GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MEMOIR 338

MARION LAKE MAP-AREA, QUEBEC-NEWFOUNDLAND

(23 I/13)

J. A. Donaldson

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PREFACE

In recent years, the Geological Survey of Canada has carried out a program of systematic mapping within the Proterozoic belt of sedimentary and volcanic rocks commonly called the Labrador Trough. This report outlines the geology of an area underlain in part by such rocks, and in part by quartzo-feldspathic gneisses and amphibolites.

History of the sedimentary strata is emphasized, and evidence is presented to suggest that most of the sediments within the map-area were deposited in shallow water. Of particular interest is the dolomitic Denault Formation, in which abundant stromatolites record the important role of algae in the accumulation of these Precambrian sediments.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, April 28, 1964

Memoir 338 — Kartenblatt Marion Lake, Quebec-Neufundland
Von J. A. Donaldson

Eine ausführliche Beschreibung der proterozoischen Gneise und der darüber gelagerten sedimentären und vulkanischen Gesteine an der Ostseite der Labrador-mulde, 56 km östlich von Schefferville.

Мемуар 338 — Дж. А. Дональдсон. Картографированная площадь оз. Марион, Квебек-Ньюфаундлэнд.

Подробное описание протерозойских гнейсов и вышележащих пород осадочного и вулканического происхождения, расположенных на востоке Лабрадорского прогиба, 35 миль восточнее Шеффервиля.

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MARION LAKE MAP-AREA, QUEBEC-NEWFOUNDLAND

Abstract

The eastern third of the map-area is underlain by amphibolites and quartzo-feldspathic gneisses; the western two thirds is underlain by meta-basalt, meta-gabbro, serpentinite, and slightly metamorphosed sedimentary rocks of the Labrador Trough. The gneisses and amphibolites, which either are part of the Archaean basement or are metamorphosed rocks of the Labrador Trough, form an eastern block that truncates northwest-trending folds and faults in the western block. The north-trending contact is a reverse fault, along which the gneissic block moved up relative to the western block.

In the southwestern corner, sedimentary strata of the Knob Lake Group, with a possible total thickness of more than 20,000 feet, are separated from the volcanic belt in the central part of the area by a northwest-trending fault. Immediately east of the fault, greenschists of the Murdock Group outcrop. The overlying Doublet Group comprises 3,500 feet of sedimentary rocks, and more than 10,000 feet of metavolcanic rocks. Remarkably conformable basic sills underlie much of the area. The volcanic and intrusive rocks were probably derived from the same magma. The sills, which are as much as 5,000 feet thick, were intruded prior to and during the early stages of folding.

Most sedimentary rocks in the area show evidence of deposition on a stable shelf, which was, at most times, covered by shallow water. Graded beds interpreted as varves are exhibited by many of the fine-grained sedimentary rocks. Crossbedding attitudes in sandstone beds west of Marion Lake indicate sediment transport from the west.

To investigate conditions of carbonate sedimentation during the Proterozoic, the Denault Formation of the Knob Lake Group was studied in detail. On the basis of five measured sections, the formation is composed of about 30 per cent finely laminated siliceous dolomite, 20 per cent massive dolomite, 5 per cent intraformational conglomerate, and 45 per cent stromatolitic dolomite. Five zones of distinctive stromatolites were correlated in sections more than 2 miles apart. Algal activity was important in trapping sediment, and may have played a dominant role in primary precipitation of dolomite. A shallow-water to intertidal environment of deposition is inferred.

Résumé

Le tiers oriental de la région repose sur des amphibolites et des gneiss à quartz et à feldspath; les deux autres tiers, à l'ouest, reposent sur du métabasalte, du métagabbro, de la serpentinite et sur des roches sédimentaires légèrement métamorphisées de la fosse du Labrador. Les gneiss et les amphibolites, qui font tous deux partie du socle archéen ou sont des roches métamorphisées de la fosse du Labrador, forment un bloc à l'est qui coupe les plis à direction nord-ouest et les failles du bloc de l'ouest. Le contact à direction nord est une faille

inverse le long de laquelle le bloc de gneiss s'est soulevé par rapport au bloc de l'ouest.

Dans le coin sud-ouest, les strates sédimentaires du groupe Knob Lake, d'une épaisseur totale possible de plus de 20,000 pieds, sont séparées de la zone volcanique, dans la partie centrale de la région, par une faille à direction nord-ouest. Immédiatement à l'est de la faille, les schistes verts du groupe Murdock affleurent. Le groupe Doublet sus-jacent comporte 3,500 pieds de roches sédimentaires et plus de 10,000 pieds de roches métavolcaniques. Des filons-couches basiques d'une remarquable concordance sont sous-jacents à la plus grande partie de la région. Les roches volcaniques et intrusives proviennent probablement du même magma. Les filons-couches, qui peuvent atteindre 5,000 pieds d'épaisseur, ont fait intrusion avant ou durant les premières phases du plissement.

La plupart des roches sédimentaires de la région portent la preuve qu'elles ont été déposées sur un plateau stable qui la plupart du temps a été recouvert d'eau peu profonde. Plusieurs des roches sédimentaires à grain fin comportent des couches stratifiées que l'on a considérées comme des varves. Des stratifications entrecroisées dans des couches de grès à l'ouest du lac Marion indiquent qu'il y a eu transport de sédiments en provenance de l'Ouest.

On a fait l'étude complète de la formation Denault du groupe Knob Lake pour déterminer la sédimentation des carbonates au cours du Protérozoïque. En se fondant sur les mesures de cinq coupes, la formation paraît composée d'environ 30 p. 100 de dolomite silicée finement feuilletée, 20 p. 100 de dolomite massive, 5 p. 100 de conglomérat intercalaire et 45 p. 100 de dolomite stromatolitique. On a fait la corrélation, dans des coupes situées à plus de deux milles de distance, de cinq zones de stromatolites bien distinctes. Les algues ont joué un rôle important de fixation des sédiments et peuvent avoir contribué fortement à la précipitation primaire de la dolomie. On en déduit que la déposition s'est faite en eau peu profonde soumise à l'effet des marées.

Chapter I

INTRODUCTION

Marion Lake map-area, bounded by latitudes 55°00′ and 54°45′N and longitudes 66°00′ and 65°30′ W, is in the eastern plateau region of the Canadian Shield. Schefferville, centre of mining activity in the Quebec-Labrador iron range, is about 35 miles west of Marion Lake.

Quebecair has scheduled flights to Schefferville, and Quebec North Shore and Labrador Railway provides passenger service between Schefferville and Sept Iles, some 360 miles south. During the field season, seaplanes may be chartered at Squaw Lake, 2 miles north of Schefferville. There are no good water routes to Marion Lake, but canoes greatly facilitate work within the area.

Mapping was carried out during the periods June 29 to August 26, 1957, and June 27 to September 8, 1958. Mapping was for publication at a scale of 1 inch equals 1 mile, but sections of well-exposed sedimentary rocks west of Marion Lake were studied in greater detail.

Acknowledgments

Sincere thanks are due Dr. F. J. Pettijohn for guidance during laboratory studies at The Johns Hopkins University, where much of the material in this report was submitted as a doctoral thesis. Dr. Olcott Gates, also of Johns Hopkins, offered many helpful suggestions during preparation of the manuscript.

Capable field assistance was provided in 1957 by N. L. McIver, A. W. Wells, and L. G. MacDonell, and in 1958 by R. I. Thorpe, D. E. Essing, and L. Prevec. Geologists of Labrador Mining and Exploration Company made available unpublished maps, and extended many other courtesies in the field.

Previous Work

First geological investigations in the vicinity of the map-area were carried out by A. P. Low (1896)[1], who in 1894 reached the headwaters of the Ashuanipi River system, about 20 miles west of Marion Lake. No further work was done in the general region until the summer of 1929, when W. F. James and J. E. Gill discovered iron ore near Knob Lake. Since that time, officers of the Geological Survey have

[1]Names and dates in parentheses refer to publications listed in *References*.

mapped numerous adjacent and nearby areas. Willbob map-area (Frarey, 1952) to the northwest, and Griffis Lake map-area (Fahrig, 1951) to the north have been published on a scale of 1 inch equals one-half mile. Menihek Lake (east half) map-area (Frarey, 1961) to the west, and Michikamau Lake (west half) map-area (Wynne-Edwards, 1960), which includes Marion Lake map-area, are published on a scale of 1 inch equals 4 miles.

Physiography

The Marion Lake area is crossed by the height of land marking the unsurveyed provincial boundary between Quebec and Labrador. Gauthier, Moss, and Marion Lakes, on the Labrador side of the watershed, are headwaters of McKenzie River, which drains southeast to the Atlantic via Hamilton River. Rivière de Pas drains the Quebec side northward to Ungava Bay via George River.

Topography is closely related to lithology and structure of the bedrock. Folded and faulted volcanic, sedimentary, and mafic to ultramafic intrusive rocks underlie numerous hills and ridges, which rise 400 to 600 feet above intervening lakes in the western two thirds of the area; gneisses and amphibolites underlie comparatively flat and swampy terrain in the eastern third. Lakes occupy nearly one quarter of the area, and muskeg covers almost half of the remainder. The larger lakes have elevations between 1,500 and 1,600 feet above sea-level, and the highest hill, just west of Lac Tantouin, is 2,091 feet above mean sea-level.

Black spruce is the most abundant evergreen. Some white spruce and balsam grow in the thicker stands of timber, and tamarack is abundant at the margins of lakes and swamps. In protected valleys, the trees are commonly more than 100 feet high, with butt diameters up to 30 inches, but on wind-blown slopes they are seldom more than 50 feet high. Willows, alders, and small shrubs cover the sides of hills and form dense thickets along stream channels. The ubiquitous arctic moss is, in many places, the only bedrock covering.

The climate is sub-arctic and the weather is generally unsettled. More than half the days of the 1957 and 1958 field seasons were overcast, windy, and rainy. Summer temperatures seldom drop below freezing or rise above 80°F, but fluctuate abruptly between these limits. Some snow remains until early July, and may be expected again in early September. Most lakes are free of ice by the end of June, and seldom freeze over until mid-September. The mean annual temperature is approximately 23°F and the annual precipitation exceeds 30 inches.

Pleistocene Geology

Glacial striae and grooves on the surface of outcrops, especially those exposed on the crests of hills, indicate at least two different directions of regional ice-movement. The strike of the youngest and most prominent set ranges from 49 to 55 degrees. *Roches moutonnées,* drumlin configurations, and plucking at the ends of grooves indicate that the ice-sheet advanced from the southwest. The earlier set of striae, partly obliterated by the later movement, strikes at 115 to 130 degrees, parallel to the trend of bedrock ridges. Ice-movement for this set was from the northwest.

Glacial drift consists mostly of boulder till, but there are extensive sandy outwash deposits around Marion Lake and east of Lac Villedonne. Erratics are commonly less than a mile from their source. Where overburden is only a few feet thick, frost-wedging has brought to the surface abundant angular blocks derived from underlying bedrock. In the eastern part of the area, where the drift has a high clay content, there are many small drumlins and larger drumlin-like ridges (drumlinoids). Only the small drumlins can be recognized easily in the field; the drumlinoids, particularly abundant east of Lac Gouffier, are features clearly seen in aerial photographs. They are up to 50 feet high and 3,000 feet long, and their long axes are parallel to striae and grooves formed by the last glacial advance.

