foot-thick east-trending massive fresh diabase that has chilled margins and consists of ophitic plagioclase and pyroxene set in an aphanitic groundmass. Irregular thin apophyses of the younger diabase penetrate the older diabase and country rocks.

Structure

Regional foliation throughout this area has a general north-northwest trend and is particularly consistent in the area west of Nakvak Brook. In detail trends are diversified and complicated by the fact that foliations of more than one type and age both, predating and postdating basic dyke intrusion, are present.

Few macroscopic folds were recognized. Minor folds in the gneisses and migmatites that comprise units 8 to 10 are similar to structures described in basement rocks east of the Ramah Group. Isoclinal folds, commonly rootless (Fig. 11) due to extreme plastic deformation, occur throughout.

Locally, for example in the vicinity of Quartzite Mountain about 7 miles north-northwest of the west end of Ramah Bay, basement rocks (unit 8) are metamorphosed, folded and deformed with Ramah Group rocks. The orogeny that affected the Ramah Group is considered to have caused the reworking of the basement to the west.

Possibly the most characteristic feature of basement rocks west of the Ramah Group is the widespread evidence of cataclastic events of more than one age. The amount of recrystallization and grade of metamorphism exhibited by these cataclastic rocks is varied and is evidence for cataclasis at different crustal depths.

Although the majority of the cataclastic rocks in the area show evidence of recrystallization, metasomatized mylonitic rocks with crystalloblastic textures are rare.

Occurrence of blastomylonitic textures in the leucocratic granulites (unit 9), particularly where these rocks are nonmigmatitic, and in paragneiss (unit 11) has been noted above. Some of the foliation planes shown on the map (in pocket) record these mylonitic planes particularly in the southwest where trends are very constant. Cataclastic foliation planes in the paragneiss (unit 11) are remarkably consistent in attitude: they trend north-northwest and dip west at angles between 50 and 80 degrees. Ribbon structure lineations in the paragneiss lie within these planes and plunge to the north and south at shallow angles, commonly about 10 degrees. These linear structures are considered to record a phase of transcurrent fault movement. The shearing and cataclasis of these rocks (units 9 and 11) has been associated with extensive recrystallization under granulite facies conditions and caused thorough reworking. This resulted in development of a regional foliation postdating the country rock foliation that existed prior to basic dyke intrusion.

Older basic dykes in unit 12 that cut across the regional trend in amphibolite facies and granulite facies gneisses (units 8 to 10) have been described above. The deformation that foliated and folded these amphibolite dykes and immediately adjacent country rocks, clearly postdates the development of the predyke regional foliation in the gneisses and predates later faulting. This later foliation is commonly tightly folded in the east, where it appears to have formed along localized shear zones, and occurs on a regional scale in the west. Re-orientation of the east- or east-northeast-trending amphibolite dykes is more pronounced to the west and resulted in near convergence of the dykes with reworked older northeast- or north-trending gneissic structures. This re-orientation may, in part, be the result of transcurrent sinistral movements in the basement rocks.

Later thrusting and faulting resulted in mechanical milling down and retrogression of the granulites and paragneiss (units 9 to 11) with formation of tectonic breccia, mylonite and pseudotachylyte.

The entire western basement block between Nachvak Fiord and Saglek Fiord is bounded by a major fault system on its east. This fault system, although displaced by several later northeast- and northwest-trending faults, has a slightly undulose outcrop pattern,

Figure 11.

Isoclinal and rootless intrafolial folds outlined by basic horizons in leucocratic pyroxene gneiss. 11 miles west southwest of the south end of Little Ramah Bay. (M.E. Cherry). GSC Photo 162653

Figure 12.

Reworked Archean gneisses thrust to the east over Ramah Group metasediments. North slope of Quartzite Mountain south of Adams Lake. (G. D. Jackson). GSC Photo No. 202531-I

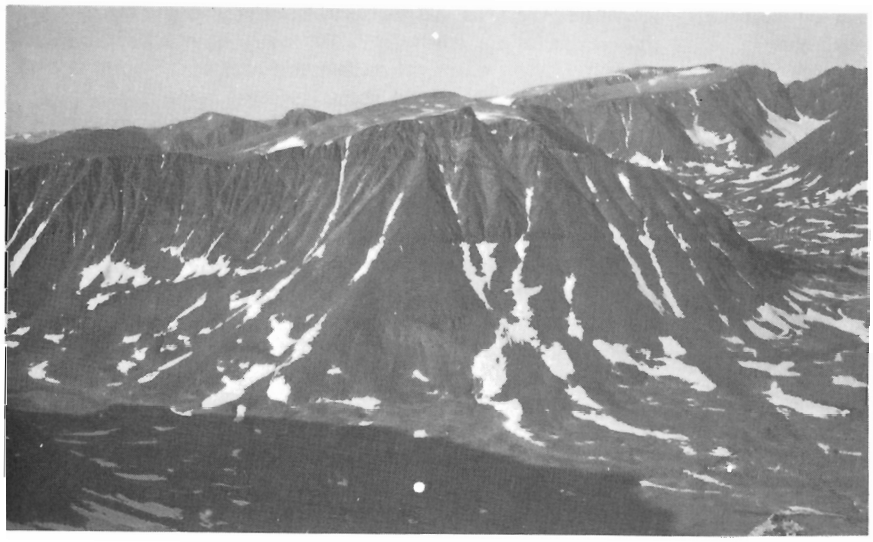

Figure 13.

Thrust planes exposed on 3,000 feet high mountain wall, one mile west of Quartzite Mountain. (G. D. Jackson). GSC Photo No. 162516

and a general north trend. The contact between basement rocks and the Ramah Group is a thrust in the north and a high angle fault in the south. The thrust extends for about 26 miles south from Tinutyarvik Cove on Nachvak Fiord and dips to the west at low to moderate angles (Fig. 12). An unconformity between the Ramah Group and rocks of unit 8 (acid gneiss and migmatite) is, however, preserved at a few localities on Quartzite Mountain where erosion has cut down through the thrust plane and revealed unfaulted contact relationships. For the remaining 20 miles to the southern margin of the area mapped this contact, in part poorly exposed, is a subvertical fault.

For about 5 miles north from Nakvak Brook the contact between unit 8 and unit 9 is sharp and is a west-dipping low-angle thrust fault. Mylonitized rocks are common in the thrust zone. There is an abrupt change from east to west across this thrust from highly mylonitized migmatitic rocks of amphibolite facies (unit 8) cut by numerous amphibolite dykes (unit 12), to considerably less mylonitized granulite facies rocks (unit 9) with fewer basic dykes.

Although the granulite facies rocks west of this thrust are less mylonitized, they possess a very pronounced sheeting structure that dips at low to moderate angles (20 to 40 degrees) in a general west direction. This sheeting structure is present throughout the granulite facies rocks here, and extends to the western limit of the area mapped, about 3½ miles west of the thrust. Detailed examination proved that this sheeting was caused by fractured zones along which cataclasis had occurred. Tectonic breccias, irregular veins of pseudotachylyte, and west-plunging slickensides were observed in some fracture zones.

Additional evidence of thrusting was also observed within basement rocks at other localities, and showed up particularly well on clean cut mountain walls, for example on the cliff one mile west of Quartzite Mountain (Fig. 13). Locally dark brown granulite facies rocks have been thrust over light weathering amphibolite facies rocks. These thrust planes could not be traced for more than a mile or two, and are not shown on the accompanying map. Their presence, however, shows that basement rocks west of the Ramah Group may in part be composed of a series of thrust slices.

The contact between amphibolite facies rocks (unit 8) and granulite facies rocks (unit 9) is faulted for a distance of about 10 miles north from the north shore of Saglek Fiord along, and in the vicinity of, Nakvak Brook. Rocks near here are reddened and have been subjected to a high degree of cataclasis with widespread development of fault breccia, mylonite and pseudotachylyte. There is probably a zone of faulting here rather than the one discrete fault shown along the contact on the present map. Granulites retrograded by cataclasis are possibly included in the acid gneiss and migmatite (unit 8).

Metamorphism

The general grade of metamorphism west of the Ramah Group is high, with extensive areas of granulite facies basement rocks (units 9 to 11). Metamorphic grade also increases from amphibolite facies in the east to granulite facies in the west.

On tracing rocks of unit 8 in a general westward direction, where faults are absent or unimportant, the sporadic appearance of hypersthene is noted and leucocratic gneiss and migmatite pass gradationally into acid granulite (unit 9). The difference between much of unit 8 and unit 9, at least where contacts are transitional, is thus mainly one of metamorphic grade and not lithology. The appearance of hypersthene in leucocratic rocks that are composed essentially of quartz and feldspar has been taken to mark the contact.

Additional evidence for progressive metamorphism in a westerly direction is shown by the amphibolite dykes in unit 12. These dykes are, in general, less metamorphosed and deformed in unit 8 than in unit 9.

Within the granulite facies area paragneisses (unit 11) consist mainly of quartz and feldspar, with garnet, biotite, graphite and sillimanite. Basic pyroxene gneiss bands (unit 10), mineralogically similar to rocks of unit 2 (basic gneiss and pyroxene amphibolite), do not show the widespread retrogressive metamorphic effects that are a conspicuous feature of basic horizons east of the Ramah Group.

Amphibolite dykes, bordered by a zone of amphibolite facies country rocks that have undergone retrograde metamorphism and that, cut regional granulites, are common and this is evidence of two distinct ages of metamorphism. The amphibolites represent original diabase dykes that were intruded into granulites and were later metamorphosed, deformed and converted into foliated amphibolite along shear zones. Although amphibolite dykes are rare in the acid granulite (unit 9) and paragneiss (unit 11) west of Nakvak Brook, in the southwest of the map-area, several thin conformable basic pyroxene gneiss bands are present. If some of these represent reworked older basic dykes, then the later metamorphic grade must have reached granulite facies.

Correlation of Basement Rocks East and West of the Ramah Group

Equivalent lithologies can be recognized east and west of the Ramah Group and are shown in Table I.

The cataclastic leucocratic gneisses and migmatites of unit 8 are considered to be equivalent to the rocks of unit 1 east of the Ramah Group.

Blastomylonitic textured quartzofeldspathic granulites and migmatite granulites (unit 9) have a gradational contact, that appears to represent an increase in metamorphic grade, with rocks of unit 8. Small areas of leucocratic granulite facies rocks that have been recognized in unit 1 may be the equivalent of unit 9.

Bands of basic pyroxene gneiss (unit 10) are similar to rocks in unit 2 but do not appear to show the retrogressive metamorphic effects that are a conspicuous feature of equivalent horizons east of the Ramah Group.

Small bodies and pods of metamorphosed ultramafic rocks that have been observed to the west of the group, but are not shown on the map, are probably equivalents of unit 3.

Paragneiss units west (unit 11) and east (unit 4) of the Ramah Group contain similar lithologies and mineral assemblages and are considered equivalent.

No lithologies that can be correlated with units 5 and 6 were found in the basement rocks to the west of the Ramah Group.

The older amphibolite dykes in unit 12 that cut basement rocks west of the Ramah Group are considered to be the deformed and metamorphosed equivalents of the main dyke swarms of massive diabase and feldsparphyric diabase (unit 7) that cut basement rocks east of the group. However due to the presence of the supracrustal rocks between the two basement areas it was not possible to demonstrate categorically that the dykes are the same. Younger fresh ophitic diabase dykes included in unit 12 may have their equivalents cutting basement rocks east of the Ramah Group.

Equivalents of 6 lithological units that have been mapped can thus be recognized in basement rocks east and west of the Ramah Group. In contrast to the area to the east, however, basement rocks to the west have undergone widespread cataclasis and are of higher metamorphic grade with extensive areas of granulite facies rocks. The foliated metadiabase and amphibolite dykes to the west are considered to be reworked equivalents of the post-orogenic massive diabase intrusions to the east. Basement rocks to the west are therefore concluded to be chiefly Archean rocks that were reworked in the Proterozoic.

Ramah Group (Units 13 to 21: Aphebian)

The Ramah Group (Table II; Fig. 14) consists of a thickness of about 5,000 feet of stratified rocks that

TABLE I

Table of Formations in Basement Rocks

Basement rocks west of the Ramah Group

Age	Map-unit	Lithology
Chiefly Archean reworked in Proterozoic	12	Foliated metadiabase and amphibolite; locally feldsparphyric; includes some fresh ophitic diabase of undetermined age.
	INTRUSIVE CONTACT	
	11	Garnet-biotite-quartz-feldspar paragneiss with local sillimanite and graphite; characterized by blastomylonitic textures.
		Small metamorphosed ultramafic bodies, chiefly as pods and lenses. Not shown on present map.
	10	Basic gneiss and amphibolite with hypersthene, diopside and garnet.
	9	Quartzofeldspathic granulite and migmatite granulite; commonly characterized by blastomylonitic textures.
	8	Quartzofeldspathic gneiss and migmatite; rare pyroxenes; widespread cataclasis.

Basement rocks east of the Ramah Group

Age	Map-unit	Lithology
Archean	7	Nonfoliated diabase; minor feldsparphyric diabase; includes post-Archean diabase.
	INTRUSIVE CONTACT	
	6	Massive to weakly foliated biotite granite and pegmatite; forms veins and sheets.
	5	Feldspar megacrystic quartz monzonite and granodiorite gneiss; locally migmatized.
	4	Garnet-biotite-quartz-feldspar paragneiss with local sillimanite and graphite; minor quartzite and feldspathic quartzite; slightly migmatized.
	3	Foliated serpentinized peridotite; some pyroxenite, hornblendite and amphibolite.
	2	Basic gneiss and amphibolite with hypersthene, diopside and garnet; commonly associated with paragneiss and ultramafic rocks.
	1	Leucocratic granitic and granodioritic gneiss; migmatite and agmatite; rare pyroxenes.