Eskers are prominent topographic features in the eastern half of the map-area, where the drift is relatively thick. The eskers, which consist mostly of well-sorted sand, are as much as 40 feet wide and 20 feet high, but the average cross-sectional dimensions are about half these figures. Although locally sinuous and discontinuous, they are for the most part remarkably linear and persistent. Their trend is almost perpendicular to the latest direction of ice-movement, suggesting that the ice-sheet was stagnant as it melted, with transverse subglacial drainage towards a salient. The eskers could also have formed as deposits in fissures that opened parallel to the front of the retreating ice-sheet.

Chapter II

GENERAL GEOLOGY

The eastern third of Marion Lake map-area is underlain by amphibolites and quartzo-feldspathic gneisses. The remaining part is underlain by meta-basalt, meta-gabbro, serpentinite, and slightly metamorphosed sedimentary rocks of the Labrador Trough, a narrow belt of Proterozoic rocks that extends about 450 miles northwest and 125 miles southeast of Marion Lake.

The gneisses and amphibolites form an eastern block that truncates northwest-trending folds and faults in a western block comprising strata of the Labrador Trough. The north-trending contact is a reverse fault, along which the eastern block moved up relative to the western block. The gneisses and amphibolites either are part of the Archaean basement or are metamorphosed Proterozoic rocks of the Labrador Trough.

Sedimentary strata and volcanic rocks of the Knob Lake Group, with a possible thickness of more than 20,000 feet, have been mapped in the southwestern part of the map-area. A northwest-trending fault separates these rocks from the presumably younger Murdock-Doublet belt in the central part. The Murdock Group is composed mostly of greenschists derived from sedimentary and volcanic rocks; the Doublet Group comprises 3,000 feet of sedimentary rocks and more than 10,000 feet of metavolcanic rocks.

Remarkably conformable mafic and ultramafic sills underlie much of the area. The sills, as much as 5,000 feet thick, were intruded prior to folding and during its early stages. Folds in the Knob Lake Group plunge steeply northwest, in contrast to those in the Murdock and Doublet Groups, which plunge gently southeast.

Rocks of the Knob Lake, Murdock, and Doublet Groups, together with the abundant conformable sills with which they are closely associated, represent the main rock types of the central part of the Labrador Trough. Most of the rocks have been metamorphosed to some extent, but sedimentary, volcanic, and igneous names are herein applied to rocks in which primary structures and textures are well preserved.

Gneiss and Amphibolite

The quartzo-feldspathic gneisses and amphibolites that underlie the eastern part of the map-area, differ from rocks of the Labrador Trough in structure and grade of metamorphism. Drift is thick and bedrock exposures are scarce in much of the low, swampy eastern part, but there are sufficient outcrops to indicate the areal distribution of the

Table of Formations

Era	Group	Formation	Lithology	Approximate thickness (feet)
Cenozoic			Unconsolidated boulder till, sand, gravel	0-100
UNCONFORMITY				
Proterozoic			Diabase Gabbro, serpentinite, diorite, quartz diorite	
	Doublet		Meta-basalt; minor tuff and volcanic breccia	10,000
			Slate, argillite, quartzite	3,000
	Murdock		Chlorite schist, massive basic igneous rocks; minor sedimentary rocks	3,000
	FAULT CONTACT			
	Knob Lake	Menihek	Slate, shale; minor quartzite, argillite	5,000?
		Wishart	Sandstone, conglomerate, siltstone	300
		——— UNCONFORMITY ———		
		Denault	Dolomite	3,000
			Meta-basalt	2,500
		Marion Lake	Sandstone, siltstone, slate, conglomerate	4,000
		Attikamagen	Slate, phyllite	5,000?
	FAULT CONTACT			
			Gneiss, amphibolite, migmatite; minor schist	

gneiss and amphibolite units. Most of the amphibolite occupies a north-trending belt, 1 mile to 3 miles wide, east of Lac Civille and Lac Bonnivet. The gneisses underlie the area between the amphibolite belt and the fault that, within the map-area, marks the eastern boundary of the Labrador Trough.

Gneiss

Most of the gneisses are medium-grained, well-foliated, leucocratic to mesocratic rocks that commonly exhibit a near-horizontal lineation. Alternation of biotite layers a few millimetres thick and quartzo-feldspathic layers less than 1 cm thick is responsible for the foliation; the main linear elements are crenulations and mineral streaks in the foliation. Massive to faintly foliated biotite diorites, included with the gneiss on the map, occur sporadically as nebulous, lenticular bodies as much as 100 feet long, elongate parallel to the foliation of the enclosing leucocratic rocks. Layers, inclusions, schlieren, and irregular pods of plagioclase-quartz-hornblende gneiss and plagioclase-hornblende-biotite gneiss are sufficiently abundant in some exposures to lend a migmatitic appearance to the rocks.

The quartzo-feldspathic gneisses characteristically have a granoblastic to poikiloblastic texture. Modal compositions of typical specimens, determined by point-count analysis, are shown in Table I. Plagioclase, An_{28-32}, occurs as equant, anhedral grains as much as 5 mm in diameter, but most grains are less than 2 mm. Excellent albite twinning is exhibited by the plagioclase, and pericline twin lamellae are present in some grains. Much of the plagioclase contains abundant euhedral inclusions of apatite, epidote, biotite, and zircon. Wavy extinction and bent twin lamellae are common features, many of the grains contain planes of dusty inclusions, and in some specimens the plagioclase is slightly zoned. A few plagioclase grains exhibit incipient saussuritization, but most are clear and fresh.

Table I

Modal Compositions of Quartzo-Feldspathic Gneisses

(Volume per cent, based on 800 points for each specimen)

Mineral	DF58-1A	DF58-17A	DF58-58A	DF58-65A	DF58-73A
Quartz	28.2	24.8	34.2	43.2	24.2
Plagioclase	59.7	52.5	38.8	32.5	64.5
Biotite	8.1	13.2	15.3	13.4	5.7
Muscovite	*	*	9.0	1.8	2.1
Chlorite	—	—	—	1.2	—
Hornblende	—	3.2	—	*	—
Epidote	3.0	3.8	2.3	6.7	2.9
Sphene	0.6	1.5	0.4	*	0.6
Apatite	0.4	1.0	—	—	—
Calcite	—	—	0.3	1.2	—
Iron oxides	*	—	*	—	—
Pyrite	*	—	*	—	—

*Less than 0.2 per cent

The largest quartz grains are 3 mm in diameter; the average size is 0.5 mm. Undulatory extinction is common, and many of the larger grains are extensively fractured. Most grain boundaries are smooth, but some interfaces between quartz and 001 terminations of twinned plagioclases are sutured. Small ovoid patches of unstrained quartz sieve some of the larger plagioclase grains.

Biotite occurs as fresh euhedral to subhedral laths with pleochroic formula: X = pale yellow, Y = greenish yellow, Z = deep olive-brown. Dark pleochroic haloes envelop tiny inclusions of allanite and zircon in the biotite. Epidote occurs as euhedral prisms as much as 2 mm long, but smaller anhedral grains are more abundant. Some epidotes enclose rounded cores of orange coloured allanite, which are not in crystallographic continuity with the rims. Sphene forms clusters, less than 1 mm in diameter, which in most places are intergrown with segregations of biotite and epidote. Blue-green hornblende, apatite, zircon, and muscovite are minor accessories. In a few outcrops, euhedral red garnets, as much as 1 cm in diameter, occur in thin layers parallel to foliation of the gneiss. In some of these zones, the garnets are marginally altered to chlorite, indicating retrogressive metamorphism. Large cordierite grains showing ragged margins were observed in one thin section, and apatite, zircon, magnetite, ilmenite, and pyrite are commonly present.

Prominent strain features of the quartz and plagioclase indicate that the gneisses were subjected to extensive cataclasis. Biotite and epidote, however, show no evidence of mechanical deformation, although they mark the gneissic foliation. These minerals probably attained their present size after the deformation, growing from seed crystals that were distributed along shear planes during deformation. The rounded boundaries of allanite within many of the euhedral epidotes may well mark the cessation of cataclastic action for this particular mineral.

In Table II the chemical composition of a leucocratic gneiss sample is compared with the composition of Nockolds' average muscovite-biotite tonalite and Pettijohn's average greywacke. The gneiss sample differs from the tonalite in having lower alumina and higher magnesia contents, but closely resembles the tonalite in the content of other

Table II

Chemical Composition of a Leucocratic Gneiss Sample

	A	B	C
SiO_2	71.7	70.63	64.7
TiO_2	0.1	0.37	0.5
Al_2O_3	14.1	15.69	14.8
Fe_2O_3	0.3	0.86	1.5
FeO	1.46	1.40	3.9
MnO	0.0	0.04	0.1
MgO	2.0	0.83	2.2
CaO	2.5	2.82	3.1
Na_2O	4.6	4.91	3.1
K_2O	1.0	1.68	1.9
H_2O	0.66	0.62	3.1
P_2O_5	0.0	0.15	0.2
CO_2	0.32	—	1.3
Total	98.7	100.00	100.4

A. Composite sample, leucocratic gneiss (58-65A)
Analyst: G. Bender, Geol. Surv., Canada
B. Average of 9 muscovite-biotite tonalites (Nockolds, 1954, p. 1015)
C. Average of 23 greywackes (Pettijohn, 1957, p. 307)

oxides. The sample differs most from the greywacke in having a high silica content and very low iron content. The parent rock of the gneiss could therefore have been a magnesium-rich quartz diorite or an iron-poor and silica-rich greywacke. If metasomatism accompanied metamorphism, other rock types could have formed the gneiss.

Mesocratic, medium- to coarse-grained, massive and poorly foliated biotite diorites form pod-like bodies within the quartzo-feldspathic gneisses. Because they are conformable with the enclosing gneiss, exhibit porphyroblastic textures, and show no intrusive relationship to the quartzo-feldspathic gneisses, they are interpreted as local facies of the metamorphic complex. The plagioclase of these rocks has the same range of anorthite content as the plagioclase of the associated leucocratic gneisses. Biotite, the next most abundant mineral (58-20A, Table III), is strongly pleochroic (X = pale yellow, Y = sepia, Z = greenish brown). Small, ragged flakes of biotite form patches at the margins of the large, equant, plagioclase grains. Both plagioclase and biotite commonly exhibit undulatory extinction, but a recrystallized, unstrained generation of biotite is present in some of the biotite diorites. Apatite and magnetite are abundant, and small, sieved, blue-green hornblende needles are present in some specimens.

Table III

Modal Compositions of Some Mafic Rocks Associated with the Quartzo-Feldspathic Gneisses

(Volume per cent, based on 800 points for each specimen)

Mineral	58-2A	58-20A	58-77A
Quartz	17.4	5.3	8.9
Plagioclase	16.9	58.1	20.5
Hornblende	54.4	0.5	26.8
Biotite	2.9	25.3	38.6
Chlorite	2.8	*	4.3
Clinozoisite	0.4	—	0.5
Sphene	0.3	*	*
Iron oxides	—	6.3	—
Pyrite	0.8	0.6	0.4
Apatite	*	3.8	*

* Less than 0.2 per cent

58-2A Hornblende-rich gneiss, which is interlayered with quartzo-feldspathic gneiss (Sp. 58-1A, Table I)

58-20A Biotite diorite from a large massive body enclosed by leucocratic gneiss

58-77A Plagioclase-hornblende-biotite gneiss

Concordant tabular layers, angular inclusions, lenticular schlieren, and irregular pods of mesocratic to melanocratic, fine- to medium-grained plagioclase-quartz-hornblende gneiss and plagioclase-hornblende-biotite gneiss compose more than 15 per cent of the gneissic complex. Some mafic layers are as much as 20 feet thick, but most are only a few inches thick, intercalated with the quartzo-feldspathic gneisses on a scale sufficiently small to give the appearance of a migmatite. Elongate mafic inclusions are commonly aligned parallel to, but with internal foliation athwart foliation of the enclosing leucocratic gneiss, suggesting origin by mechanical disruption of the tabular layers. The lenticular schlieren and irregular pods, in turn, appear to represent further stages of deformation with marginal replacement giving rise to nebulous outlines. Foliation in many of the mafic lenses passes into the adjoining quartzo-feldspathic rock, substantiating replacement.

The hornblende-rich rocks exhibit lepidoblastic textures and contain abundant hornblende, plagioclase, and quartz (58-2A, Table III). The plagioclase-hornblende-biotite gneisses also are lepidoblastic and are composed mostly of strongly pleochroic yellowish brown biotite, blue-green hornblende, and fresh plagioclase (An_{32-34}). The modal composition of a typical specimen (58-77A) is shown in Table III.

Amphibolite

The amphibolites are fine- to medium-grained, well-foliated, greenish grey to black rocks and exhibit an excellent lineation in the foliation. The foliation consists of alternate feldspathic and hornblendic layers 0.5 to 2 mm thick, and the lineation is defined by subparallel hornblende prisms. All specimens examined in thin section have excellent lepidoblastic textures. Modal compositions of three typical amphibolites are shown in Table IV.

Table IV

Modal Compositions of Three Amphibolites

(Volume per cent, based on 800 points for each specimen)

Mineral	58-78A	58-80A	58-82A
Quartz	3.1	—	—
Plagioclase	24.2	18.9	16.1
Hornblende	61.5	66.3	70.9
Augite	8.3	7.7	1.8
Clinozoisite	0.8	6.5	10.3
Sphene	2.1	0.4	0.9
Pyrite	*	0.2	*
Apatite	*	*	—

*Less than 0.2 per cent

Moderately pleochroic hornblende (X = neutral, Y = greenish yellow, Z = green), occurring as acicular prisms 0.5 to 1 cm long, is the most abundant mineral. The plagioclase (An_{36-42}) is xenoblastic, fresh, and commonly exhibits sharply defined albite and pericline twinning. Prisms of colourless clinozoisite are very abundant and granular sphene is invariably present. Most specimens contain a colourless, non-pleochroic clinopyroxene showing the prominent (100) parting characteristic of augite. It is fresh and poikiloblastic, suggesting growth during metamorphism. Magnetite, pyrite, apatite, and quartz are accessory minerals.

The chemical composition of a representative amphibolite sample and Nockolds' average pyroxene gabbro are compared in Table V. The amphibolite sample contains more lime and magnesia and less silica, soda, titania, and alumina, but a slight difference in composition of original pyroxene could account for these differences. None of the common sedimentary rocks compositionally resemble the amphibolite sample. The amphibolites were therefore probably derived from sills or flows of gabbroic composition.

Table V

Chemical Composition of an Amphibolite Sample

	A	B
SiO_2	48.1	50.78
TiO_2	0.6	1.13
Al_2O_3	12.6	15.68
Fe_2O_3	1.9	2.26
FeO	7.15	7.41
MnO	0.1	0.18
MgO	10.7	8.35
CaO	14.7	10.85
Na_2O	1.2	2.14
K_2O	0.2	0.56
H_2O	1.22	0.48
P_2O_5	0.0	0.18
CO_2	0.06	—
Total	98.5	100.00

A. Composite amphibolite sample (58-82A)
Analyst: G. Bender, Geol. Surv., Canada
B. Average of 38 pyroxene gabbros (Nockolds, 1954, p. 1020)

Knob Lake Group

Harrison (1952) compiled the type section of the Knob Lake Group on the basis of detailed study at Knob Lake, 35 miles west of Marion Lake. In Table VI the type section is compared with the section exposed in Marion Lake map-area. The Sokoman, Ruth, and Fleming Formations are missing in the Marion Lake area, and a formation, not present in the type section, has been mapped.

Ferruginous slates, which outcrop on the north shore of Marion Lake, possibly are equivalent to the Sokoman and Ruth Formations. However, because no breaks in the record of sedimentation were noted in the field, the rocks are here included in the Menihek Formation. The Fleming Formation may be absent in the map-area because of erosion or local non-deposition; Harrison (1952, p. 9) noted that the Fleming Formation in the Knob Lake area is thin and discontinuous. Chert fragments, which are abundant in the Wishart Formation of the Marion Lake area, may have been derived from the Fleming. It is also possible that units here mapped as lower Wishart are actually correlative with the Fleming Formation.

A sequence of sedimentary rocks, herein named the Marion Lake Formation, occurs between the Attikamagen and Denault Formations in Marion Lake map-area. Because the lithology of the Marion Lake Formation is similar to that of the Wishart, rocks mapped as Wishart Formation in more structurally complex areas may actually be equivalents of the Marion Lake Formation.

Volcanic rocks are interlayered with formations of the Knob Lake Group in some parts of the Labrador Trough, particularly in the eastern half. In Marion Lake map-area, one thick sequence of such flows occurs between the Marion Lake and Denault Formations.

Table VI

Stratigraphy of the Knob Lake Group

TYPE SECTION[1]		MARION LAKE[2]	
Formation	Lithology	Formation	Lithology
Menihek	Grey to black slate	Menihek	Grey to black slate Rusty weathering slate Black slate
Sokoman	Iron formation with slaty members		
Ruth	Black slate		
Wishart	Quartzite, arkose	Wishart	Quartzite Chert conglomerate
Fleming	Massive chert, chert breccia, chert conglomerate, quartzite	(+Fleming?)	Cherty siltstone, quartzite
Denault	Buff- to grey-weathering dolomite	Denault	Buff- to grey-weathering dolomite
			Meta-basalt
		Marion Lake	Pink to white quartzite Grey, green, and buff siltstone Conglomerate
Attikamagen	Black, green, and grey slates; minor granular chert	Attikamagen	Black to grey slate and phyllite; minor siliceous argillite

[1]Modified from Harrison, 1952 [2]This report

Attikamagen Formation

This formation is represented by widely scattered outcrops south and southeast of Marion Lake. The base of the formation is not exposed in the area, but steep dips and areal extent indicate a possible thickness of more than 5,000 feet. Attitudes of the strata are not consistent, however, and reversals in dip have been observed in outcrops less than 100 feet apart. This strongly suggests that the thickness of the formation has been exaggerated by structural repetition.

Description

Finely laminated, exceptionally fissile, rusty weathering, grey to black slates and silvery grey phyllites are the dominant rocks; a few interbeds of light grey to bluish grey siliceous argillite are exposed in the upper part of the formation.

Grain size for most Attikamagen rocks ranges from 0.005 to 0.1 mm. Bedding in the slates consists of alternate quartz-rich and mica-rich laminations, commonly less than 0.5 mm thick, which form tabular units of relatively uniform thickness. Micaceous layers of the slates are finer grained and more carbonaceous than the siliceous layers, and small-scale crossbedding can commonly be seen in the silty layers. Primary lamination and structure of the phyllites are obscured by cleavage.

Some minerals in the phyllites can be identified by petrographic methods, but accurate modal analyses cannot be obtained because of the fineness of grain. The average mineral composition of an Attikamagen phyllite, based on estimates for several thin sections, is 50 per cent quartz, 25 per cent chlorite, 15 per cent muscovite, and 10 per cent albite. In some phyllites, biotite takes the place of muscovite and chlorite. Because the black slates are extremely fine grained and commonly clouded with carbon, the mineralogy of several representative samples was determined by X-ray diffraction. The results indicated a mineralogy identical to that of the phyllites, with the minerals present in the same order of relative abundance.

In Table VII the chemical composition of a representative slate sample from the Marion Lake area is compared with the compositions of two Attikamagen samples from the type area (Gross, 1951, p. 51).

Table VII

Chemical Compositions of Attikamagen Samples

	58-93A	L2	L3
SiO_2	68.5	64.43	68.72
TiO_2	0.4	0.66	0.53
Al_2O_3	14.3	18.39	14.69
Fe_2O_3	0.7	2.71	2.83
FeO	5.91	2.56	1.67
MnO	—	—	—
MgO	2.1	1.69	1.40
CaO	0.2	—	—
Na_2O	1.5	0.80	2.02
K_2O	1.5	4.92	4.35
H_2O+	3.38	3.75	3.58
H_2O-		0.24	0.42
P_2O_5	—	0.03	T
CO_2	—	—	—
SO_3			
C	1.46	—	—
Total	99.9	100.18	100.21

58-93A Black slate, Attikamagen Formation, Marion Lake map-area
Analyst: K. Hoops, Geol. Surv., Canada

L2, L3 Slate, Attikamagen Formation, Knob Lake area
Analyst: W. H. Herdsman, Glasgow

The three samples have notably high silica and low lime contents, and in contrast to normal pelitic rocks, contain no carbonate minerals (indicated by the lack of CO_2). The sample from Marion Lake map-area differs from the other two in having a lower potash content, a higher magnesia content, a much higher ferrous to ferric iron ratio, and a significant carbon content.

Origin and Depositional Environment

Absence of coarse clastic sediments in the Attikamagen Formation suggests deposition far from shore, but may also be explained by near-shore sedimentation adjacent to a low-lying landmass. The delicate lamination indicates relatively quiet water deposition, but common occurrence of crossbedding demonstrates at least intermittent current or wave action, suggesting that depth of water was not great. Carbon in the Attikamagen Formation suggests contribution of organic material, but because fossils are absent, the source of carbon is unknown. Excellent preservation of lamination indicates the absence of bottom-dwelling organisms, and probably, therefore, pelagic organisms were the contributing life forms. The lack of carbon in the two samples from the Knob Lake area may reflect unequal density of biota within the basin, but could also be the result of local variations in oxidation potential.

Marion Lake Formation

The name Marion Lake Formation is here proposed for the sequence of sandstones, siltstones, slates, and conglomerates that overlies the Attikamagen. The formation comprises three layers of sedimentary rock, now separated by basic sills. These layers are assumed to have been contiguous prior to intrusion. On the basis of lithology, the formation is divided into eight units (*see* Table VIII). Because the base of the lowest unit lies beneath the southwest arm of Marion Lake, the nature of the contact with the

Table VIII
Stratigraphy of the Marion Lake Formation

Unit	Lithology	Approximate Thickness (feet)
8	Rhythmically bedded, buff, pale green, and dove grey siltstone; lenses of conglomerate and sandstone	600
	— Basic sill —	
7	Rhythmically bedded, pale green and buff siltstone	1,000
6	Massive, crossbedded, cream, pink, and pale green sandstone	200
5	Intercalated rusty- to grey-weathering dark slate, and grey, very fine grained sandstone with small-scale crossbedding	600
4	Pale green to buff rhythmically bedded siltstone	100
3	Massive pink sandstone	100
	— Basic sill —	
2	Rhythmically bedded, grey and white siltstone; laminated pink siltstone	1,200
1	Crossbedded pink sandstone; massive, pale yellow sandstone; interbedded conglomerate	200
	Total	4,000

Attikamagen Formation is unknown. However, chert, slate, and quartzite pebbles in conglomerate beds near the base of the Marion Lake Formation suggest an unconformity.

Siltstones make up about 70 per cent of the Marion Lake Formation (Table VIII, units 2, 4, 7, and 8), sandstones less than 30 per cent (Table VIII, units 1, 3, 5, and 6), conglomerates about 1 per cent (30 feet of unit 1; 10 feet of unit 8), and black slates less than 1 per cent (interbeds in units 5 and 8).