Basement rocks west of the Ramah Group are considered to be chiefly Archean rocks that were thoroughly reworked in the Proterozoic. Equivalent lithologies can be recognized east and west of the Ramah Group (e.g. unit 8 is equivalent to unit 1).

are predominantly sedimentary in origin but which include one volcanic flow and a number of diabase sills. The group comprises six formations (units 13, 15 and 17 to 20) that have not been named yet. Although metamorphism and deformation are much more intense than previously reported, sedimentary structures and textures are very commonly preserved.

Rocks of the Ramah Group outcrop widely in the study area and form a north-trending belt that essentially separates Archean basement rocks on the east from basement rocks, considered to be mainly reworked Archean, on the west. In general the group is limited by an unconformity on the east and by subvertical faults or by a low angle west-dipping thrust fault on

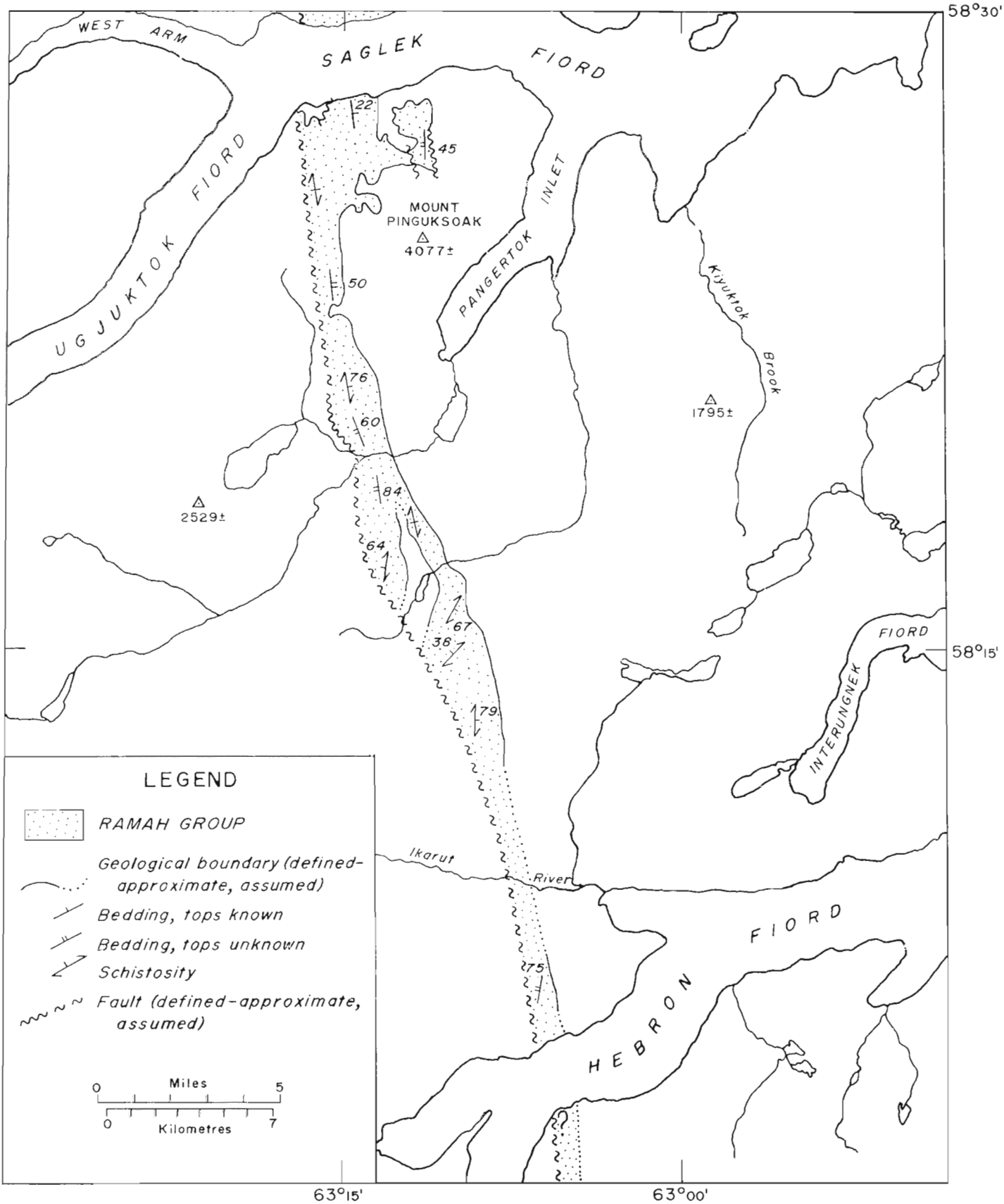

Figure 14. Map showing the extension of the Ramah Group south from Saglek Fiord to Hebron Fiord.

TABLE II

Table of Formations in the Ramah Group

Age	Group (Thickness in feet)	Formation (Thickness in feet)	Map unit	Lithology
		(20-200)	21, 21a	Chiefly nonfoliated altered diabase and amphibolite with local ultramafic core.
		INTRUSIVE CONTACT		
		VI (500-600)	20	Metagreywacke and slate; minor meta-arkose and calcareous or dolomitic metasandstone; local phyllite and mica schist.
		V (500)	19	Thin bedded slate with minor quartzite, metasandstone, calc-silicate rocks and crystalline limestone; locally graphitic with pyrite and/or pyrrhotite; rare concretions.
Aphebian (L. Proterozoic)	Ramah (±5000)	IV (1000)	18	Dolomite, chiefly argillaceous; calcareous and dolomitic slates; intraformational dolomite breccias and conglomerates including turbidites; minor crystalline limestone, quartzite, metasandstone and slate.
		III (1000-1500)	17	Colour-banded slates; in part dolomitic, calcareous, graphitic or pyrite-rich; minor chert, dolomite and crystalline limestone; a thin massive pyrite bed; local phyllite and schist.
		II (200-500)	15	Quartzite and pelite, chiefly interbanded or laminated; some turbidites; minor replacement dolomite; local slate, phyllite and schist.
		I (800-1500)	13, 14	Quartzite, meta-arkose and metasandstone; includes a thin metabasalt volcanic flow, minor pebble orthoconglomerate, breccia and pelite; local slate, phyllite and schist.
Angular unconformity on Archean basement rocks.				

Numerals I to VI refer to metasedimentary formations that were mapped in the present study but are not yet named.

the west. The group has been mapped for a distance of 47 miles from the east side of Tinutyarvik Cove, on Nachvak Fiord, to the southern limit of the map-area, some 5 miles south of the south shore of Saglek Fiord. In addition previously unmapped highly deformed and metamorphosed Ramah Group rocks have been traced south for a farther 22 miles to Hebron Fiord (Fig. 14). The linear belt of Ramah Group rocks is commonly about 5 miles wide. It attains a maximum width of 10 miles south of Little Ramah Bay, and is less than ½ mile wide at several localities between Saglek and Hebron fiords. Outcrop is poor in the latter area and although the belt is probably continuous there detailed mapping may prove otherwise.

A high-angle angular unconformity (Fig. 16) that is spectacularly exposed on numerous mountain walls separates stratiform rocks at the base of the Ramah Group from the underlying Archean basement (units 1 to 7). It occurs along the entire eastern margin of the belt in the present map-area and has a planar surface,

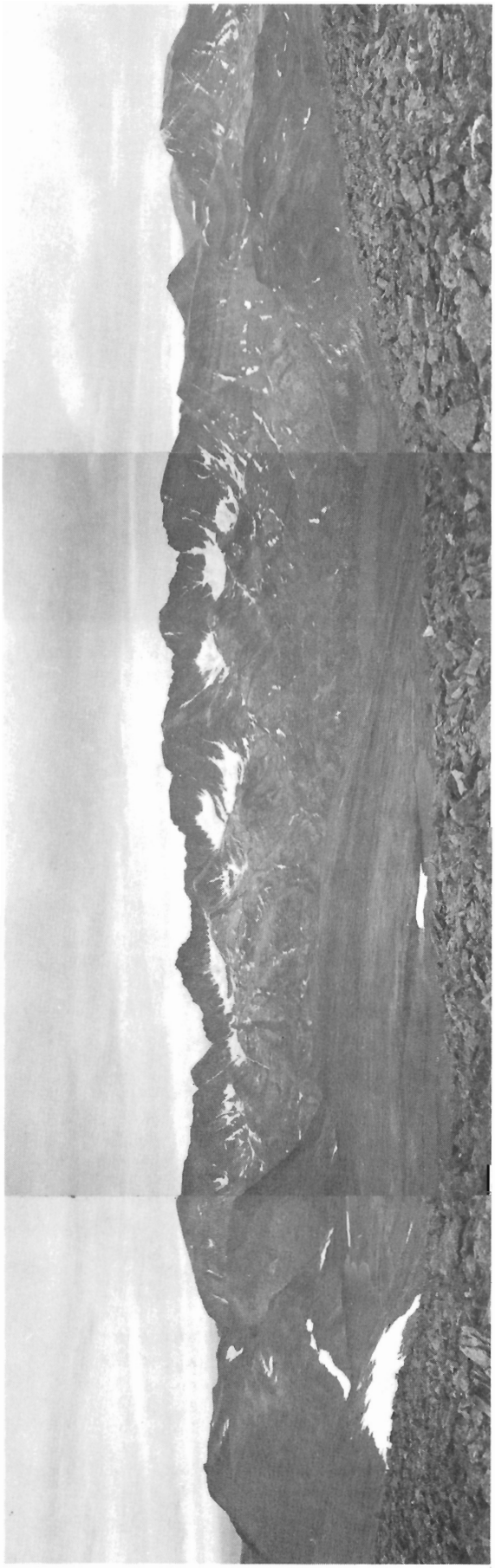

Figure 15. View east across Little Ramah Bay (south end visible) showing the Ramah Group (right and foreground) unconformably overlying Archean rocks. GSC Photo Nos. 162225, 162226-162227

with only local minor irregularities, that dips west at between 20 and 30 degrees (Fig. 17). This surface sharply truncates the structures and rock types present in the basement block to the east. The unconformity on the west side of the Ramah Group is exposed at two localities on the west slope of Quartzite Mountain. No basic dykes (units 7 and 12) which are the youngest rock types mapped in basement rocks both to the east and to the west of the Ramah Group, cross the unconformity and cut the group.

The unconformity surface is the result of a prolonged period of erosion that resulted in the development of a peneplain. This pre-Ramah erosion surface is known to extend for 65 miles between Nachvak Fiord and Hebron Fiord and is probably correlatable with the pre-Mugford Group surface (Taylor, 1972a), the most distant exposure of which is 56 miles southeast of Hebron Fiord.

Many mountain tops underlain by Archean rocks east of the Ramah Group (Fig. 18), for example The Muzzle, are flat or inclined at low angles. Some are probably remnants of the pre-Ramah surface, and their variable attitudes may have been caused by deformation. Exposures of the folded unconformity surface occur on the walls of Saglek Fiord and west of Quartzite Mountain.

A post-Archean pre-Ramah regolith that ranges considerably in thickness to a maximum of about 50 feet is present beneath the unconformity surface. The regolith is well exposed along much of the eastern contact and also at the two localities west of Quartzite Mountain. It was not observed at all localities examined and may have been removed by pre-Ramah Group erosion. Highly cleaved outcrops of regolith occur locally, and south of Saglek Fiord, where intense shearing occurred at the basement-Ramah contact, no regolith could be recognized.

Mineralogical changes that resulted from the pre-Ramah weathering commonly caused extensive alteration of the acid gneiss and migmatite (unit 1). Although compositional banding and mineral foliation tend to be obscured by the weathering, variations in grain size and pegmatitic zones are preserved. Basic gneiss bands and basic dykes (units 2 and 7) are readily recognizable in the regolith despite advanced mineral decomposition. They tend to be rust-stained, and show evidence of spheroidal weathering with iron-rich crusts.

The regolith contains quartz, chert, jasper, dolomite, siderite, magnetite and a green chrome mica. These minerals can commonly be located in basement rocks and in the Ramah Group immediately adjacent to the regolith. A yellow replacement dolomite, which may be up to 20 feet thick, is locally associated with the regolith, and is well exposed on the east side of the group near Saglek Fiord, about 6 miles north-northwest of the north end of Branagin Island.

The precise contact between the exhumed regolith and the Ramah Group is commonly obscured and can be difficult to position. The first sign of sedimentary stratification is taken as the base of the group. Unless otherwise stated, thicknesses refer to sections measured near Ramah Bay.