Siltstone

Description

Rhythmically bedded siltstones compose approximately 70 per cent of the Marion Lake Formation. The rhythmic sedimentation unit, or couplet, consists of a basal silt-rich siliceous layer and an upper micaceous layer in which clay-size particles predominate. Boundaries between couplets are sharp, but contacts between the coarse-grained siliceous and fine-grained micaceous layers of individual couplets are generally gradational. The gradation in size and composition commonly cannot be seen on fresh or weathered surfaces of hand specimens, but is easily recognized in thin section and on polished surfaces cut perpendicular to the bedding. In the upper part of unit 2, however, where the silty layers have weathered cream to white and the finer grained layers have weathered drab greenish grey to black, the grading is prominent (Pl. II A).

The silt-rich layers are 0.5 to 10 cm thick and all clay-rich layers are less than 1 cm. Variations in the thicknesses of 42 successive couplets are illustrated in Figure 1A. The total thicknesses of these beds were grouped in classes, and the cumulated frequencies in each class were plotted on logarithmic probability paper. The distribution is log normal (Fig. 1B).

Most of the graded beds are finely laminated (Pl. II B). The laminations, which are tabular and less than 1 mm thick, are commonly parallel to the boundaries of the bed in which they occur, but in some silty layers, they form planar cross-stratified units. Many laminations are graded in the same way as are the beds in which they occur.

The largest quartz grains, which occur at the base of the beds, have maximum diameters of 0.05 to 0.3 mm, but the average grain size is less than 0.05 mm. Grain size diminishes towards the tops of the beds; few grains in the upper layers exceed 0.01 mm in diameter. The quartz grains are equant and subangular to angular, and most of them are slightly strained. Fresh, sharply twinned albite is present in all the siltstones, and occurs in grains of the same shape and size as the quartz. Detrital outlines are visible in some larger quartz and plagioclase grains.

The micaceous minerals, muscovite and chlorite, are interstitial to the quartz and albite in the coarse-grained layers and are the predominant minerals in the fine-grained layers. A few flakes of muscovite are probably detrital, because they show a size gradation corresponding to the size gradation of silt particles. However, most of the muscovite and chlorite does not show this variation, and probably developed by recrystallization of clay minerals.

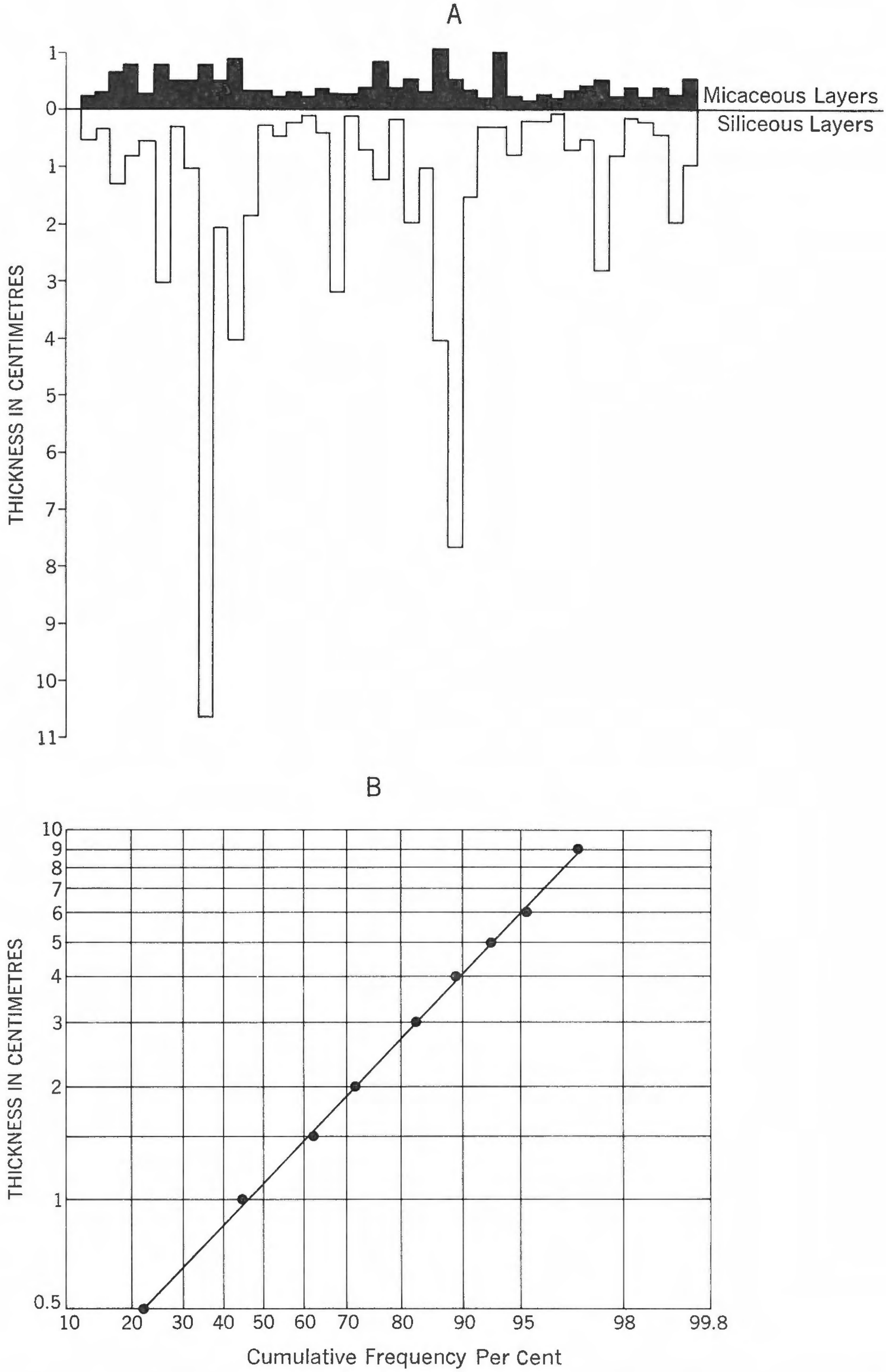

FIGURE 1. **Thickness data for graded beds in unit 2 of Marion Lake Formation. A, Thicknesses of the siliceous and micaceous layers of 42 bipartite beds. Oldest couplet to the left. B, Cumulative frequency distribution of the 42 total thicknesses on a logarithmic probability chart.**

Limonite is common in the siltstones as patches, up to 1 mm in diameter, dispersed through the silty layers, and as surface stains along fractures and cleavage surfaces. The limonitic patches apparently represent weathered pyrite grains, because pyritic cores are present in some of the patches, and euhedral pyrite of probable authigenic origin is present in unweathered specimens of the siltstones. Detrital zircons, less than 0.1 mm in diameter, were seen in all thin sections of siltstones, and slender euhedral rods of pleochroic bluish green tourmaline, as much as 0.2 mm long, are abundant in some specimens. The subhedral tourmaline is clearly a product of in situ growth, possibly through authigenesis, pneumatolysis, or metamorphism, but some crystals have rounded detrital cores. Carbon is disseminated through the dark, fine-grained layers of the unit 2 siltstones, and apatite, magnetite, and epidote are visible in some thin sections of the siltstones.

Modal compositions of silt-rich layers in the rhythmically bedded siltstones are shown in Table IX, and the chemical composition of a representative siltstone sample is shown in Table X.

Table IX

Modal Compositions of the Silt-rich Layers of Six Marion Lake Siltstones
(Modal analyses based on 600 Counts)

Specimen No.	Unit	Quartz	Plagioclase	Muscovite	Chlorite	Carbonate	Opaques	Zircon	Tourmaline
57-131A	2	34	27	30	6	*	3	*	*
57-134A	2	45	23	12	16	—	4	*	*
57-50A	4	37	15	36	9	—	2	*	*
57-50C	4	38	17	32	10	*	3	*	0.6
57-53A	7	48	12	24	14	—	2	*	1.8
57-147A	8	41	22	23	11	2	1	*	*

*Less than 0.5 per cent

Table X

Chemical Composition of a Rhythmically Bedded Siltstone[1]
from the Marion Lake Formation

SiO_2	61.7	CaO	0.2
TiO_2	0.7	Na_2O	2.7
Al_2O_3	19.7	K_2O	4.1
Fe_2O_3	1.7	H_2O	2.89
FeO	2.80	P_2O_5	0.0
MnO	0.0	CO_2	0.04
MgO	2.0		
		Total	98.5

[1]Sample 57-131A

Analyst: K. Hoops, Geol. Surv., Canada

Origin and Depositional Environment

The common occurrence of crossbedding in the Marion Lake siltstones is indicative of some current action, but the excellent preservation of delicate laminations and graded bedding precludes the possibility of deposition above wave base. The environment of deposition must therefore have been one of relatively tranquil water. However, the siltstones are interbedded with sandstones and conglomerates, which apparently were deposited in shallow water and subaerial environments. Deposition of the siltstones at great depth is therefore unlikely, as this would necessitate extensive upwarping and downwarping during a geologically short period. Deposition immediately below wave base is postulated for the Marion Lake siltstones, as this would require the least tectonic activity at the site of deposition, or, in the case of eustatic change in sea-level, no tectonic activity.

Graded beds of the Marion Lake siltstones closely resemble varves of Pleistocene deposits, but do not show evidence of glacial origin such as rafted pebbles or association with tillites. However, response to the annual climatic cycle, not glaciation, is directly responsible for Pleistocene varves, and such response may well also account for size and compositional gradation in the siltstones. Abundance of micrograded laminations within the couplets precludes the possibility that the couplets record a single event as do graded beds of turbidites, but if climatic control is invoked, the couplets can be attributed to seasonal change, and the micrograded laminations to slight fluctuations in sedimentation, caused, perhaps, by storms.

Other rocks, many of Precambrian age, show marked similarity to varved Pleistocene deposits. Siltstones of the Abram Series (Pettijohn, 1936, p. 623), the "argillite facies" of the Mississagi Formation (Collins, 1925, p. 42), siltstones of the Halifax Formation (Belyea and Scott, 1935, pp. 225-239), and the Bothnian "varved schists" (Simonen and Kuovo, 1951) all closely resemble the Marion Lake siltstones in showing rhythmic graded bedding of approximately the same scale. They also exhibit similar mineralogy and grain size. The students of these rocks all advocate climatic seasonal variation as the factor essential in producing the rhythmic graded bedding.

Sandstone

Description

The sandstones of units 1, 3, and 6 are tough, massive, ridge-forming rocks, which are pink, tan, cream, or pale yellow on fresh and weathered surfaces. Bedding, where visible, is marked by streaks of iron oxide and heavy minerals, and ranges from 1 to 5 mm in thickness. Tabular units showing planar cross-lamination occur in a few outcrops of unit 1; more abundant, however, is cross-lamination of the festoon type, forming wedge-shaped, crossbedded units, 3 to 8 inches thick and 1 foot to 3 feet long. Inclinations of both types of crossbedding range from 10 to 27 degrees. The attitudes of fourteen planar crossbeds were measured in sandstone outcrops along the west shore of Marion Lake, and the attitudes of ten crossbeds were also measured in outcrops of Wishart sandstone at Squaw Lake, 40 miles west of the map-area. Both sets of data, corrected for bedding tilt by the stereonet method (Haff, 1938), indicate predominant sedimentary transport from the west. Most sandstone outcrops show thin, even, planar bedding, but associated with the normal bedding in many places are tabular units, 1 inch to 3 inches thick, that contain small, concave-upward, ripple-like structures. On outcrop surfaces these structures appear as symmetrical, curved traces with amplitudes less than 0.5 inch and wave-lengths of 1 inch to 3 inches, and they are commonly truncated, as a result of overlap, in a fashion suggesting scour and fill. Investigation of these structures in sections perpendicular to outcrop surfaces reveals that they are actually small-scale festoon cross-laminations, such as are described by Hamblin (1961).

Unit 5 consists of intercalated black slates and very fine grained, rusty weathering, light grey sandstones. The slate layers, which are 1 to 5 mm thick, alternate rhythmically with sandstone layers 1 to 4 cm thick. Many sandstone layers are crossbedded and tend to pinch and swell laterally. Contacts between the sandstone and slate beds are sharp; gradation in composition or grain size from bottom to top of individual beds is notably absent.

The sandstones contain 46 to 92 per cent quartz, most of which occurs as grains showing clastic boundaries. The grains are subangular to well rounded, highly spherical, and only a few have overgrowth rims. Most of the quartz is strained, but few grains are fractured. Clear, sharply twinned detrital plagioclase (mostly oligoclase) is abundant, together with small amounts of untwinned albite, and most specimens contain a few grains of fresh microcline. The feldspars have the same roundness, sphericity, and size distribution as the quartz. Some quartz and feldspar grains are marginally replaced by fine-grained micas, and many have microstylolitic boundaries in common with adjacent grains (Pl. I A). Most sandstone specimens of the Marion Lake Formation contain a few rock fragments that are similar in size and shape to the quartz and feldspar grains. Chert is the most abundant rock fragment, but siltstone, quartzite, and slate are common. Size distributions for several sandstones (Fig. 2), calculated according to the method outlined in Appendix A, show modal size classes in the range of fine- to medium-grained sand, and indicate that the sandstones are well sorted.

The matrix consists mostly of intimately intergrown muscovite, chert, and in places, chalcedony. Biotite and chlorite are less abundant matrix minerals. Detrital tourmaline and zircon, in grains less than 0.1 mm in diameter, are common accessory minerals. The tourmaline and zircon grains are well rounded and commonly exhibit euhedral overgrowths. Opaque minerals include magnetite, ilmenite, leucoxene, hematite, and pyrite. The pyrite is probably authigenic, because it occurs as euhedral grains, and is not concentrated along the bedding.

Modal compositions of five sandstone specimens are shown in Table XI. According to Pettijohn's classification (1957, p. 291), the predominant rock types are feldspathic sandstones, but one specimen, representative of unit 6, is an orthoquartzite. The chemical composition of a sample representative of the orthoquartzite is shown in Table XII.

Table XI

Modal Compositions of Five Marion Lake Sandstones

(Volume per cent, based on 800 points for each specimen)

Specimen No.	Unit	Quartz	Plagioclase	Microcline, Orthoclase	Rock Fragments	Muscovite	Biotite Chlorite	Opaques	Zircon	Tourmaline	Silica Cement	Average Roundness	Average Sphericity	Median Diameter, mm	S_0, Sorting Coefficient	Classification (Pettijohn, 1957)
57-51A	6	91.3	*	—	—	7.7	1.0	*	*	—	*	0.9	0.8	0.58	1.28	Ortho-quartzite
57-130A	1	61.8	9.5	5.2	1.8	12.8	*	0.8	*	*	8.1	0.2	0.5	0.60	1.42	Subarkose
57-132A	1	71.0	16.0	*	1.7	8.0	*	0.8	*	*	2.5	0.6	0.7	0.32	1.38	Arkose
57-133A	1	62.5	12.3	*	*	13.1	*	0.9	0.3	0.7	10.2	0.3	0.4	0.22	1.35	Subarkose
57-50B	5	46.4	5.1	*	*	9.7	5.1	7.5	*	—	26.2	0.2	0.6	0.11	1.45	Subarkose

*Less than 0.2 per cent

Table XII

Chemical Composition of a Marion Lake Orthoquartzite[1]

SiO_2	95.4	CaO	0.0
TiO_2	0.0	Na_2O	0.1
Al_2O_3	2.9	K_2O	0.9
Fe_2O_3	0.2	H_2O	0.52
FeO	0.16	P_2O_5	0.0
MnO	0.0	CO_2	0.00
MgO	0.4		
		Total	100.6

[1]Sample 57-51A orthoquartzite, unit 6, Marion Lake Formation
Analyst: G. Bender, Geol. Surv., Canada

Origin and Depositional Environment

Size distributions of the well-sorted Marion Lake sands (Fig. 2) are similar to those of modern sands deposited in shallow water, fluviatile, and aeolian environments (Udden, 1914, p. 703 and pp. 714-719; Wentworth, 1932, pp. 36-75). The abundant festoon crossbeds are indicative of scour and fill action by shifting currents. Knight (1930) attributed the formation of festoon crossbedding in the Casper and Tensleep Formations, Wyoming, to "oscillating currents in comparatively shallow water", but McKee (1953, pp. 27, 31 and Fig. 22) has described festoon crossbedding in alluvial fans and aeolian sand dunes. Bagnold (1941, p. 201) and McKee (1953, p. 27) have noted that aeolian crossbeds commonly have inclinations ranging from 30 to 34 degrees. Inclinations of crossbeds measured in the Marion Lake sandstones are all less than 27 degrees, suggesting subaqueous deposition.

The sandstones in which thin planar laminations can be traced 100 feet or more closely resemble sand deposits of modern beaches, such as the California beach sands described by Thompson (1937, p. 727). The sandstone-slate interbeds of unit 5 are

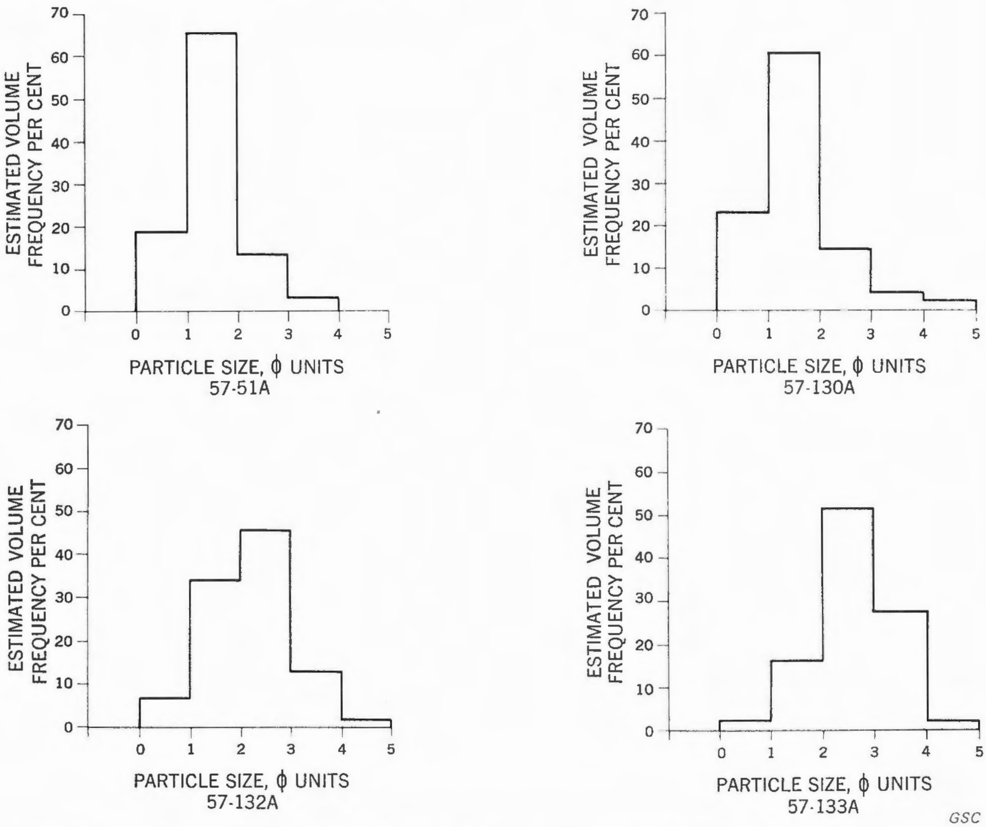

FIGURE 2. Size histograms for four Marion Lake sandstones, showing the estimated volume per cent distribution of detrital grains.

similar to sand-shale associations now being deposited on tidal flats of the Waaden Sea. The Waaden Sea sediments show the following features (Van Straaten, 1951): alternation of sand and clay layers; lack of graded bedding; abundance of crossbedding in the sandstone layers; lateral irregularity in thickness of individual beds; sands are very fine grained. The unit 5 rocks exhibit all these features, and the scale of the interbedding (beds less than 4 cm thick) approximates the scale of the tidal flat deposits.

As demonstrated by crossbed data, direction of sedimentary transport was from the west. The quartz- and feldspar-rich crystalline rocks that flank the west side of the Labrador Trough are probable source rocks, and probably uplift along the west side of the Trough initiated the periods of arkose deposition.

Conglomerate

Description

Layers and lenses of conglomerate, less than 15 feet thick, are conformably interbedded with sandstones in the lower parts of units 1 and 8. The conglomerates are grey-to-tan weathering, greenish grey to buff, massive and extremely well indurated rocks.

Pebbles and granules of quartzite, chert, and vein quartz compose 25 to 35 per cent of the conglomerates, and a few slate fragments are present in some specimens. Most of the siliceous rock fragments are well rounded and equidimensional, but the slate fragments have distorted lenticular shapes. Frameworks are disrupted; the rock fragments are enclosed by a matrix similar in composition to the associated arkosic sandstones.

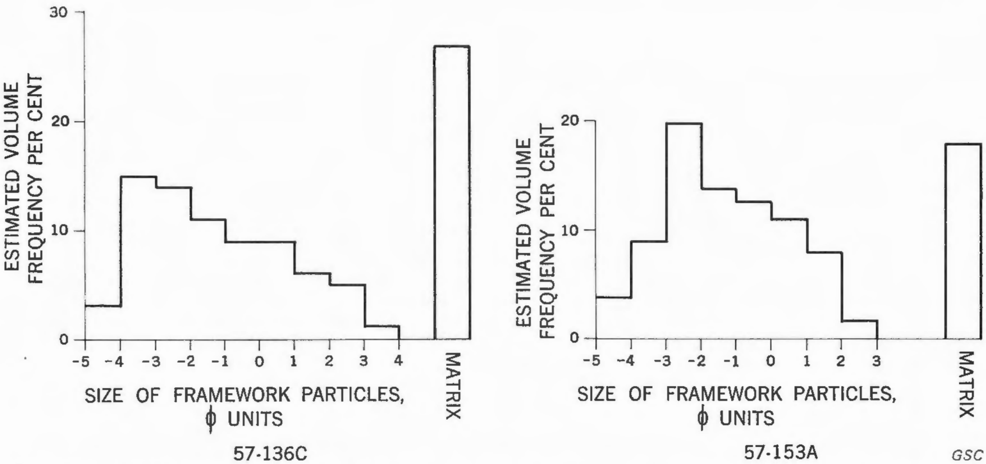

FIGURE 3. Size histograms for two Marion Lake conglomerates, showing the estimated volume per cent distribution.