Figure 16. High angle angular unconformity separating rocks of the Ramah Group (units 13 and 15) from underlying Archean gneisses. North side of Rowsell Harbour. GSC Photo No. 202531-B

Figure 17. Unconformity between Ramah Group and Archean gneisses, exposed on mountains 4 miles north of the west end of Bears Gut. Note the planar nature of the unconformity surface, with only local minor irregularities. GSC Photo No. 202531

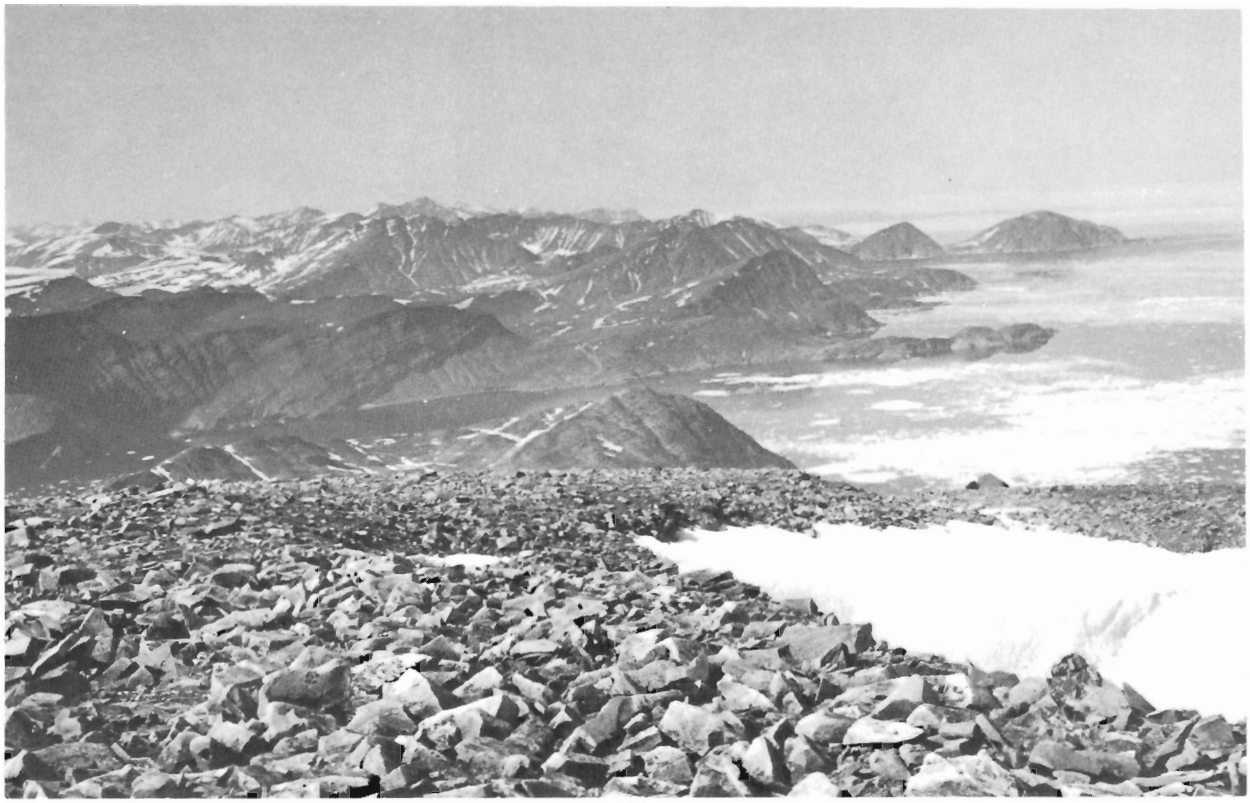

Figure 18. View north across Ramah Bay showing inclined mountain tops, underlain by Archean rocks, that are located east of the Ramah Group. GSC Photo No. 162067

Between Nachvak Fiord and Saglek Fiord the group occupies a large asymmetrical synclinorium. Consequently lower formations occur around the margins of the belt with younger formations in the centre. A depression south of Ramah Bay causes the structure to plunge south in the north and north in the south.

Quartzite (Unit 13)

This basal formation has been recognized at the periphery of the belt throughout the area. It is dominantly quartzite but also contains pelite, slate, a volcanic flow, minor conglomerate and breccia. Five lithological members have been recognized by the author and by Knight (1973).

In certain areas where unit 13 has not been differentiated from the second formation (unit 15) a composite map-unit (unit 16) is used. This is the case south of Ramah Bay along the western margin of the group, and for 11 miles in the south of the belt.

The quartzite (unit 13) is very well exposed. However partial sections occur along the western margin of the group where units 13 to 16 are tightly folded and extensively faulted.

Total thickness of the formation is varied, but is commonly in the order of 800 feet. A maximum thickness of 1,500 feet was measured in the south of the area, 2 miles north of Saglek Fiord.

The base of the formation is locally marked by a 5- to 30-foot-thick pebble orthoconglomerate that locally contains cobble-sized fragments. Clasts are commonly subrounded to subangular and consist of jasper, white quartz and rare acid gneiss. Elsewhere the base consists of very coarse- to coarse-grained pebbly or granule-bearing arkosic metasandstone with thin beds and lenses of pebble conglomerate (Fig. 19a). This grades up into coarse- to medium-grained metasandstone, in which clastic fragments of feldspar are less common. Above this pale yellow to white quartzite occurs in this lower member and is predominant until about 200 to 300 feet from the base of the formation. Trough crossbedding is common in the white quartzite and is picked out by magnetite-rich laminae (Fig. 19b) at certain horizons, particularly in the lower part.

A thin metavolvanic flow occurs above the white quartzite. This flow (unit 14) is the only lithological member of this formation that was mapped in the present investigation. It is described below under a separate heading.

The next member, alternating beds of different thickness of fine- to medium-grained purple or rarely green quartzite and grey or purple pelite, is 200 to 300 feet thick. Many quartzite beds are lenticular, have numerous rust-spots, and contain pelite clasts. Parts of this member consist of thinly laminated very fine grained quartzite and pelite. Primary structures

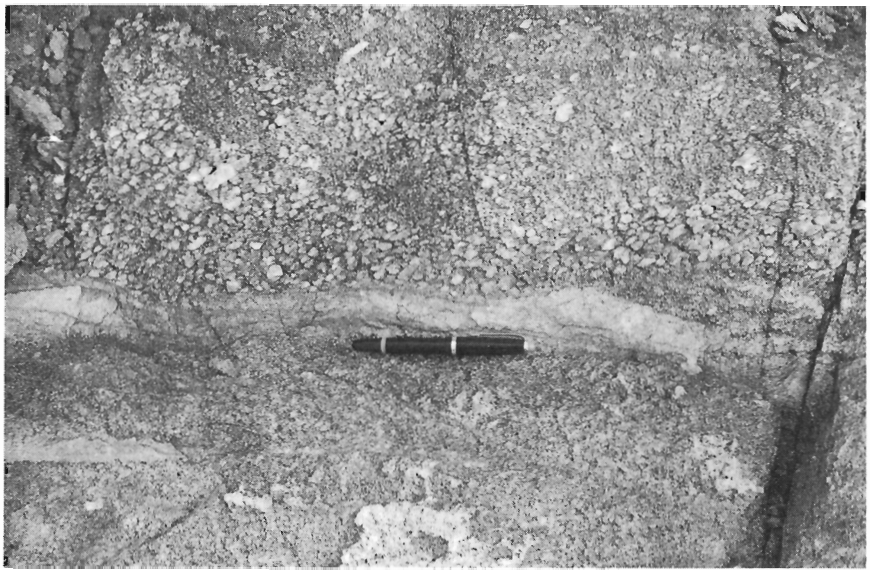

Figure 19a.

Deformed pebbly meta-sandstone with stretched clasts. 2 miles north northwest of Quartzite Mountain. (M. E. Cherry). GSC Photo No. 162668

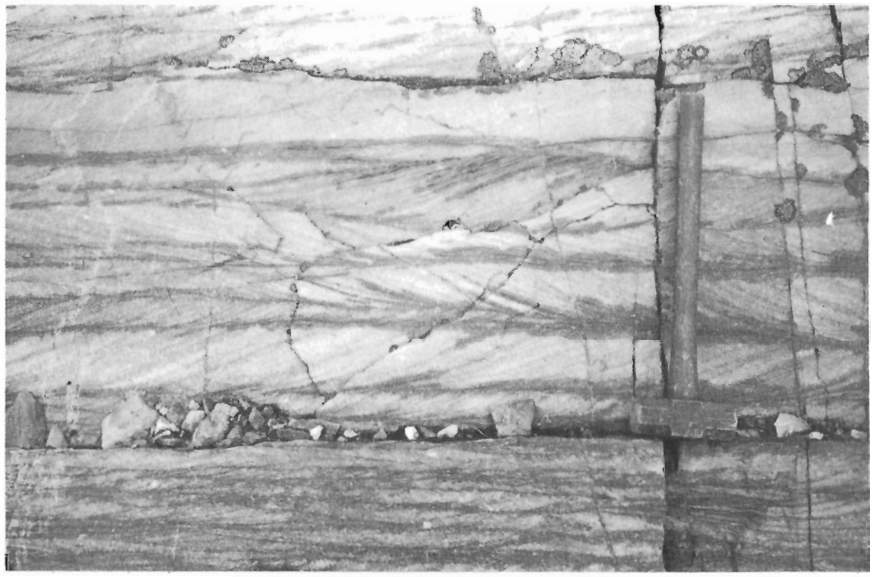

Figure 19b.

Trough cross-bedding in quartzite outlined by magnetite-rich laminae. Same locality as 19a. (M. E. Cherry). GSC Photo No. 162673

are abundant and include tabular crossbeds, trough crossbeds, large scale ripples, ripple-drift cross-laminations, erosional scour marks and sedimentary dykes.

This member is overlain in the Ramah Bay - Rowsell Harbour area by 50 feet of pelite and slate with rare thin quartzite beds. The colour of this argillaceous member varies and may be yellow, brown, grey or purple. Scour marks and ripple-drift cross-laminations are present.

The upper member of this formation (unit 13) consists of 400 to 500 feet of fine- to coarse-grained yellow or brown weathering white and grey quartzite. Yellow, purple and grey pelite bands comprise about 15 per cent of the strata. Some thin conglomerate and pebbly metasandstone horizons, and rare black quartzite beds are also present. Towards the top quartzite beds with irregular carbonate lenses and crosscutting replacement areas are common. Quartzite beds with pyrite cubes or pelite clasts occur locally. Sedimentary structures include tabular and trough crossbeds, small ripples, megaripples, and scour marks. Heavy mineral laminations are not common and are restricted to the base of this member. Mudcracks are common and structures that resemble rain prints are present. Possible biogenic structures occur in a quartzite bed south of Delabarre Bay, approximately 1½ miles west of Mount Dalhousie.

Metabasalt Flow (Unit 14)

A 20- to 60-foot-thick altered basic lava flow occurs within the quartzite (unit 13) about 200 to 300 feet above the unconformity. The flow has been located with certainty only in the east of the belt and has been mapped discontinuously for 20 miles from Rowsell Harbour to Bears Gut. In general this unit is poorly exposed and deeply weathered.

Figure 19c.

Dyke, presumed to be a feeder to the metabasalt flow (unit 14), cutting quartzite 3½ miles southwest of Bears Gut. GSC Photo No. 162192

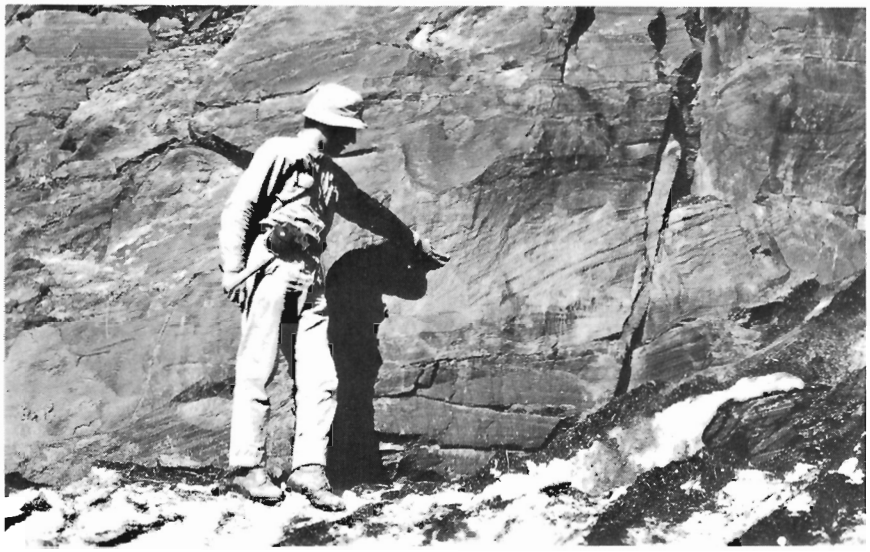

Figure 19d.

Soft sediment folding and slumping in meta-sandstone unit 15. Northeast side of Ramah Bay. GSC Photo No. 202531-E

The lower contact of the flow is irregular with a selvage overlying quartzite. Weathered surfaces are green or rust-stained and in some places are enriched in iron and dolomite. Fresh surfaces are massive, grey green, aphanitic to very fine grained and contain up to 20 per cent disseminated carbonate. Pillow-like outlines can be discerned in places and are locally associated with flattened amygdules. Amygdule cylinders and amygdule trains (Macdonald, 1972) are also present. In thin section the rock is extremely altered, consisting of carbonate, plagioclase, amphibole, chlorite, quartz and opaques. Chemical analyses indicate that it is a tholeiitic basalt.

The top of the flow is amygdaloidal, fragmented, irregular and commonly shows evidence of erosion. Fissures are filled with quartzite or pelite. Well-rounded metabasalt clasts are present locally in quartzite above the flow. Ripples and mudcracks commonly occur in the overlying quartzite.

Two subvertical west-trending dykes composed of rock that is similar to the metabasalt flow (Fig. 19c) cut across the bedding in quartzite (unit 13) approximately 3½ miles and 5½ miles southwest of Bears Gut. The dykes have a maximum thickness of 40 feet and are up to ½ mile long. Contacts are sharp and the dykes are highly cleaved and jointed. Inch-thick veins of specular hematite occur in one dyke. These dykes are presumed to be feeders although no metavolcanic flows occur in the vicinity and they are isolated in quartzite.

Laminated Quartzite and Pelite (Unit 15)

The second formation (unit 15), composed of quartzite, metasandstone, pelite and dolomite, has a total thickness that ranges from 200 to 500 feet. Lithologies in this formation vary laterally and vertically so that subdivision is difficult. However a lower member of different lithologies and an upper dolomite member

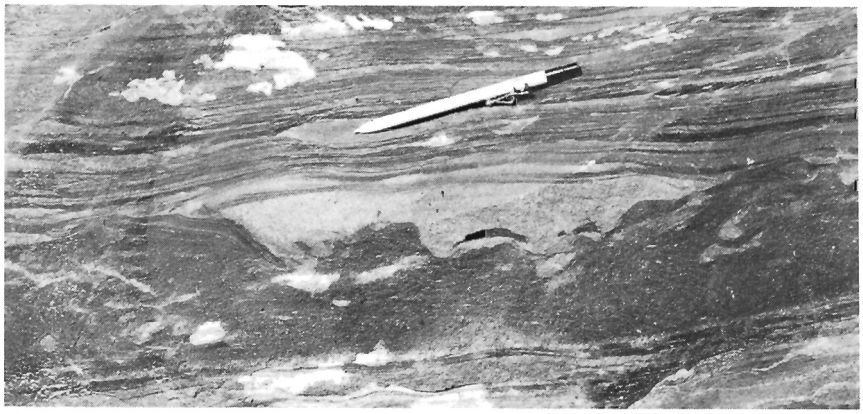

Figure 20.

Load structures in laminated quartzite (unit 15). Northeast side of Ramah Bay. GSC Photo No. 202531-E

have been recognized in the present study. Unit 15 has a sharp to gradational conformable contact with the quartzite formation (unit 13) which it overlies throughout most of the belt. Parts of the map-area where units 13 and 15 have not been differentiated are shown as unit 16. Unit 15 occurs throughout much of the composite unit north of Saglek Fiord but its extent to the south is not known.

The base of the formation, marked by grey or black quartzite with pelite, contrasts sharply with the underlying white quartzite member at the top of unit 13. Pelite clasts in quartzite beds, scour marks, trough cross-beds and mudcracks are common.

Bioturbation has been reported by Knight (1973) and although this was not observed in unit 15 by the writer, carbonaceous matter, possibly anthraxolite, was found approximately ¾ mile south-southwest of the south end of Little Ramah Bay. The carbonaceous matter has the appearance of coal and occurs as a 2-inch-thick bed, associated with vein quartz, in a very fine grained white to pale grey laminated metasandstone.

A well-laminated unit, composed of alternations of grey, purple and pink very fine- to fine-grained quartzite and metasandstone with pelite occurs at different stratigraphic horizons throughout unit 15. Quartzite beds are commonly lenticular and show soft sediment folding and slumping. Convolute laminations, flame structures, load-structures (Fig. 20) and pseudonodules are also present.

In the vicinity of Ramah Bay thicker beds, commonly about 1½ to 2 feet thick, with sharp erosional bases are present. The lower half of each individual bed consists of "dirty" grey coarse- to medium-grained, massive, quartzite with pelite clasts but with little graded bedding. The upper half is finer grained, more argillaceous, and contains parallel laminae formed by alternations of pelite with metasandstone. Small scale ripples are rare. A thin division of laminated slate is present locally at the top of the beds. These beds are considered to be examples of the Bouma sequence (Bouma, 1962) with certain divisions missing, and are probably proximal turbidites.

In the Ramah Bay area finely laminated red-brown, grey-green and blue-grey slates with thin quartzite beds containing lenses and crosscutting veins of replacement carbonates overlie the turbidite sequence. These in turn are overlain by massive black quartzite beds in which slate clasts and pyrite cubes are common.

The top of the formation is marked by a 10- to 30-foot-thick, very conspicuous, yellow or yellow-brown weathering replacement dolomite. This member forms an excellent marker horizon that occurs throughout the area but is thinner and less well developed in the south. The secondary nature of the dolomite is apparent at its lower contact, which is commonly irregular and transgressive to bedding in the underlying quartzite. Whereas margins are commonly laminated, central portions tend to be composed of massive light grey dolomite. Locally where it overlies coarse-grained calcareous metasandstone it is impure and is a dolomitic metasandstone or dolomite with quartz grains and evidence of original crossbeds. Laminated calcareous and dolomite slates are also replaced and occur as irregular masses included within or partly enclosed and replaced by, the dolomite. Irregular crosscutting veins of quartz, chert and crystalline dolomite are common.

Slate (Unit 17)

This unit consists of approximately 1,000 to 1,500 feet of variously coloured slate with a discontinuous pyrite bed and several chert horizons. Some of the slates are highly graphitic; others are rich in pyrite. They are dolomitic towards the top of the formation where beds of dolomite and crystalline limestone are relatively common. Accurate estimates of thickness are difficult as the formation is tightly folded and cut by thrusts and faults. Altered diabase sills are common along the western outcrop area of this unit and also south of Little Ramah Bay.

Outcrops of the lower slate formation are in general poor and the slates weather rapidly to scree-covered slopes. Exposures are, however, excellent on near vertical cliff faces, such as the northeast shore of Ramah Bay, and are good in stream sections.

Rusty or bright yellow-weathering, graphitic, black, pyrite-rich slates occur immediately above the replacement dolomite and are very distinctive. They are overlain by more competent slates that are grey-blue, red-brown or green. Some are slightly dolomitic. Colour banding, which varies in thickness

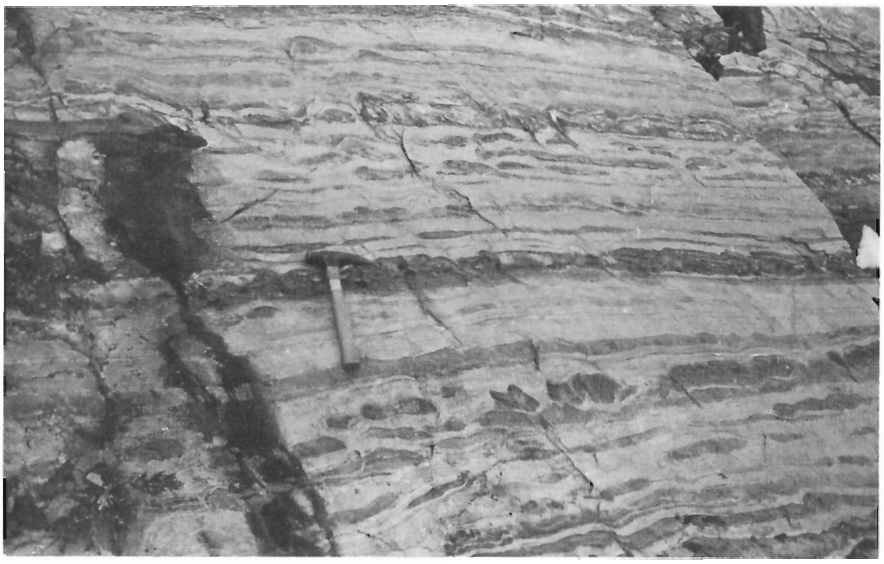

Figure 21a.

Soft-sediment boudinage structure in dolomite (unit 18). ½ mile north of Ramah. (C.W. Jefferson). GSC Photo No. 162779

Figure 21b.

Clastic dyke in argillaceous dolomite. Same locality as 21a. (G.D. Jackson). GSC Photo No. 162526

to a maximum of several inches, is characteristic of these rocks. Individual bands have a constant lateral thickness and show little change in colour or composition.

A conspicuous 5- to 20-foot-thick chert horizon occurs about 150 to 250 feet from the base of the formation. North of Ramah Bay there are four individual chert beds. The chert is white, grey or black and although it is commonly massive, bedding is present at some localities. It overlies a 5- to 10-foot-thick massive pyrite bed that contains graphite, pyrrhotite and traces of chalcopyrite. Although the chert occurs at this horizon throughout the formation the pyrite bed has not been located north of Rowsell Harbour or south of Bears Gut. Locally, for example on the north shore of Ramah Bay, the pyrite bed is only represented by irregular nodules or thin filaments and is discontinuous.

Laminated slates that are locally dolomitic with irregular nodules and replacement areas of carbonate overlie the chert. A few brown weathering thin dolomite beds are present. In general the rocks above this are more argillaceous slates and include laminated phyllites and chlorite schists. Towards the top of the formation the carbonate content increases and the slates are dolomitic with thin crystalline limestone and dolomite beds.

Unit 17 commonly has a sharp base with the underlying replacement dolomite that occurs at the top of unit 15. The upper contact with the overlying formation of dolomite (unit 18) is, however, transitional.

Dolomite (Unit 18)

Unit 18 outcrops discontinuously from Adams Lake south to west of Bears Gut. A small area of dolomite

Figure 22a.

Intraformational breccias in dolomite, exposed on cliff immediately north of Ramah. Typical breccia showing partial replacement of intraclasts by white calcite. (C.W. Jefferson). GSC Photo No. 162264

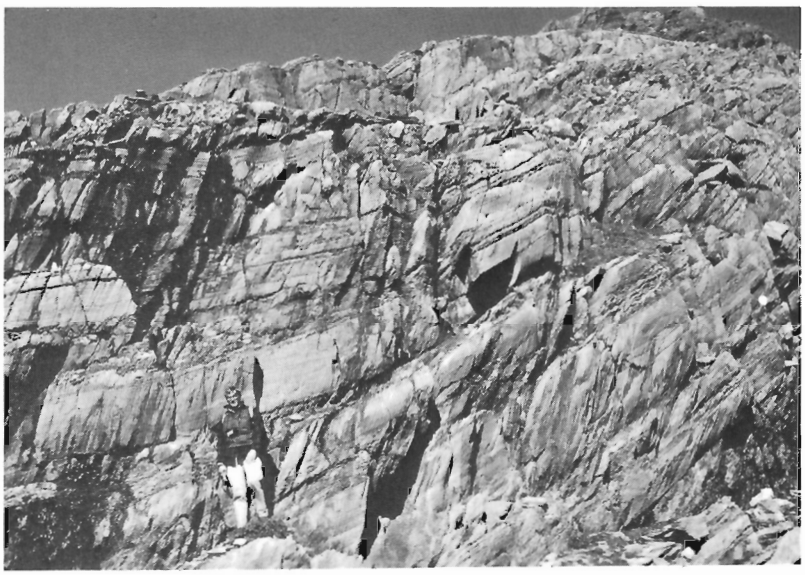

Figure 22b.

Intraformational breccia beds alternating with cleaved, laminated argillaceous dolomite beds. GSC Photo No. 202531-K

was also mapped about 10 miles south of the west end of Ramah Bay. In general the unit is poorly exposed. Subdivision of the formation, which is 1,000 feet thick at the east end of the north shore of Ramah Bay, is not possible on the basis of present information.

Cleaved argillaceous dolomite interbedded with calcareous and dolomitic slate is typical of the unit as a whole. The argillaceous dolomite is bluish grey on fresh surfaces but is characterized by yellowish brown or locally rusty weathered surfaces. Quartz grains tend to be common in some beds. Calcareous and dolomitic slates are more variable in colour and may be green, grey or brown. Beds of black or green slate, argillaceous crystalline limestone, dolomite, quartzite, and metasandstone are also present. The metasandstone beds can be carbonate-free, calcareous or dolomitic. Intraformational dolomite breccias and conglomerates are common in the succession. Conspicuous crystals of pyrite are present in most beds throughout the formation.

Planar continuous bedding and continuous laminations are typical of the argillaceous dolomite and slates. Ripple-drift cross-laminations and small scour marks occur in these rocks, but are rare. Evidence of soft sediment deformation is, however, ubiquitous throughout unit 18, particularly in the argillaceous dolomite horizons, and includes boudins (Fig. 21a), ball-and-pillow structures, clastic dykes (Fig. 21b), ductile faults, folds, thrusts, convolute laminations, intraformational breccias and conglomerates.

Intraformational breccias and conglomerates are located at different horizons within the dolomite formation and are present throughout much of the area

Figure 22c.

Breccia, showing fragments with highly folded laminations, caused by soft-sediment slumping. Intraclasts are extensively replaced by white calcite. GSC Photo No. 202531-C

Figure 22d. Intraformational breccia, composed of tabular intraclasts, with evidence of soft-sediment deformation and poorly graded fragments. GSC Photo No. 202531-H

underlain by unit 18. In general the breccias tend to be concentrated in the lower half of this unit, but they are not present at all localities. In some measured sections dolomite breccias are rare and occur only in the upper half of the unit. Intraformational carbonate breccias do not invariably occur at the base of unit 18 and consequently cannot be mapped throughout its extent. Use by Knight (1973) of this important marker horizon to define the contact between unit 17 and unit 18 is therefore questionable, and has not been followed in the present study.

The intraformational breccias and conglomerates occur in beds from less than one foot to several tens of feet thick (Fig. 22a). They alternate with planar continuously bedded or laminated argillaceous dolomites and slates (Fig. 22b), and in some instances with metasandstones. Clasts are composed of rock types similar to those present in adjacent beds, may be angular or rounded, range in size from less than one inch to several feet, and are set in a fine-grained matrix of dolomite, argillaceous dolomite, or carbonate-rich slate. Sand-sized grains of quartz and irregular replacement areas of white calcite are locally present in both intraclasts and matrix.

A variety of types of intraformational breccias and conglomerates can be distinguished in unit 18. Some intraclastic beds can be traced into horizons that have undergone extensive sedimentary boudinage (Fig. 21a). Others contain fragments with highly folded and convoluted laminations (Fig. 22c). These have formed mainly as a result of soft sediment deformation accompanied by varying degrees of down-slope slumping. Whereas some beds show no grading of fragments, others are well graded (Fig. 22d). Soft sediment recrystallization probably played an important part in the formation of some breccias.

Many intraformational breccia and conglomerate beds in this map-unit show evidence of deposition by powerful currents. These commonly have divisions similar to Bouma sequences and are turbidites. Graded breccia and conglomerate beds (Fig. 23a) with erosional bases may be overlain by successive zones characterized by parallel lamination, ripple-drift cross-lamination and further parallel lamination. Graded beds of metasandstone, that in places contain carbonate and quartzite are commonly associated with these dolomite turbidites. Convolute laminations, slump folds, load structures and flame structures (Fig. 23b) are typically present. Alternating beds of intraformational dolomite breccia or conglomerate, metasandstone, argillaceous dolomite, and calcareous or dolomitic slate commonly occur.