Origin and Depositional Environment

Estimated size frequency distributions (Appendix A) for two Marion Lake conglomerates are shown in Figure 3. The distributions resemble those of modern alluvial gravels (Wentworth, 1932, pp. 32-37) and flood gravels (Krumbein, 1940). The poor sorting reflects a short history of transport. Some of the pebbles are well rounded, but studies of recent gravels (Plumley, 1948) have shown that pebbles become well rounded by stream transport within relatively short distances. Beach gravels are commonly well rounded, but, unlike the Marion Lake conglomerates, show good sorting. Glacial till is characterized by a wide range of size grades, but because the Marion Lake conglomerates form lenses and layers intercalated with well-sorted sandstones, glacial origin is unlikely. Lacking are cobbles, boulders, faceted and striated pebbles, glacial pavements, and other evidence of glacial origin. The conglomerates are perhaps best interpreted as rapidly deposited alluvial gravels that invaded the environment of sand deposition.

The Attikamagen Formation probably was the source of the chert and slate fragments in the conglomerates; basal quartzites and conglomerates of the Knob Lake Group (Wynne-Edwards, 1960) may have been the source of the quartzite pebbles. An unconformity at the base of the Marion Lake Formation is therefore possible, but cannot be verified because the contact is not exposed in the map-area. As some conglomerates occur in the upper part of the Marion Lake Formation, their source rocks must either have occupied an area of non-deposition during Marion Lake time, or have been re-exposed as a result of local uplift and erosion. A further possibility is that early cemented sands composing basal units of the Marion Lake Formation were reworked to yield intraformational conglomerate.

Volcanic Rocks

Description

Volcanic rocks within the Knob Lake Group in Marion Lake map-area comprise numerous, very fine grained, pale greenish grey, rusty-to-grey weathering flows. Pillows 1 foot to 5 feet long and rimmed by chloritic selvages 0.5 to 1 inch thick occur in about 20 per cent of the outcrops. Because many of the pillows are balloon-shaped, upper sides of flows can commonly be determined. Glacially polished surfaces show excellent pillow cross-sections, but in most outcrops, cross-sections suitable for top determinations are found only by extensive stripping of moss cover. All attitude determinations indicate conformability with the overlying and underlying sedimentary rocks. The upper parts of the steeply dipping flows weather deeply, forming valleys that appear as prominent lineaments on air photos. Parallelism of these lineaments indicates that the flows are fairly uniform in thickness, and although some flows are possibly as much as 600 feet thick, most are less than 100 feet.

Thin sections of these volcanic rocks show abundant acicular feldspar laths, as much as 1 mm long but less than 0.1 mm thick, randomly oriented in a very fine grained felted groundmass. Many feldspar laths are slightly curved, and terminations of the slender crystals commonly appear to be forked. Because such delicate feldspars would be best preserved in an originally glassy groundmass, the primary texture was probably intersertal or hyalopilitic.

Composition

Albite and clinozoisite replace original calcic feldspar, and chlorite, actinolite, and clinozoisite forming the fine-grained groundmass probably replace volcanic glass. Small amounts of sphene, magnetite, ilmenite, leucoxene, carbonate, quartz, and sulphide minerals are invariably present. Accurate modal analyses cannot be made because the matrix minerals are very fine grained and intimately intergrown. In Table XIII, the chemical composition of a representative sample is compared with the chemical compositions of typical basalts and andesites (Nockolds, 1954, pp. 1019-1020).

The volcanic sample from the Knob Lake Group has low potash and titania contents, as do most of the basalt types, and the silica content is similar to that of the normal tholeiite. However, in lime and soda contents, the sample closely approximates the tholeiitic (basaltic) andesite. The overall chemical composition suggests that the original lava was intermediate in composition between a tholeiitic basalt and basaltic andesite. Chemical composition may have changed somewhat as a result of metasomatism during metamorphism, but because of the close approach to basaltic composition, the most important change was probably addition of water.

Table XIII

Chemical Composition of a Volcanic Sample (Knob Lake Group) Compared with Average Chemical Compositions of Volcanic Rock Types

	1	2	3	4	5	6	7	8
SiO_2	49.6	50.83	47.90	45.78	43.69	51.33	51.43	47.63
TiO_2	1.0	2.03	1.65	2.63	2.12	1.10	2.60	2.84
Al_2O_3	15.7	14.07	11.84	14.64	9.06	18.04	13.05	14.57
Fe_2O_3	0.5	2.88	2.32	3.16	3.46	3.40	3.36	3.97
FeO	10.19	9.06	9.80	8.73	9.43	5.70	9.74	7.83
MnO	0.2	0.18	0.15	0.20	0.16	0.16	0.19	0.18
MgO	7.4	6.34	14.07	9.39	19.68	6.01	5.28	7.25
CaO	8.7	10.42	9.29	10.74	9.18	10.07	8.78	9.48
Na_2O	3.6	2.23	1.66	2.63	1.49	2.76	3.18	3.75
K_2O	0.1	0.82	0.54	0.95	0.69	0.82	1.04	1.20
H_2O	3.18	0.91	0.59	0.76	0.74	0.45	0.87	0.78
P_2O_5	0.0	0.23	0.19	0.39	0.30	0.16	0.48	0.52
CO_2	0.16							

1. Knob Lake volcanic sample, 57-27A. (Analyst: G. Bender, Geol. Surv., Canada)
2. Normal tholeiite (137)
3. Tholeiitic olivine basalt (28)
4. Alkali basalt (96)
5. Alkali-olivine basalt (31)
6. "Central" basalt (56)
7. Tholeiitic (basaltic) andesite (26)
8. Alkali andesite (37)

(2–8) Average compositions, based on number of analyses shown in parentheses; Nockolds, 1954.

Denault Formation

The well-exposed Denault Formation consists almost entirely of fine grained to very fine grained dolomite and siliceous dolomite. A thin layer of black slate, which outcrops at two places on the east shore of Keco Lake, possibly is the basal member of the formation. Sedimentary structures, abundant and amazingly well preserved in the dolomites and siliceous dolomites, can best be seen on weathered surfaces or polished surfaces etched by dilute hydrochloric acid. Specimens etch well, not because of the presence of calcite, but because of grain-size differences related to the structures.

Rock types recognized are finely laminated siliceous dolomite, massive dolomite, intraformational conglomerate, and stromatolitic dolomite. To determine their distribution and relative abundance, five sections were measured and studied in detail (Fig. 4). On the basis of the detailed work, the Denault is divided into nineteen lithological units, most of which are laterally persistent within the map-area. Section descriptions, accompanied by the measured thickness and percentage exposure of each unit, are tabulated in Appendix B, and the data are summarized in a stratigraphic cross-section (Fig. 4). The top of unit 17 is used as a horizontal datum, because this unit can be readily recognized in all the measured sections. The measured section data indicate the following distribution of lithologies:

Lithology	*Per cent*[1]
Finely laminated siliceous dolomite	30
Massive dolomite	20
Stromatolitic dolomite	45
Intraformational conglomerate	55

[1]Average for exposed rock in the 5 measured sections.

Finely Laminated Siliceous Dolomite

Description

These dolomites are characterized by tabular beds 0.5 to 10 mm thick. Fresh surfaces are cream to light grey, and weathered surfaces orange to yellowish brown. The siliceous dolomites are even textured, finely crystalline, and break with a smooth conchoidal fracture. Tabular laminations are readily apparent in outcrops, because selective weathering has produced prominent ribbed surfaces (Pl. III A). Thin sections and etched, honed surfaces show that many of the beds are graded, and that some of the thicker, silty beds are cross-stratified. The cross-stratified beds and basal parts of the graded beds contain as much as 50 per cent quartz grains 0.5 to 0.1 mm in diameter. Grain size and quartz content decrease gradually towards the tops of the graded beds; in the upper one third, the grains are less than 0.01 mm in diameter and the quartz content is less than 15 per cent.

The quartz grains are rounded to subangular, and some exhibit detrital outlines within overgrowth rims. Silt-sized grains of plagioclase, biotite, and muscovite can be seen in most thin sections, and zircon, tourmaline, pyrite, and leucoxene are common accessory minerals, which occur as detrital grains less than 0.01 mm in diameter. Traces of fine, yellowish brown iron oxides, probably derived from the dolomite as a result of weathering, are dispersed through most specimens. The dolomite is pale yellow to colourless, mostly untwinned, and occurs in subhedral, subspherical grains identical in size to the terrigenous silt with which it is associated. Grain gradation of the dolomite corresponds to grain gradation of the clearly detrital silicates, and is of the normal, waning current type.

Origin

Crossbedding and graded bedding indicate detrital origin for the finely laminated siliceous dolomites. Erosion of pre-existing formations could yield the fine terrigenous detritus, but because no older dolomites occur in either the Labrador Trough or the nearby basement, the fine-grained dolomite probably formed by direct precipitation. Erosion and comminution of the older Denault beds may have contributed sediment to unit 19 (Fig. 4), but such a process cannot be invoked for the lowermost beds of unit 1, which also are finely laminated. Probably much of the dolomite in laminated Denault beds represents precipitated muds which, because of some transport prior to deposition, have formed beds showing grain gradation and cross-stratification. Deposition in relatively quiet waters is suggested by fineness of grain and preservation of delicate lamination.

Massive Dolomite

Description

Tough, light grey to white, fine- to medium-grained massive dolomite composes about 20 per cent of the Denault Formation. It is dark weathering, and breaks with an irregular fracture. Joints are prominent, and indistinct widely spaced stratification can be seen in some outcrops (Pl. III B).

The massive dolomite contains less than 10 per cent quartz and only traces of other silicate minerals. Most of the quartz occurs as scattered anhedral grains less than 0.5 mm in diameter, but quartz grains, well rounded and as much as 1 mm in diameter, are dispersed through the upper part of unit 8 (Fig. 4). Most of the dolomite occurs as colourless anhedral grains, 0.2 to 1.5 mm in diameter, and although some grains show rounded outlines suggestive of clastic origin, most form a granoblastic mosaic in which the original nature of grain boundaries has been obscured by solution along microstylolitic seams. In some massive beds, sand-sized pellets composed of very fine grained dolomite are abundant. The pellets are ellipsoidal to subspherical, well rounded, and well sorted. Grain size of the dolomite cement is less than 0.2 mm and that of most pellets is less than 0.05 mm. Some pellets contain dolomite rhombohedra, as large as 0.5 mm in diameter, apparently formed at expense of the microcrystalline dolomite. All stages between pelletoid and granoblastic dolomite can be seen in thin section, suggesting that the granoblastic rocks are recrystallized dolomite sands. The control of recrystallization is not known, but abundance of microstylolites in the granoblastic dolomites shows that pressure and access of solutions probably were important factors.

Origin

The massive dolomites are interpreted as partly recrystallized dolomite arenites which, as suggested by good sorting of the detrital particles, were deposited in a turbulent, shallow water environment. Penecontemporaneous reworking of underlying beds, perhaps hardened by subaerial exposure, may have yielded the dolomite sands; at least some reworking is indicated by the association of intraformational conglomerates (discussed later) with the massive units. The dolomite sand grains could also have formed by aggregation and cementation of fine-grained muds, as have some modern carbonate sands in the Bahamas (Illing, 1954, p. 26). The sparse quartz sand grains probably were derived from a low-lying or distant landmass.

Stromatolitic Dolomite

Description

The term 'stromatolite' denotes a laminated structure that is believed to record algal activity (Kalkowsky, 1908, p. 68). Stromatolites are abundant in the Denault Formation, and Denault rocks are here described as 'stromatolitic dolomite' if such structures can be seen megascopically in more than 20 per cent of the rock.

Six different forms of stromatolites are recognized in the formation, and non-biologic names are used to identify the forms. Figure 5 illustrates the classification; less desirable generic names are in parentheses after the descriptive names. Justification for the purely descriptive classification is outlined by Donaldson (1960, pp. 41-42).