The carbonate content of rocks in this unit decreases towards the top and bottom of the formation which is bounded by slates (units 17 and 19). Both lower and upper contacts are gradational and on the present map are placed where carbonate beds are numerous in carbonate-rich slates.

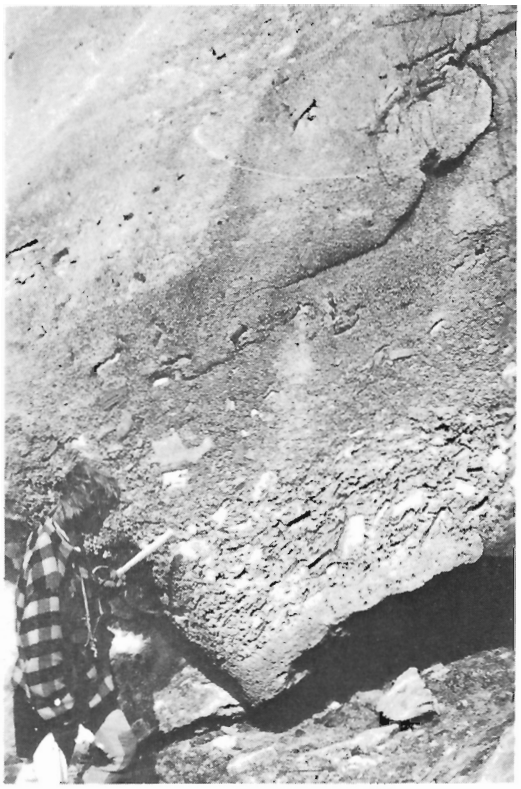

Figure 23a. Well graded dolomite breccia deposited by turbidity currents. 1½ miles northeast of the west end of Ramah Bay. GSC Photo No. 202531-D

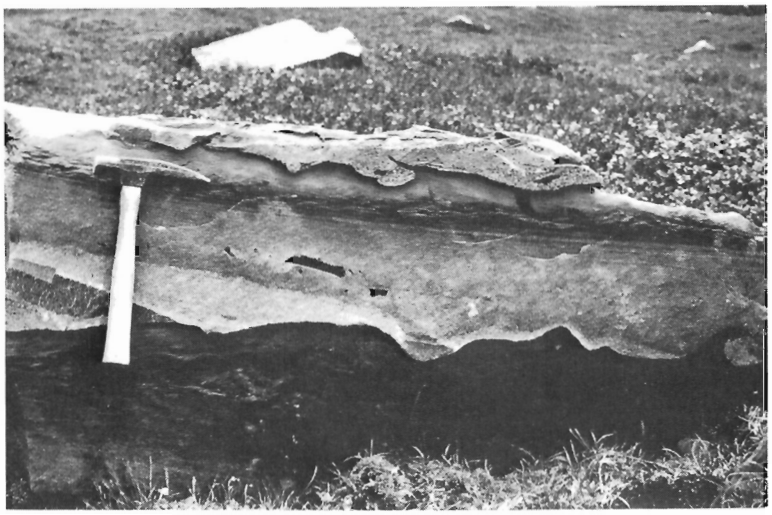

Figure 23b. Flame structures and ripple-drift cross-lamination in dolomite beds associated with meta-sandstone and quartzite. Same locality as 23a. GSC Photo No. 202531-J

Slate (Unit 19)

Unit 19 consists of about 500 feet of dark grey to black slate and local phyllite with minor beds of quartzite, metasandstone, calc-silicate rocks and crystalline limestone. This unit extends discontinuously from Rowsell Harbour south to a point about 4½ miles southwest of the south end of Little Ramah Bay. A number of diabase sills (unit 21) of different and variable thicknesses occur within the slate both north and south of Ramah Bay.

The slates are commonly rusty weathering and are blue grey or black on fresh surfaces. Black slates are graphitic and contain pyrite commonly as cubes but locally as irregular lenses and nodules. Carbonate-rich slates are also present and tend to contain thin beds of fine-grained grey green crystalline limestone and dark grey calc-silicate rock composed of carbonate, tremolite and opaques. Thin bedding, colour banding and lamination are characteristic of the slates. Laminae or beds up to one foot thick of metagreywacke, grey metasandstone and white weathering, fine-grained, dark blue quartzite that tends to be calcareous, occur locally. Some interbeds contain slate clasts and show graded bedding, ripple-drift cross-lamination, and small scale scour and fill structures. Bedding and lamination in the slates are locally disrupted, deformed, and cut by sedimentary faults. Large concretions of grey quartzite in slate are located about 3 miles south-southwest of Lookout Point, Ramah Bay.

Both lower and upper contacts of unit 19 are gradational. Slates are calcareous and dolomitic towards the base of unit 19, and contain metagreywacke interbeds towards the top of the unit.

Metagreywacke (Unit 20)

Unit 20, which occurs at the top of the stratigraphic succession of Ramah Group rocks, consists of 500 to 600 feet of metagreywacke and slate with minor amounts of meta-arkose. This formation is poorly exposed and outcrops chiefly between Rowsell Harbour and Ramah Bay. Several small areas, two of which are shown on the accompanying map, have also been located south of Ramah Bay.

The unit consists essentially of interbedded slate and metagreywacke with beds commonly about one or two feet thick. Ten- to 20-foot-thick sets of metagreywacke beds and massive thick- and very thick-bedded units in slates are also present. The slates are dark grey to black, rusty weathering, are commonly laminated, and are locally metamorphosed to phyllite and mica schist. The metagreywackes are well cleaved, dark grey to black, poorly sorted, coarse- to very coarse-grained rocks that commonly contain pebble-sized clasts. Conspicuous clasts are fragments of slate, quartzite, white quartz, opalescent blue quartz, feldspars, and recrystallized felsites and acid volcanic rocks. Compositionally the metagreywackes range from feldspathic to lithic and have abundant matrix rich in metamorphic muscovite, biotite, chlorite, carbonate and epidote. Minor beds include calcareous and dolomitic metasandstones and meta-arkose.

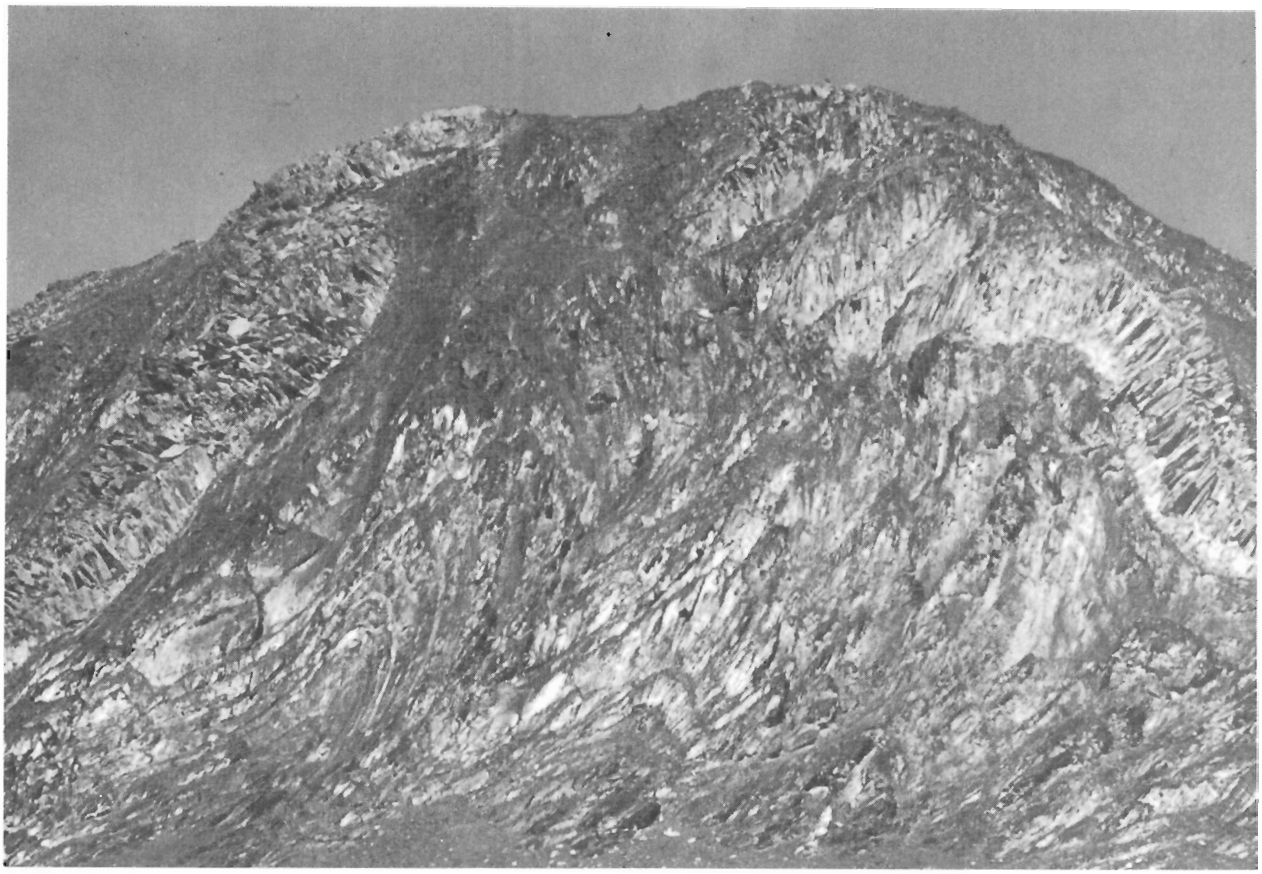

Figure 24. Openly folded diabase sills (unit 21), cut by fan-shaped fracture cleavage, enclose intensely contorted isoclines of slate (unit 19) in which radiating slaty cleavage is developed. Note the diapiric-like intrusions of slate through the diabase sill in the anticline core. ¾ mile north of Ramah. GSC Photo No. 202531-A

Primary structures commonly observed include parallel laminations, graded beds, ripple-drift cross-laminations, scour and fill structures, load casts, flame structures, convolute beds and pseudonodules. Features characteristic of the Bouma sequence are also present and include graded intervals overlain by intervals of parallel lamination and current ripple lamination.

The metagreywacke formation (unit 20) has a gradational lower contact with the underlying slate formation (unit 19). The upper contact is not preserved because of erosion.

Diabase (Unit 21)

Brown or grey-green weathering diabase sills with intrusive contacts occur in Ramah Group metasediments throughout the map-area. Many thin sills are not shown on the accompanying map. The sills have been folded with the metasediments and are cut by a fracture cleavage that fans around fold closures (Fig. 24). Although altered and metamorphosed to varying degrees they are only locally sheared and schistose, and are not schistose or foliated to the extent of the amphibolite and metadiabase (unit 12) intrusions that cut basement rocks west of the group. A few show primary igneous layering. No diabase intrusion of unit 21, or units 7 and 12, was found to cut across the unconformity at the base of the Ramah Group.

Diabase intrusions are found in each of the six metasedimentary formations that make up the Ramah Group. Sills in units 15, 18 and 20 are not shown on the map, but do occur, albeit rarely in units 15 and 18.

The sills differ greatly in thickness and although they commonly range from a few feet to 200 feet, they are locally up to 400 feet thick. Individual sills may thicken or thin considerably or terminate abruptly. Due to folding thin sills can occupy extensive areas.

The sills tend to be slightly transgressive but some, for example the thick diabase located in slate (unit 17) 4 miles west of Bears Gut, are markedly transgressive. West of Bears Gut this sill is in the lower part of the lower slate unit (unit 17), whereas 6 miles north it is in contact with dolomite (unit 18).

Crosscutting dyke-like offshoots to the diabase sills are rare. One 40-foot-thick feeder dyke that is altered, cleaved and sheared, particularly at its margins, is located in quartzite (unit 13) about 6 miles southwest of Bears Gut.

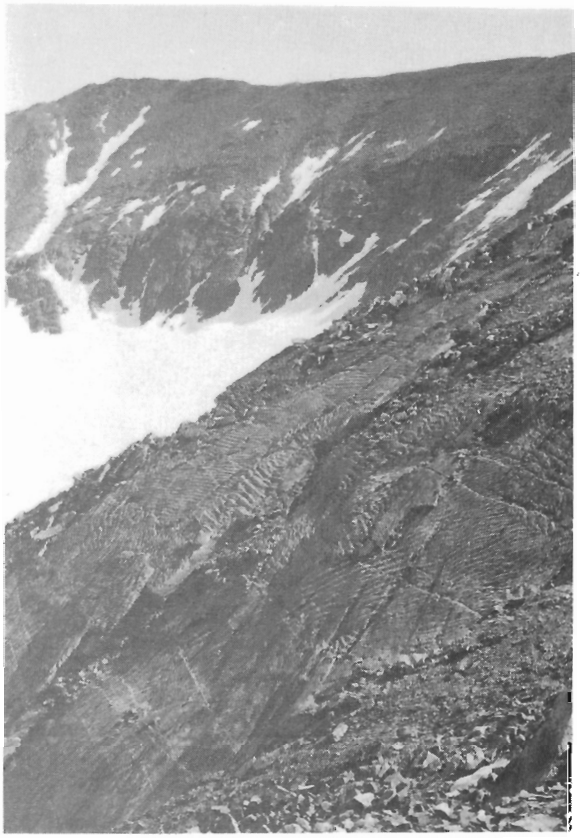

Figure 25 Mega-ripple marks in quartzite exposed on bedding planes. 3 miles southwest of the west end of Bears Gut. GSC Photo No. 162090

The intrusive nature of the sills is clearly shown by their transgressive chilled contacts, by metasedimentary xenoliths at upper contacts, by minor apophyses that invade overlying rocks, and by contact metamorphism.

Contact metamorphic effects are well preserved at the upper contact of the thick transgressive sill west of Bears Gut. Chlorite-muscovite slate (unit 17) contains altered porphyroblasts, now composed mainly of muscovite and chlorite, probably pseudomorphs after pre-orogenic cordierite and/or andalusite. The porphyroblasts are stretched, deformed and cleaved.

Although all diabase intrusions in unit 21 are altered, original textures are commonly preserved. Pyroxenes, partly or completely altered to tremolitic amphiboles, and lath-shaped feldspar crystals form ophitic texture. However some more highly metamorphosed sills are now massive hornblende amphibolites devoid of primary textures.

Ultramafic Rocks (Unit 21a)

A core of dark red-brown-weathering ultramafic rock (unit 21a) is present in the thick transgressive diabase sill that occurs in slate (unit 17) 4 miles west of the west end of Bears Gut. This ultramafic phase can be traced north for 7 miles, and has also been mapped for one mile in what is probably the same diabase sill, 6½ miles west southwest of the west end of Bears Gut. This rock, which is grey on fresh surfaces, is massive, tends to be banded and is considerably altered. In thin section it consists essentially of serpentine and talc, but also contains pyroxene, amphiboles, biotite, chlorite, carbonate and pyrite. Amphiboles occur as fibres in local shear zones.

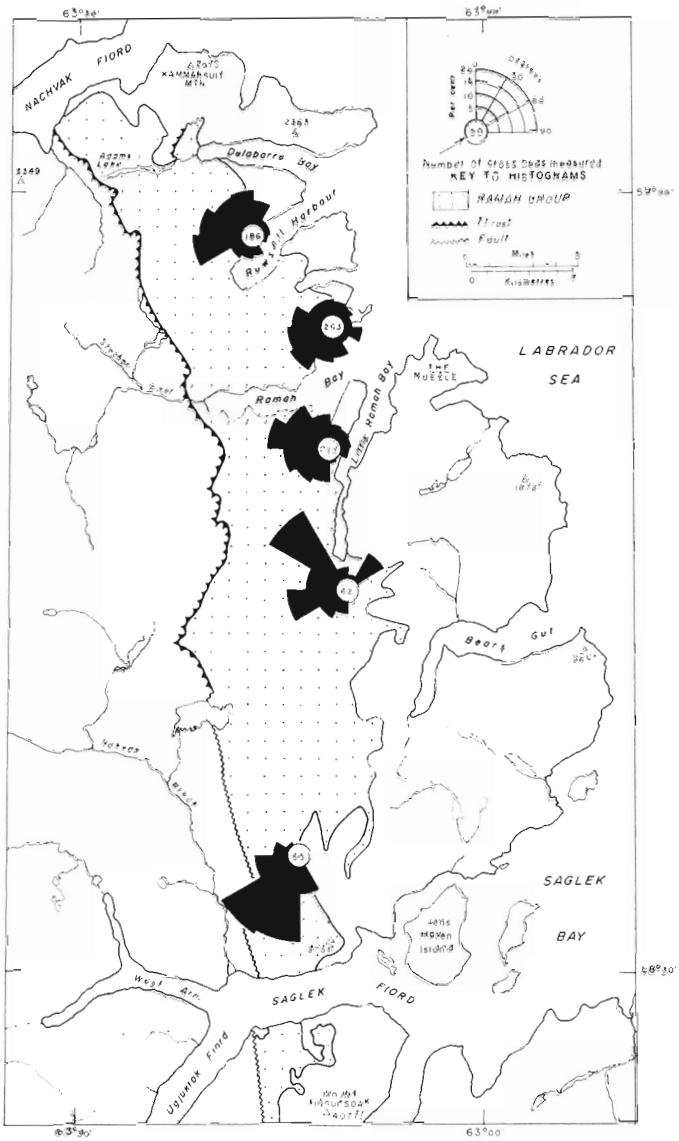

Figure 26. Cross-bedding in the quartzite formation (unit 13) of the Ramah Group.

Paleocurrents

Sedimentary structures are very common in the Ramah Group but are obscured by deformation and metamorphism in the western part of the area and also south of Saglek Fiord. Consequently, paleocurrent data derived from sedimentary structures, particularly in the lower part of the group (units 13, 15 and 16),

were chiefly collected at localities along the eastern margin of the belt north of Saglek Fiord.

The quartzite, metasandstone and meta-arkose in units 13, 15 and 16 contain abundant crossbeds and ripple-marks, and local conglomerates have some imbricated pebble layers. Although ripple-marks are very common (Fig. 25) and were measured they have not been considered here due to the abundance of crossbed azimuths recorded.

Detailed analysis of paleocurrent directions in the various members of units 13 and 15 that have been recognized by Knight (1973) was beyond the scope of the present study. However paleocurrents derived from crossbeds in the white quartzite member of unit 13 beneath the metabasalt were examined at several localities near the east end of Ramah Bay and indicated dominantly bimodal distributions. At individual localities paleocurrent directions are respectively west-northwest to east-southeast, northwest to southeast, east to west, and northeast to southwest.

Crossbed data measured on tabular and trough crossbeds in the entire quartzite formation (unit 13) throughout the area are shown in Figure 26. Each paleocurrent rose diagram summarizes crossbed readings measured at a number of stations at different stratigraphic levels throughout unit 13 at a particular locality. Although there is a considerable range in crossbed orientation in the quartzite it was deposited by currents that chiefly flowed westward. The rocks on the north and south shores of Ramah Bay were deposited by currents that flowed dominantly to the west. In the north, between Rowsell Harbour and Delabarre Bay, however, the main paleocurrent direction is northwest. Paleocurrents are more variable in the south of the area, between Little Ramah Bay and Saglek Fiord, but this may be due to the lower number of crossbeds measured there. Whereas current directions are polymodal, but indicate chiefly northwest transport at the south end of Little Ramah Bay, they are unimodal and suggest southwest transport near Saglek Fiord.

Limited data collected from unit 15 in the northern half of the area suggest polymodal distributions with paleocurrents directed north-northwest and north-northeast but chiefly south-southwest and southeast.

Although data collected from the dolomite formation (unit 18) are inconclusive, a general westward direction of transport is indicated. Attempts to deduce the paleoslope in unit 18 from directions of overturning of slump folds led to ambiguous results that indicated a paleoslope inclined in northerly and southeasterly directions.

An apparent south direction of transport for the metagreywacke formation (unit 20) at the top of the Ramah Group has been reported by Knight (1973).

Sedimentary Environments

The Ramah Group as a whole shows some variation in thickness of individual formations throughout the area studied and represents a general transgressive sequence of miogeosynclinal sediments. Recognition of possible generalized ancient sedimentary environments of the group has been facilitated by criteria described by Selley (1970). A brief description of depositional environments in the Ramah Group has been given by Knight (1973).

A prolonged period of erosion and peneplanation followed by subaerial weathering and regolith development preceded sedimentation which commenced with deposition of unsorted granitic gneiss material and arkose in unit 13. This was followed by deposition of the well-sorted white quartzite with thin conglomerate horizons that is overlain by the metabasalt flow. The quartzite represents a transgressive shallow marine barrier sand environment. The lower parts containing heavy mineral trough crossbeds are probably channel sand deposits. Development of a tidal flat complex is indicated by the purple or green quartzite with grey or purple slate beds that overlies the volcanic flow. A deeper water marine environment is represented by the succeeding slate member. Sedimentation of unit 13 terminated with deposition of white and grey quartzite with subordinate argillaceous beds. These indicate a regression and return to shallower water marine conditions as witnessed by the occurrence of mudcracks and possible rain prints. The white quartzite at the top of unit 13 is possibly a beach deposit.

The laminated quartzite and pelite of unit 15 represent a general transgressive phase that continued until the upper part of the slates of unit 17 was laid down. Conditions under which rocks of unit 15 were deposited varied but were chiefly deltaic. The basal part of the lower member, composed of grey quartzite and metasandstone with slate bands, contains mudcracks and indicates sedimentation under subaerial to intertidal conditions. Parts of this member, for example in the vicinity of Ramah Bay, have been deposited by local turbidity currents. The laminated parts of the lower member, consisting of alternations of fine quartzite and metasandstone with pelite and slate, were probably deposited on a subaqueous delta platform. Quartzite with slate beds near the top of unit 15 may represent distributary channel deposits.

Deeper water marine conditions prevailed when the varicoloured slates of unit 17 were deposited. The lower black, graphitic, pyrite-rich part of the slate unit, the massive pyrite bed and the bedded chert provide combined evidence for restricted circulation in a strongly reducing environment. A transition towards a shallower water marine shelf environment is indicated by the appearance of carbonate-rich slates with occasional crystalline limestone or dolomite beds in the upper part of unit 17.

The dolomite unit (unit 18) indicates regressive conditions with a change to a shallower water open marine environment. Repetition of thin planar continuous beds and fine continuous laminations in the argillaceous dolomite shows that regular fluctuations took place in the depositional environment. A general absence of erosional structures indicates quiet water conditions below wave base, probably at a moderate depth. Evidence for a reducing environment with restricted

Figure 27. Open folds in Ramah Group quartzite, pelite and diabase (units 16 and 21) exposed on the 3,000 feet high north wall of Saglek Fiord. The regolith, unconformity surface and Archean basement rocks (right) are folded with the Ramah Group. (M. P. Cecile). GSC Photo Nos. 162439, 162437, 162440

circulation is provided by the common occurrence of pyrite. This quiet environment was periodically subjected to slumps, mudflows and turbidity currents. Intraformational conglomerates and breccias on the north shore of Ramah Bay at the east end of the dolomite outcrop are local slump deposits that in general show little evidence of graded bedding, rarely show Bouma-type sequences, and may be proximal turbidites. Bouma cycles are, however, common in intraformational conglomerates and breccias associated with beds of quartzite and metasandstone at the west end of Ramah Bay, northwest of Rowsell Harbour and southwest of the south end of Little Ramah Bay. This possibly indicates that deeper water conditions periodically subjected to turbidity currents prevailed towards the western edge of the present dolomite outcrop. Massive dolomite beds in unit 18, however, commonly contain coarse detrital quartz grains and this, together with occurrences of crossbeds may represent phases of shallow-water deposition.

The upper slates (unit 19) represent a general return to transgressive deeper water marine conditions with localized restricted circulation in a reducing environment.

The preserved record of sedimentation terminated with deposition of greywacke and shale (unit 20) probably by turbidity currents.

Structure

The Ramah Group is preserved in an asymmetrical north-trending, doubly plunging synclinorium. This elongated synclinal structure is slightly arcuate so that its axial trace trends northwest between Nachvak Fiord and Rowsell Harbour but trends north from Rowsell Harbour to Saglek Fiord. Whereas the structural basin is mainly bounded by thrusts and faults to the west and contains highly deformed rocks along its western margin, the unconformity is well preserved along the eastern contact and deformation is considerably less. In the area extending south from west of Bears Gut to Saglek Fiord, however, the main synclinal structure is complicated by faulting near its eastern contact.

The regolith, unconformity surface and basement rocks beneath the Ramah Group are also folded by the deformation that affected the Ramah Group. Evidence of this is well exposed on Quartzite Mountain in the west, and on the shores of Saglek Fiord in the south (Fig. 27). The Ramah Group, regolith, and Archean rocks are all highly sheared near the folded contact.

The extent and intensity of folding varies within the area and in general increases from east to west, and also from lower to higher stratigraphic levels. In the east, from Nachvak Fiord to about 4 miles north of Saglek Fiord, the lower formations (units 13 to 16), composed mainly of competent quartzite and metasandstone, show no evidence of mesoscopic folding. Although recrystallized the rocks retain clastic fragments, possess no deformational fabric, and form a well-bedded homoclinal succession dipping gently to the west. Folding is, however, intense in the west (Fig. 28) where the rocks contain stretched clasts and are

sheared, schistose tectonites, with ubiquitous mesoscopic and macroscopic folds.

Axial traces of individual macroscopic folds within the synclinorium can be followed for distances of several miles. Maximum amplitudes are in the order of 1,500 feet to 2,000 feet; wavelengths are up to 4,000 feet. Profile sections of the folds are well exposed on the cliffs at Ramah Bay, Saglek Fiord (Fig. 27), and Quartzite Mountain. Diabase sills that intrude slate and metagreywacke at Ramah Bay outline inclined and overturned open to tight folds with axial planes that dip at high to moderate angles to the west. Overturned subisoclines on Quartzite Mountain have axial planes that dip west at low to moderate angles. Folds in quartzite and pelite (unit 16) exposed on the walls of Saglek Fiord are more open and are not overturned (Fig. 27). Fold hinges are curvilinear so that fold axes plunge at low angles, commonly 5 to 15 degrees, both north and south. Doubly plunging macroscopic folds are common on the south side of Saglek Fiord.

Diabase sills (unit 21) intrusive into slate (unit 19) on the shores of Ramah Bay illustrate effects of competence difference during deformation (Fig. 24). The sills form relatively open folds between which slates are intensely contorted into isoclines. In some instances anticlinal hinges of sills have fractured and slate has squeezed through the anticline in a diapiric-like manner.

Although the Ramah Group has been subjected to polyphase deformation, the earliest phase is dominant and effects of later phases are slight. Mesoscopic folds and microfold lineations are mainly parallel to the trend of the macroscopic folds in the synclinorium. Local microfolds, rarely associated with strain-slip cleavages, trend at high angles to the first phase lineations. Third phase folds that refold earlier structures are rare. They have axes subparallel to the main folds and include open folds, monoclines and kink bands.