Data for measured sections (Appendix B) indicate that more than 45 per cent of the Denault Formation consists of stromatolitic dolomite. The distribution of the stromatolite types is as follows:

Type	Per Cent[1]
Columnar, hemispherical, and bulbous	10
Digitate	5
Undulatory	25
Pisolitic	5
Total	45

[1]Average for the five measured sections

Columnar stromatolites occur in five distinct zones; diameters of the columns range from 6 to 12 inches in three of the zones, and from 2 to 8 inches in the other two (Fig. 4). Axes of the columns are perpendicular to bedding, and adjacent columns are attached to the same bedding surface. Hemispherical and bulbous stromatolites commonly occur with the columnar stromatolites, and appear to represent early growth stages of the columnar type. The laminations, which range from 1 to 20 mm in thickness, are commonly continuous through several adjacent columns. The laminated structure is accentuated by alternation of dark grey to black layers and light grey to buff layers (Pl. IV A). Thin sections show that the dark layers are composed of anhedral grains of dolomite 0.001 to 0.01 mm in diameter. Coloration is due to less than 1 per cent amorphous carbon, dispersed through the layers as thin films between dolomite grain boundaries. Grain size in the light coloured layers ranges from 0.01 to 0.05 mm. Fragmental detritus and quartz silt are abundant in the carbon-poor layers but scarce in the carbonaceous layers. Some carbonaceous layers are sharply truncated (Pl. IV A), and the interspaces between columns commonly contain platy carbonaceous fragments that correspond in thickness, texture, and structure to the truncated layers.

Digitate stromatolites form beds less than 1 foot thick. In longitudinal section, these stromatolites appear as finger-like columns, 1 to 5 mm in diameter and less than 2 cm high (Pl. IV B). They exhibit domical, convex-upward laminations, 0.05 to 1.0 mm thick, marked by thin, crenulate films of carbon. In transverse section the carbonaceous films within individual columns show as somewhat irregular but concentric rings. The columns are separated by interspaces occupied by fine-grained carbonaceous dolomite, which, in places, exhibits a faint concave-upward lamination. Fragmental detritus and quartz silt are abundant in the interspaces but scarce in the columns. Grain size of dolomite in the stromatolites ranges from 0.001 to 0.05 mm and, in the interspaces, from 0.01 to 0.2 mm. Successive laminations in adjacent stromatolites show a definite correspondence in thickness (Pl. IV B). The stromatolites are locally closely packed, but in most places they compose less than half the bed in which they occur.

Pisolitic stromatolites, 5 to 15 mm in diameter, occur abundantly in 1- to 5-foot zones, which commonly are dark grey to black because of a carbon content of as much as 1 per cent. Carbonaceous pellets, mostly 1 to 10 mm in diameter, are invariably associated with the pisolites, and many of the pisolites contain one or more such pellets as a nucleus (Pl. IV C). Successive laminations composed of anhedral dolomite grains 0.001 to 0.02 mm in diameter, concentrically envelop the nucleus, and commonly are accentuated by carbon concentrated in thin films marking the laminations. The enveloping laminations are somewhat crenulate, and successive laminations are commonly eccentric. Outer sets of laminations truncate inner sets in many of the stromatolites. Few of the pisolites are spherical; ellipsoidal to irregular "flower-like" forms predominate

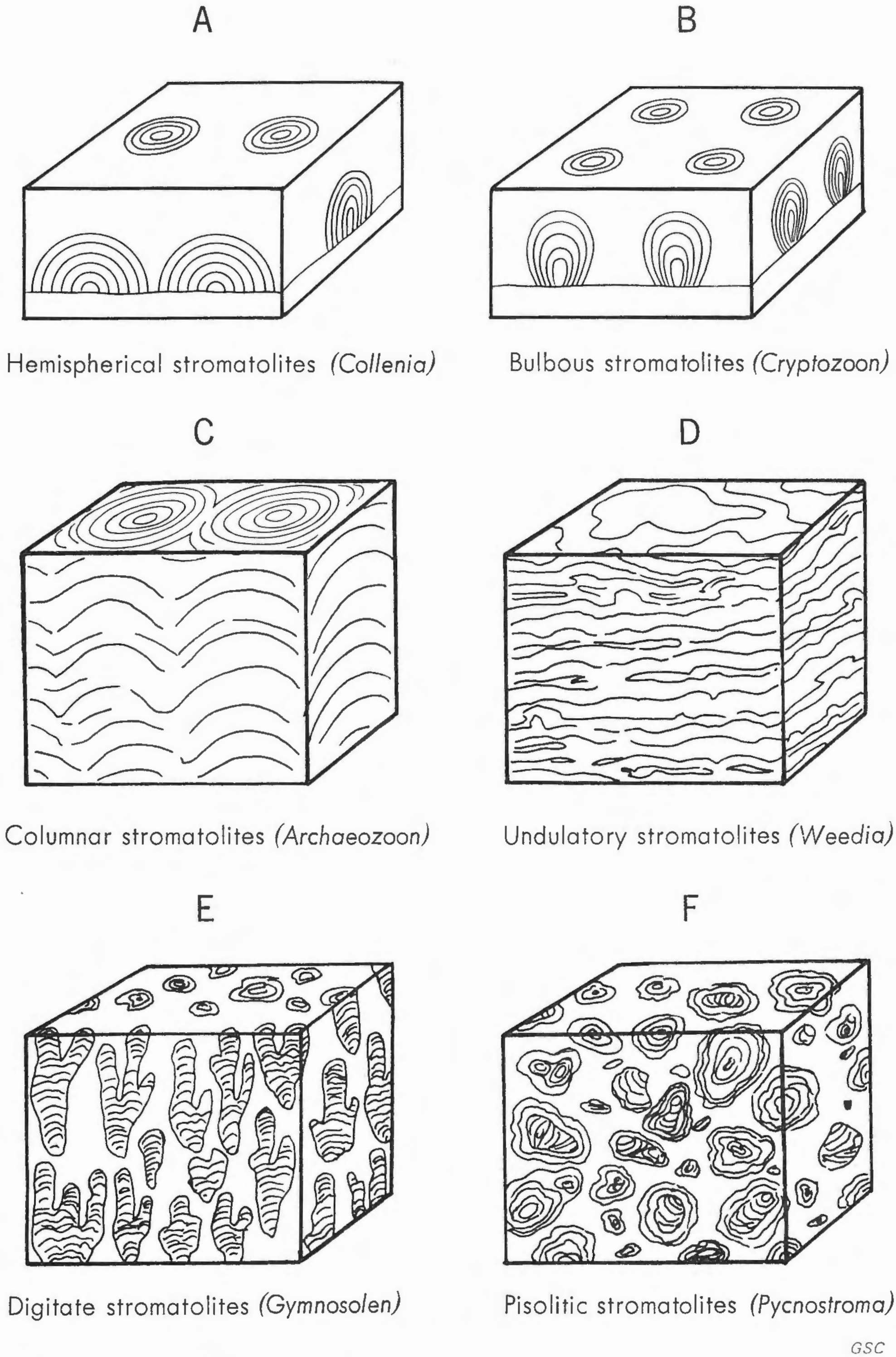

FIGURE 5. The six basic types of stromatolites in the Denault Formation.

(Pl. IV C). In some beds, carbonaceous pellets are more abundant than the pisolitic stromatolites, and fragmental pisolites are common.

Undulatory stromatolites are very abundant in the Denault Formation. They are recognized in the field by characteristic crinkly ribbed weathered surfaces (Pl. IV D). Little can be seen on fresh surfaces, but careful examination of weathered surfaces reveals the intricate structures that compose this type of stromatolitic dolomite, and polished surfaces show even more detail. Many of the undulatory layers, which occur 5 to 20 mm apart and are 1 to 10 mm thick, can be traced several yards, and although some are structureless, most exhibit crenulate lamination. The intervening spaces are commonly occupied by pisolites, pellets, fragments, and small columnar stromatolites.

Origin

Occurrence in stratigraphic zones and truncation of laminations evidence primary origin for the Denault stromatolites; organic origin is indicated by the regular and distinct forms as well as by the carbonaceous nature of the structures. The stromatolites are interpreted as algal structures on the basis of similarity to algal structures forming today.

Algae can contribute to carbonate deposition either by direct precipitation (Murray, 1895; Clarke, 1900; Roddy, 1915) or by trapping detrital carbonate swept in by currents (Black, 1933, p. 186; Ginsburg, 1958, p. 311). Common occurrence of carbonate detritus and quartz silt in laminations of the columnar and undulatory stromatolites supports a sediment-trap origin for these structures. The digitate and pisolitic stromatolites, however, are characterized by a paucity of detritus in the laminations, although detritus is abundant between 'fingers' of the digitate stromatolites and in the matrix associated with the pisolitic stromatolites. Further, both types are characterized by a delicate, crenulate lamination. The digitate and pisolitic stromatolites may well record precipitation of carbonate by algae.

Because algae that form discrete structures need light for photosynthesis, they seldom grow profusely at depths greater than 10 metres (Cloud, 1942, p. 371). Evidence of a shallow water environment for the Denault stromatolites includes association with intraformational conglomerates, truncation of laminations, and abundance of water-worn stromatolitic detritus.

Intraformational Conglomerate

Lithology

Beds of intraformational conglomerate, as much as 3 feet thick, compose about 5 per cent of the Denault Formation. According to Walcott (1894, p. 192), an intraformational conglomerate is "formed within a geologic formation of material derived from and deposited within that formation", and it is in this sense that the term is used here. Some Denault conglomerates separate individual beds of stromatolites or occur at the tops of the stromatolitic zones; others form beds a few feet thick in the massive units.

The intraformational conglomerates associated with the stromatolites consist of thin, curled, dark carbonaceous dolomite fragments, as much as 3 cm long, in a light coloured matrix of silt-sized dolomite grains (*see* top of photograph, Pl. IV B). The fragments are angular, and many have length to width ratios of more than 20:1. They are commonly laminated and, under the microscope, exhibit structure and texture identical to dark layers of the columnar stromatolites.

The intraformational conglomerates in the massive dolomites consist of poorly sorted, subangular to rounded dolomite fragments in a matrix of sandy or pelletoid dolomite. The fragments, which are as much as 5 cm long, range from subspherical to markedly tabular. Some of the flat pebbles have length to width ratios of more than 10:1, and, in places where such platy fragments are abundant, imbricate structure can commonly be seen. Most pebble-matrix contacts are sharp and regular, but irregular penetration of a few pebbles by matrix evidences some solution. Beds of the conglomerate are commonly less than 2 feet thick, but are laterally continuous for as much as several hundred feet. In thin section, the pebbles show the same texture as the massive dolomite with which they are associated. Pebbles, sand grains, and pellets are cemented mostly by very fine grained dolomite, but small patches of dolomite grains 0.1 to 0.5 mm in diameter are common.

Origin

The intraformational conglomerates are clearly of sedimentary rather than tectonic origin, because they are confined by stratigraphic boundaries, much of the matrix is sandy, and many of the fragments show water-wear. The conglomerates are evidently of local derivation, because phenoclasts in conglomerates associated with the massive dolomite are identical to the massive beds in composition and texture, and phenoclasts associated with the stromatolitic dolomite are carbonaceous and possess lamination identical to that of the stromatolites. Strong current or wave action is demonstrated by the edgewise arrangement of some of the conglomerates.