Penetrative cleavage is characteristic of slates, phyllites and dolomites (units 17 to 20) in the central part of the basin, and is also present in pelitic bands within quartzite (units 13, 15 and 16). The cleavage is commonly axial planar to folds but locally fans out around closures in slate (Fig. 24). Fracture cleavage is found in quartzite in more intensely deformed areas, and also radiates around folded diabase sills (Fig. 24).

The western contact of the group is marked by a low-angle west-dipping thrust fault between Nachvak Fiord and west of Bears Gut (Fig. 12), south of which the contact is a subvertical fault. Ramah Group rocks near this contact may be sheared, mylonitized, brecciated or schistose and are intensely folded and highly recrystallized. Appressed overturned folds have axial planes with orientations similar to the main thrust plane. Quartzite is strongly recrystallized, commonly contains a pronounced low-angle cataclastic foliation, and has a strong mineral lineation that plunges southwest or west. The thrusting is related to the main folding of the group but as the thrust truncates several folds at least some later movement along the thrust plane is likely.

A number of other low-angle thrusts and reverse faults with general north trends cut the Ramah Group and are common in the eastern part of the basin. They cause repetitions of Archean, unconformity, and basal quartzite units (units 13 and 15) between Delabarre Bay and Rowsell Harbour. The main thrust fault in that area extends to the west end of Rowsell Harbour and a fault, which may be its continuation, can be traced discontinuously to south of Ramah Bay near the contact between dolomite and upper slate (units 18 and 19). Low-angle thrust faults are also well exposed on the northeast shore of Ramah Bay where they cause repetition of the distinctive yellow-brown weathering dolomite at the top of unit 15. Thrusting is responsible for attenuation of the lower slate and dolomite (units 17 and 18) south of Lookout Point, Ramah Bay. Limited observations indicated that a number of thick diabase sills have thrust or fault contacts, and also that some thrusts may be locally folded.

A break can be traced north from Archean rocks, near the east end of the group at Saglek Fiord, through the stratigraphic succession of the Ramah Group to dolomite (unit 18) west of Bears Gut. This break is a thrust fault in the north and a high-angle fault in the south. It developed along the limb separating an anticline to the west from a syncline to the east. A folded

Figure 28.

Intensely folded Ramah Group quartzite on the west side of the belt. 2 miles south of Quartzite Mountain. GSC Photo No. 202531-L

Figure 29.

Folded and faulted outlier of Ramah Group quartzite and pelite (unit 16) exposed at base of 4,000-feet-high mountain of Archean gneisses (unit 1) and diabase dykes. 3½ miles north northwest of Branagin Island. GSC Photo No. 162314

Figure 30.

Highly contorted amphibolite facies Ramah Group pelite (unit 16) with gneissic banding caused by quartzofeldspathic segregation. 11 miles south of the south side of Saglek Fiord. (M.P. Cecile). GSC Photo No. 162498

and faulted outlier of unit 16 (Fig 29) located 3½ miles north of the north shore of Saglek Fiord, is related to this structure. The outlier is situated at low elevation in a valley separating 4,000-foot peaks that are capped by basal members of the Ramah Group.

Northeast- and northwest-trending high-angle faults have also been mapped and three with a dextral-slip component postdate the main thrusting and faulting at the eastern contact of the group.

Ramah Group rocks that have been traced south from the limit of the map-area to Hebron Fiord (Fig. 14) are very highly deformed. They are intensely folded, sheared and mylonitized. Pelitic horizons are commonly schistose and locally contain gneissic banding caused by quartzofeldspathic segregation (Fig. 30).

Metamorphism

At this stage in the investigation mineral assemblages have been examined in only a few thin sections, chiefly of pelitic rocks. Nevertheless it is apparent that the grade of regional metamorphism in the Ramah Group increases chiefly from north to south but also shows an increase from east to west. Between Nachvak Fiord and the southern limit of the map-area near Saglek Fiord the rocks lie in the greenschist and low amphibolite facies of regional metamorphism. Five and one half miles south of Saglek Fiord the grade has increased to high amphibolite facies and rocks of this grade can be traced discontinuously south to Hebron Fiord.

Pelitic rocks in the group extending south from Nachvak Fiord to about 4 miles north of the north shore of Saglek Fiord are commonly muscovite-rich slates or phyllites that contain chlorite or biotite. Chloritoid is present in places and locally these rocks contain cordierite and/or andalusite. Metamorphic grade within this part of the map-area increases from east to west. Quartzites (units 13 and 15) along the east of the belt retain original clastic grains of quartz and feldspar

with no evidence, or very little evidence, of recrystallization. Original clastic outlines have, however, been chiefly obliterated in the highly recrystallized quartzites (units 13, 15 and 16) to the west. Metamorphism of argillaceous bands in the quartzites displays a similar increase in grade from east to west. Pelites along the east are locally chloritoid-muscovite phyllites, and cordierite-bearing varieties in the east are restricted to south of Ramah Bay. Pelites along the west are commonly mica schists with porphyroblasts and include local andalusite-muscovite schist.

South from the vicinity of Saglek Fiord to the limit of the map-area pelitic rocks are more crystalline and porphyroblastic but there is little apparent difference in metamorphic grade from east to west. Argillaceous rocks near Saglek Fiord are slates, phyllites and schists that contain muscovite, biotite and local chloritoid, andalusite or cordierite. Andalusite, cordierite and chloritoid crystals have grown with random orientation across bedding and cleavage. Chloritoid crystals are locally folded and have strained extinction and may also be partly or completely included in andalusite porphyroblasts.

The southern extension of the Ramah Group to Hebron Fiord is in the high amphibolite facies. Pelitic rocks are schists and gneisses with mineral assemblages that include sillimanite + biotite + muscovite; garnet + biotite + muscovite ± sillimanite; and sillimanite + staurolite + muscovite + biotite. Some garnets contain "S"-shaped inclusion trails. Sillimanite occurs as fibrolite masses and as distinct crystals. Muscovite and sillimanite have been folded after their crystallization and show pronounced undulose extinction.

AGE RELATIONS

Field Relations

Field work has not established categorial age relations between all the rock units recognized in the map-area.

The oldest rocks in the Archean basement east of the Ramah Group are interbanded units 1 to 4. The order in which the sequence is shown in Table I may not be chronological, but shows what are thought to be the oldest rocks at the bottom. Unit 5, the feldspar megacrystic gneiss has intrusive contacts against units 1 and 2. The granite and pegmatite of unit 6 intrude the other rock types and are probably late syn- to post-tectonic. The east-trending diabase dykes are chiefly post-orogenic and intrude the other rock types (units 1 to 6).

Equivalent Archean basement rock units (units 8 to 12) occur west of the Ramah Group. There they have, however, been reworked by subsequent orogenic metamorphism and deformation. No field criteria were, however, recognized to indicate that this post-Archean reworking was the result of more than one period of orogeny. Effects of the metamorphism are particularly conspicuous on the diabase dyke swarm (unit 12). The deformation formed a new foliation, involved folding, faulting and thrusting, and resulted in very extensive development of cataclastic rocks.

The unconformity at the base of the Ramah Group with basement rocks to the east clearly demonstrates that the group is post-Archean. The Ramah Group (units 13 to 21) postdates intrusion of the diabase dykes (unit 7) that are themselves post-Archean. Contact relations with the reworked Archean rocks to the west are obscured by thrusts and faults. The orogenic metamorphism and deformation that affected the Ramah Group is considered to be the same as that which caused reworking of Archean basement rocks to the west.

Radiometric Ages

K-Ar age determinations that have been undertaken on material collected from the map-area and from the immediate vicinity are listed in Table III.

Archean ages of 2545 m.y. and 2720±80 m.y. have been obtained from hornblende in rocks located to the east and northeast of the Ramah Group. The respective ages provide approximate dates for the amphibolite facies and granulite facies metamorphism of the Kenoran Orogeny. The diabase age (2425±225 m.y.) is considered to indicate an early Aphebian intrusive age for at least some dykes in the east-trending swarm.

Ages in the reworked Archean to the west of the Ramah Group are more varied. A hornblende age of 2050±65 m.y. from an amphibolite is thought to be a relict Archean age partly updated by later reworking. Another hornblende age (1680±60 m.y.), from metamorphosed anorthosite that is unrelated to the post-orogenic intrusions farther south in Labrador, possibly resulted from reworking by the Hudsonian Orogeny. A biotite age of 1330±40 m.y. from a blastomylonitic paragneiss, interpreted on field evidence as an Archean paragneiss that was subjected to penetrative deformation and metamorphism in the Proterozoic, seems to indicate an Elsonian event.

Preliminary results of Rb-Sr whole rock age determinations by the Isotope Geology Section, Geological Survey of Canada, indicate that the metabasalt flow near the base of the Ramah Group has an age of between 1800 m.y. and 1900 m.y. It is assumed that this age is a metamorphic age and not one that indicates the approximate time of extrusion. On this basis the Proterozoic Ramah Group is Aphebian, as suggested by Christie (1952), and was deformed and metamorphosed on an orogenic scale by the Hudsonian Orogeny. The Rb-Sr age agrees well with that shown for the Hudsonian Orogeny in the revised Precambrian time scale for the Canadian Shield (Stockwell, 1973). However K-Ar ages on material from the group give no indication of the Hudsonian Orogeny and are attributed to an Elsonian event. K-Ar ages on a whole rock sample of the metabasalt and on muscovite from a chloritoid schist are respectively 1180±60 m.y. and 1213±32 m.y

ECONOMIC GEOLOGY

No mineral occurrences of economic importance were located. Minor occurrences of mineralization are

TABLE III

K-Ar age determinations[1] in the general Nachvak Fiord - Saglek Fiord area

Area	Location	Rock type	Material dated	Age (in m.y.)	Comments
Ramah Group	58°54'N 63°11'W	Metabasalt	Whole rock	1180±60[3]	Ages for the metasediment and metavolcanic give approximate dates for the Elsonian event.
	58°50'30"N 63°11'40"W	Chloritoid schist	Muscovite	1213±32[2,3]	
Basement rocks west of the Ramah Group	58°59'N 63°46'W	Anorthosite	Hornblende	1680±60	Approximate age of metamorphism of anorthosite indicates this rock was involved in the Hudsonian Orogeny.
	58°56'N 63°30'W	Amphibolite	Hornblende	2050±65	Associated with the amphibolite are faults and large zones of mylonite. The amphibolite is considered to be an Archean rock that was reworked at a later date.
	58°33'N 63°27'W	Paragneiss	Biotite	1330±40[3]	The paragneiss has a blastomylonitic texture and is considered to be reworked Archean. The age provides an approximate date for the Elsonian event.
Basement rocks east of the Ramah Group	59°10'N 63°33'W	Granulite gneiss	Hornblende	2720±80	Dates indicate that these rocks were affected by the Kenoran Orogeny.
	58°56'45"N 63°11'00"W	Basic gneiss	Hornblende	2545[3]	
	58°49'N 63°10'W	Diabase	Whole rock	2425±225[3]	Diabase post-dates the Kenoran Orogeny. Age is approximately that of dyke intrusion - early Aphebian.

[1]Determinations by Isotope Geology Section, Geological Survey of Canada. Recorded in Wanless et al. (1965, 1966, 1970).

[2]New determination.

[3]Determinations on material within the present map area.

marked on the map. Disseminated mineralization is common in Archean and Ramah Group rocks but appears to be rare in the high grade rocks that occur west of the Ramah Group.

Iron-formation, commonly associated with thin bands of basic gneiss (unit 2) and paragneiss (unit 4), has been located in Archean rocks at several localities between Ramah Bay and Saglek Fiord. The iron-formation is lean silicate-oxide facies that chiefly occurs in 20- to 30-foot-thick bands, although a few 100- to 150-foot-thick bands have been observed. Thin magnetite-rich bands also occur in leucocratic granulite (unit 9) 2 miles northeast of the north end of North Arm, Saglek Fiord. Ore grade iron-formation was not located.

The numerous small ultramafic bodies (unit 3) and lenses in the Archean commonly contain long brittle fibres of actinolite, and are locally cut by veinlets, up to one half inch thick, of cross-fibre asbestos. Soapstone is present in ultramafic rocks east of Little Ramah Bay. Fibrous amphibole also occurs in parts of the ultramafic core (unit 21a) of the Ramah Group diabase sill south of Little Ramah Bay. No sulphide mineralization was noticed in the ultramafic rocks.

Archean migmatite (unit 1) east of the Ramah Group unconformity on the north shore of Ramah Bay (58°54'48"N, 63°11'00"W) is cut by a 6-inch-thick vein of galena. Although the vein is lined with quartz and minor carbonate, lead mineralization penetrates the country rock for distances of up to one inch. Minor amounts of chalcopyrite, sphalerite and pyrrhotite also occur in the vein. Assay results for silver from massive galena, chalcopyrite and sphalerite are 11.78 oz./ton, 9.26 oz./ton and 0.21 oz./ton respectively. Gold was not detected in the galena but occurs in trace amounts (<0.003 oz./ton) in the chalcopyrite and sphalerite.

The only other showing of galena observed in the map-area is in the 30-foot-thick replacement dolomite that occurs in the Ramah Group below the lower slate unit (unit 17). Thin veins of carbonate and quartz containing disseminated galena with minor sphalerite and chalcopyrite are present in the dolomite approximately 3 miles south-southeast of Little Ramah Bay.

Small amounts of locally disseminated chalcopyrite occur at several places in Archean rocks particularly in fault zones and basic gneiss bands (unit 2), for example east of Little Ramah Bay. The regolith below the Ramah Group is enriched in magnetite, silica, and carbonates, and shows local malachite stain. Traces of chalcopyrite and malachite stain are relatively common in the quartzite formations (units 13, 15 and 16) in the lower part of the group.

Allanite crystals, up to one inch long, are conspicuous in a pegmatite that cuts Archean granitic gneiss and migmatite on the south side of Saglek Fiord, 3 miles west of Cape Uivak.

Several rusty zones located in graphitic paragneiss bands in granulites occur west of the Ramah Group approximately 4 miles east of the south end of Ugjuktok Fiord. Samples of one mineralized zone that contained minor chalcopyrite gave assay results of 0.03 oz./ton silver and <0.003 oz./ton gold.

Ramah quartzite at the south end of Little Ramah Bay is cut by a fault zone that contains inch-thick quartz veins with specular hematite, digenite and malachite.

Pyrite is the dominant type of mineralization in the metasedimentary Ramah Group rocks and pyrite crystals are conspicuous in units 17 to 20. Gossans and rusty zones, consisting of disseminated or lenticular masses of pyrite and pyrrhotite, are particularly common in the slates (units 17 and 19). The principal pyrite-rich rocks are located in the basal graphitic part of the lower slate unit (unit 17) in close proximity to the conspicuous chert horizon. These pyrite beds, presumed to be at approximately the same stratigraphic horizon, have been traced discontinuously from Adams Lake to the south shore of Saglek Fiord.

Occurrences of the pyrite horizon between Rowsell Harbour and Ramah Bay plus assay results have been described by Douglas (1953). In that area pyrite occurs as disseminated crystals in the slate, or as bands and lenses that range in thickness from a few inches to about 3 feet. One and one half miles south of Little Ramah Bay the mineralized horizon consists of a 6-foot-thick massive pyrite-pyrrhotite bed with traces of chalcopyrite. Several nodule-like areas of quartz and graphite, commonly less than half an inch across, occur within the massive pyrite-pyrrhotite. These beds occur above a chert horizon and beneath a diabase sill. An assay indicated the total concentration of precious metals to be 0.015 oz./ton. The pyrite-pyrrhotite horizon observed on the south shore of Saglek Fiord, located above a continuation of the same diabase sill, contains numerous quartz and graphite nodules resembling clasts.

DISCUSSION

The map-area lies entirely within Nain Structural Province as defined by Stockwell (1963) and straddles the boundary between his Eastern Nain Subprovince and Western Nain Subprovince (Stockwell, 1964). Eastern Nain Subprovince is chiefly characterized by basement gneisses with K-Ar ages attributed to the Kenoran Orogeny but contains some younger supracrustal cover rocks that include the Ramah Group. Western Nain Subprovince contains large bodies of anorthosite and mangerite that intrude basement gneisses with a K-Ar average age of 1370 m.y. attributed by Stockwell (1964) to the Elsonian Orogeny. Reconnaissance mapping in 1967 and 1969 (Taylor, 1969, 1970), however, did not reveal a structural or metamorphic discontinuity along the western boundary of Stockwell's Nain Province and led Taylor (1971) to refute the concept of Western Nain Subprovince and to class it as an isotopically overprinted part of Churchill Province. Eastern Nain Subprovince was consequently raised to structural province status by Taylor (1971), named Nain Province, and later described in detail (Taylor, 1972a). The revision of structural provinces was subject to discussion (Douglas, 1972; Taylor, 1972b)

in which Douglas proposed a different terminology. Taylor (1972b) rejected Douglas' proposals and considered that his original recommendations (Taylor, 1971) be retained. In a recent paper Stockwell (1973) refers to the Elsonian event of Western Nain Subprovince, and does not appear to have accepted the above revisions and proposals.

The writer is in complete agreement with the revision of structural provinces and terminology proposed by Taylor (1971) with regard to the area currently under investigation. In the map-area basement rocks east of the Ramah Group (units 1 to 7) form part of an Archean craton that, with the exception of unit 7, was deformed and metamorphosed during the Kenoran Orogeny. The present study has also shown that the Ramah Group (units 13 to 21) and basement rocks to the west (units 8 to 12) have synchronously undergone orogenic deformation and metamorphism. This orogeny is considered to be the Hudsonian on the basis of a preliminary Rb-Sr whole rock age determination on the Ramah Group of between 1800 m.y. and 1900 m.y. Basement rocks west of the Ramah Group (units 8 to 11), however, are now demonstrated to have been previously deformed and metamorphosed on an orogenic scale by the Kenoran Orogeny. Helikian ages obtained by K-Ar whole rock and mineral dating of material from the study area are not considered to be evidence for an Elsonian Orogeny. They appear to indicate attainment of a threshold temperature and not the time of metamorphic crystallization (Moorbath, 1967). The status of the Elsonian Orogeny was appraised by King (1969, p. 35) who concluded that "the Elsonian is a minor event in the Canadian Shield that produced no more than an overprint on rocks already consolidated by the Hudsonian Orogeny". The Elsonian event has been attributed to thermal activity caused by intrusion of the post-Hudsonian massive anorthosite and mangerite batholiths (Taylor, 1971; Bridgwater et al., 1973a) and to uplift causing stabilization by cooling (Taylor, 1971).

The present study has shown that the boundary between Nain Province and Churchill Province should be modified in the area between Nachvak Fiord and Hebron Fiord. The Aphebian supracrustal Ramah Group can be used to mark the eastern limit of deformation and metamorphism caused by the Hudsonian Orogeny in the same way as the western limit is positioned at the boundary of the Labrador Fold Belt and Superior Province. Therefore the Ramah Group should be included in Churchill Province with the boundary between Nain and Churchill provinces located at the eastern margin of the group. North and south of the study area where supracrustal rocks are absent from the boundary between Nain and Churchill provinces it may be possible to locate the boundary in basement rocks by means of Hudsonian deformation and metamorphism of post-Kenoran basic dyke swarms.

Archean rocks, essentially unaffected by later regional metamorphic events, that occur on the Labrador coast, in East and West Greenland and in northwest Scotland have been interpreted as remnants of a North Atlantic Archean craton (Windley and Bridgwater, 1971; Bridgwater et al., 1973a, b). The Archean rocks (units 1 to 7) located east of the Ramah Group in the present area form part of the Labrador remnant of this craton.

Apart from the overall similarities there are significant differences in the geology of the different parts of the North Atlantic Archean craton. Thus in north Labrador the Archean basement has a dominant north-south structural trend that contrasts with the general isotropic interference fold patterns of West Greenland. Furthermore pre-Kenoran layered calcic anorthosites, that are a conspicuous feature of the West Greenland Archean, are rare on the Labrador coast but have been located by Hurst et al. (1974). However it is possible that the banded meta-anorthosites described by Taylor (1969) to the west and north of the present map-area represent pre-Kenoran intrusives located in reworked Archean.

Few isotopic ages other than K-Ar mineral and whole rock determinations have been published for Archean material from the Labrador coast. The Kenoran ages obtained appear to date a granulite or amphibolite facies metamorphic event. This event is an important time marker in Greenland where it is regarded as a 'blanket' metamorphism that obscures much of the geological and isotopic evidence of earlier history (Bridgwater et al., 1973b). The Archean granulite facies metamorphism in West Greenland has been dated by Pb-Pb whole rock determinations at a mean of 2850±100 m.y. (Black et al., 1973). Although field criteria has not permitted the establishment of pre-Kenoran relative chronology to date, due to parallelization of lithological boundaries caused by transposition, geochronological studies may assist in this sphere. For example preliminary U-Pb and Rb-Sr geochronological studies by Hurst (1974) have given a metamorphic age of about 3500 m.y. for Archean rocks from the vicinity of the Kaumajet Mountains in Labrador. Very early Precambrian rocks in West Greenland have yielded Rb-Sr whole rock isochron ages, interpreted as an igneous or a metamorphic event, within the range 3700 m.y. to 3750 m.y. (Moorbath et al., 1972). The metamorphism of the Isua iron-formation in West Greenland has also been dated as an early Archean event and has given a Pb-Pb isochron age of 3760±70 m.y. (Moorbath et. al., 1973).

During the early Aphebian the Archean craton in the map-area was intruded by extensive, densely distributed, basic dyke swarms. In the west, in the zone of reworked basement rocks, these dykes were later deformed and metamorphosed by the Hudsonian Orogeny. No unusual primary amphibolite or granulite facies basic dykes, similar to those described from West Greenland by Windley (1970) or from northern Labrador by Morgan and Taylor (1972), were observed in the map-area.

After intrusion of the basic dyke swarms but prior to deposition of the Aphebian Ramah Group sediments the craton was subjected to uplift and to erosion that resulted in development of a peneplain. This erosion surface must have been fairly extensive as peneplained Archean rocks underlie Proterozoic supracrustal successions at several localities in Labrador and Green-

land. The peneplain is well preserved beneath the Ramah and Mugford groups in Labrador (Taylor, 1972a) and in the Midternaes - Graenseland area of southwest Greenland (Higgins, 1970; Bondeson, 1970).

The Ramah Group, which is chiefly composed of rocks of sedimentary origin with one thin tholeiitic basalt flow and several diabase sills, was deposited by currents that flowed dominantly in a westward direction. The miogeosynclinal sedimentary rocks that form the bulk of the group were probably derived from a stabilized North Atlantic Archean craton that was formerly of greater extent and was located to the east.

The Ramah Group previously thought to be Helikian (Jackson and Taylor, 1972; Sutton et al., 1972; Bridgwater et al., 1973a) is now shown to be Aphebian. Other supracrustal successions on the Labrador coast that are probably of the same general age as the Ramah Group include the Mugford Group (Barton, 1974; Christie, 1952; Douglas, 1953; Taylor, 1970, 1972a), the Snyder Group (Barton, 1974; Morse, 1971; Speer, 1972), and the Aillik Group (Ghandi et al., 1969; Stevenson, 1970). The Ramah Group is also of the same general age as rocks of the Kaniapiskau Supergroup, in the Labrador trough, as originally suggested by Christie (1952).

Correlation of the Ramah Group with the Mugford Group is more feasible now that the Ramah Group has been traced south to Hebron Fiord, 30 miles distant from the most northerly outcrop of the Mugford Group in the Kaumajet Mountains. The Mugford Group consists of weakly deformed and metamorphosed basic volcanic rocks, including flows, agglomerates, tuffs and flow breccias, and sedimentary rocks that are chiefly black slates with some carbonates, quartzite, green slates and chert (Christie, 1952; Douglas, 1953; Taylor, 1970, 1972a). Douglas (1953) considered the Mugford Group to be younger than, and separated by an unconformity from, the Ramah Group which he interpreted to be represented by slates in the lower part of the succession in the Kaumajet Mountains. This was not confirmed by Taylor (1970) who questioned correlation of the slate unit and thought that the discordance might be only local. The writer considers that the Mugford Group is probably of Aphebian age and is composed of miogeosynclinal deposits, only weakly deformed and metamorphosed by the Hudsonian Orogeny, that rest on the peneplained surface of the Archean craton. This is supported by the very tentative Rb-Sr age of 2300 m.y. reported by Barton (1974).

Mobile belts, such as the Nagssugtoquidian of Greenland and the Laxfordian of Scotland, surround the North Atlantic Archean craton and are considered to be extensively composed of reworked Archean material (Bridgwater et al., 1973b). The present work in Labrador has supported this and has demonstrated that basement rocks (units 8 to 12) west of the Ramah Group form part of a mobile belt chiefly composed of reworked Archean.

A continuation of the boundary between the Nagssugtoquidian mobile belt and the Greenland Archean craton into Labrador has been proposed by Bridgwater et al. (1973c). They put the boundary at the Archean – Proterozoic contact shown by Taylor (1969, 1970). This present study has shown that a continuation of the Nagssugtoquidian boundary in Labrador passes through the map-area and separates Archean rocks (units 1 to 7) to the east from reworked Archean material (units 8 to 12) to the west. However the precise location of the boundary cannot be determined in the basement due to the Aphebian cover of Ramah Group rocks. The Ramah Group was deformed during the Hudsonian Orogeny synchronous with the reworking of Archean rocks to the west. It therefore seems logical to locate the continuation of the Nagssugtoquidian boundary in the map-area at the eastern contact of the Ramah Group, east of which effects of the Hudsonian Orogeny on the Archean craton and its Proterozoic cover rocks are not pronounced.

There is ubiquitous evidence of very extensive movement in the mobile belt of basement rocks west of the Ramah Group (units 8 to 12). Cataclastic rocks, including tectonic breccias, mylonites and pseudotachylyte veins, are extensively developed in this steeply dipping north-northwest trending zone. Blastomylonitic textures are also common and are characteristic of two map-units, the granulites and paragneisses (units 9 and 11). This important zone of cataclasis forms a major structure, similar to the straight belts of reworking described by Watson (1973), and was mapped on a regional scale in northern Labrador and northeastern Quebec (Taylor, 1969, 1970). Bridgwater et al. (1973c) speculated on the nature of this structure and suggested that it represents a transcurrent displacement zone between two adjacent blocks, an Archean block to the east and a Hudsonian block to the west. They (Bridgwater et al., 1973c) suggest that the Labrador boundary represents the side margin of a moving block while the Nagssugtoquidian boundary in Greenland represents the leading edge. Subhorizontal ribbon structure lineations in paragneiss (unit 11) and the re-orientation of amphibolite dykes (unit 12) in the present map-area indicate transcurrent movement in the boundary zone with a sinistral sense of displacement. This tends to support the tectonic model suggested by Bridgwater et al. (1973c). However there is also evidence of crustal shortening in the mobile belt in the form of west dipping thrusts that cut the reworked basement and the Ramah Group. Folds in the Ramah Group are commonly overturned and have axial planes that dip west. Additional field evidence therefore indicates that there has also been extensive overthrusting of the mobile belt in Labrador over the Archean cratonic block to the east.

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