Flat pebble intraformational conglomerates are commonly assigned to mud-crack origin (Walcott, 1894; Field, 1916, p. 52). The writer favours the mud-crack origin for the Denault conglomerates in the massive dolomite because it offers a method of separating thin, flat slabs from an otherwise homogeneous deposit. For the conglomerates associated with stromatolites, however, primary structure of the columnar stromatolites may have been sufficient to control fragmentation of thin flat slabs, in which case the desiccation process need not be invoked. The structure, as visualized by comparison with modern algal forms, consisted of layers bound by algal filaments, alternated with layers relatively free of algal filaments. Subjected to strong wave action, the algae-reinforced layers yielded tough fragments more resistant to attrition than the intercalated layers of sediment. The occurrence of abruptly terminated carbonaceous layers in some of the stromatolites substantiates such origin.

Composition of the Denault Formation

The chemical and calculated mineralogical compositions of a laminated siliceous dolomite sample and a stromatolitic dolomite sample are shown in Table XIV. The laminated siliceous sample is representative of unit 1, the lowermost unit of the formation

(Fig. 4), and the stromatolitic sample represents a carbon-rich layer of a columnar stromatolite.

Table XIV

Chemical[1] and Calculated Mineralogical Compositions of Two Samples, Denault Formation

	5-0	1-3
SiO_2	28.1	0.5
TiO_2	0.1	0.0
Al_2O_3	4.0	0.4
Fe_2O_3	0.2	0.2
FeO	1.51	0.17
MnO	0.0	0.0
MgO	13.7	21.0
CaO	18.9	29.6
Na_2O	0.1	0.1
K_2O	1.6	0.1
H_2O	0.53	0.18
P_2O_5	0.0	0.0
CO_2	30.20	46.30
C	0.0	0.22
Total	98.9	98.8
Dolomite	64.0	98.6
Quartz	21.6	—
Muscovite	11.8	0.7
Albite	0.8	0.5
Limonite	1.6	—
Sphene	0.2	—
Carbon	—	0.2

5-0. Laminated siliceous dolomite

1-3. Stromatolitic dolomite

[1]Analyst: K. Hoops, Geol. Surv., Canada

According to the calculated mineralogical compositions, dolomite is the only carbonate mineral in the two samples, and X-ray diffraction of 20 samples representative of other units failed to detect calcite. Notable is the presence of carbon in the sample of stromatolitic dolomite, and the abundance of quartz and mica in the sample of laminated siliceous dolomite.

Carbon was separated from representative samples of the stromatolite types by digesting the samples in excess hydrochloric and hydrofluoric acids. X-ray diffraction of the residues thus obtained demonstrated the absence of crystalline structure, and the residues oxidized readily at approximately 600°C. These observations indicate amorphous carbon rather than graphite.

Origin and Depositional Environment

The composition of the Denault Formation introduces the perennial dolomite problem, which has been well outlined by Van Tuyl (1914) and recently reviewed by

Fairbridge (1957). The main theories of dolomite origin are:

1. Dolomitization of calcite or aragonite.
2. Primary precipitation of dolomite.

Van Tuyl (1914, p. 392) observed that dolomitization normally results in an increase of grain size, and Pettijohn (1957, p. 419) found that it also tends to destroy sedimentary textures and structures. In the Denault Formation, grain size less than 0.01 mm is common, and sedimentary textures and structures are remarkably well preserved. Coarse-grained dolomite does occur in the massive beds, but it has clearly formed by recrystallization of microcrystalline dolomite rather than by replacement of calcite or aragonite. Grain size, texture, and primary structure therefore lend support to primary deposition of the formation.

Precipitation of dolomite on the sea-floor is unknown today (Fairbridge, 1957, p. 126). However, Chilingar (1956, p. 2262) caused precipitation of dolomite from sea-water in the laboratory by saturating one litre sea-water with respect to $MgCO_3$ and $CaCO_3$ and subjecting it to a CO_2 pressure of four atmospheres for two weeks. This experiment lends support to Strakhov's contention (1953) that a high CO_2 pressure of the Precambrian atmosphere may have resulted in direct precipitation of dolomite throughout much of Precambrian time. Primary precipitation of dolomite in evaporitic basins has also been proposed (Twenhofel, 1932, p. 339; Andrichuk, 1955; Edie, 1956). According to Eardley (1938, p. 1338), a mineral similar to dolomite is now precipitating in Great Salt Lake, Utah, and Strakhov (1953, p. 19) reported primary dolomite in Lake Balkhash, Russia.

In the Denault Formation, calcite or aragonite may have precipitated initially, provided dolomitization took place prior to the fragmentation and redeposition that formed the clastic dolomites. The writer has noted, however, the possibility of carbonate precipitation by the digitate and pisolitic stromatolites. Chave (1954, p. 281) has shown that some types of algae precipitate calcite or aragonite containing as much as 30 per cent $MgCO_3$ in solid solution. Perhaps algae are capable of precipitating pure dolomite in an environment of increased CO_2 pressure, high salinity, or other special conditions.

The columnar and undulatory stromatolites are interpreted as sediment-binding algal structures. They are, however, commonly associated with the pisolitic and digitate stromatolites (*see* Fig. 4), and possibly the detritus for the binding algae was derived by fragmentation and comminution of dolomite precipitated by digitate and pisolitic stromatolites. Thus, nearly half the dolomite of the Denault Formation may have formed as a direct or indirect result of algal precipitation.

The fine-grained dolomite of the laminated and massive beds may also have been derived by comminution of structures formed by lime-precipitating algae, but because these lithologies are non-carbonaceous and do not contain any recognizable stromatolite detritus, origin by inorganic precipitation is more likely. Influx of terrigenous detritus occurred during precipitation of the finely laminated beds, and slight variations in current velocity are indicated by the common occurrence of graded bedding of the waning current type. The dolomite sands of the massive beds may have formed by erosion of partly lithified muds or by aggregation of dolomite detritus.

Dolomitic formations occupying stratigraphic positions similar to that of the Denault occur in many parts of the Labrador Trough. Roscoe (1957, p. 7) and Fahrig (1955, p. 5) reported stromatolitic dolomites, which probably correlate with the Denault Formation, more than 100 miles north of Marion Lake, and 150 miles south of Marion Lake, Duffell (1959) mapped a marble formation that is probably the metamorphosed equivalent of the Denault. The possible areal extent and great thickness of the Denault Formation strongly suggest marine rather than lacustrine environment of deposition. Thick, widespread formations composed dominantly of carbonate rocks are abundant only in marine sequences (Barrell, 1906, p. 567). Because the Denault is more than 3,000 feet thick, yet shows evidence of deposition in relatively shallow water, subsidence in pace with rate of sedimentation is inferred.

Silicification of the Denault Formation

Chert, chalcedony, and quartz are abundant in the Denault Formation, particularly in the massive units. The chert occurs as nodules, most of which have the shape of oblate spheroids, flattened parallel to bedding. Boundaries are sharp and smoothly curving, and cross-sectional outlines are strongly elliptical, with axial ratios as high as 5:1. Nodules as large as 10 inches in diameter are common, but most are less than 4 inches. Several zones of abundant nodules can be recognized in the measured sections (Fig. 4). Most of the nodules are white to grey, but in one zone (unit 6, Fig. 4) they are dark grey to black. Many of the nodules contain irregular remnant patches of dolomite, embayed by the chert, and some exhibit relic bedding continuous with that of the enclosing dolomite. The nodules are therefore interpreted as epigenetic replacement bodies. The nodules are commonly intersected by joints, which, as later noted, probably formed prior to folding. This, and the restriction of nodules to stratigraphic zones, strongly suggest diagenetic origin.

Biggs (1957), in considering origin of similar chert nodules, concluded that the silica composing the nodules was derived from the host rock. This source would be adequate in the Denault Formation, because all of the nodular zones contain abundant dispersed silica. However, the laminated dolomite, most siliceous of the rock types, contains very few nodules. Therefore, if the dolomites supplied the silica, the extent of nodule formation must have been controlled by factors other than the availability of dispersed silica.

The quartz and chalcedony form scattered lenticular pods, veinlets parallel to jointing, and irregular layers accentuating bedding and stromatolite lamination. Much of this silica must have been introduced into voids, because crystals commonly line the walls of the occupied spaces, and many of the chalcedonic pods exhibit colloform banding. In places the silica infillings truncate sedimentary structures, suggesting solution origin for the voids. Soft, unconsolidated carbonate muds and sands would be incapable of supporting a network of voids, and therefore the solution and silicification probably occurred after lithification. However, many joints are unoccupied, yet transect nodules, lenticular pods, and irregular layers, suggesting that silicification ceased before all joints had developed. The veinlets parallel to jointing commonly cut the layers parallel to bedding, showing that the bedding-controlled silicification preceded at least some of the jointing-controlled silicification.

Some stromatolite zones are extensively silicified. The columnar and undulatory stromatolites are particularly susceptible. Sedimentary origin for the silica was at first suspected, but the following lines of evidence indicate that post-sedimentary origin is more likely:

1. Some highly silicified stromatolites grade laterally to stromatolites showing little or no silicification.
2. Quartzitic laminations commonly merge with joint-controlled quartz veinlets.
3. Crystallographic c-axes of quartz crystals are normal to the walls of the layers.

Silica in the silicified stromatolite zones composes as much as 60 per cent of the stromatolites, but content of dispersed silica in non-silicified stromatolites in the same zones rarely exceeds 15 per cent. This clearly indicates introduction of the silica rather than segregation of silica in the stromatolites.

Wishart Formation

The Wishart Formation overlies the Denault Formation with slight erosional unconformity, as indicated by sharp contacts exposed in several outcrops on the south shore of Marion Lake. Three measured sections show that the formation is about 300 feet thick, and is composed of 45 per cent sandstone, 25 per cent ankeritic siltstone, 15 per cent siltstone, 10 per cent cherty siltstone, and 5 per cent conglomerate. Comparison of the generalized section for Marion Lake map-area (Table XV) with sections for the type area (Howell, 1954, p. 16), suggests that the lower five units may correlate with the Fleming Formation, but because the units were not differentiated at the scale of mapping, and because the correlation is not certain, all units are here grouped as Wishart.

Table XV

Generalized Section of the Wishart Formation

Unit	Approximate Thickness (feet)
Siltstone	10
Orthoquartzite	30
Siltstone	10
Ankeritic siltstone	30
Cherty siltstone	15
Lenses of ankeritic conglomerate	0-5
Upper chert pebble conglomerate	10-15
Cherty siltstone	15
Ankeritic siltstone	45
Orthoquartzite	100
Lower chert pebble conglomerate	0-10
Siltstone	20
Total	295-315

Sandstone

Description

The sandstones are tough, massive, medium-grained rocks, which are white or light grey on fresh and weathered surfaces. They are very well sorted, chert- and quartz-cemented orthoquartzites (Table XVI). Well-rounded, highly spherical quartz and chert grains are the only framework components (Pl. I B). Overgrowth rims in crystallographic continuity with the detrital quartz grains can be seen in some specimens, most grains show strong undulatory extinction, and many contain planes of tiny opaque inclusions. Because the traces of some inclusion planes extend across several adjacent grains, the inclusions must have originated, at least in part, during metamorphism of the Knob Lake Group. Chert is the cement in some of the sandstones, but most of the rocks are welded together by mutual interpenetrations of grain boundaries. Flakes of muscovite, less than 0.01 mm long, are concentrated along the finely sutured boundaries of most sand grains. Colourless zircon and greenish blue tourmaline are accessory minerals in the orthoquartzites. They occur as well-rounded detrital grains less than 0.1 mm in diameter. Magnetite, ilmenite, leucoxene, and limonite are the major opaque minerals.

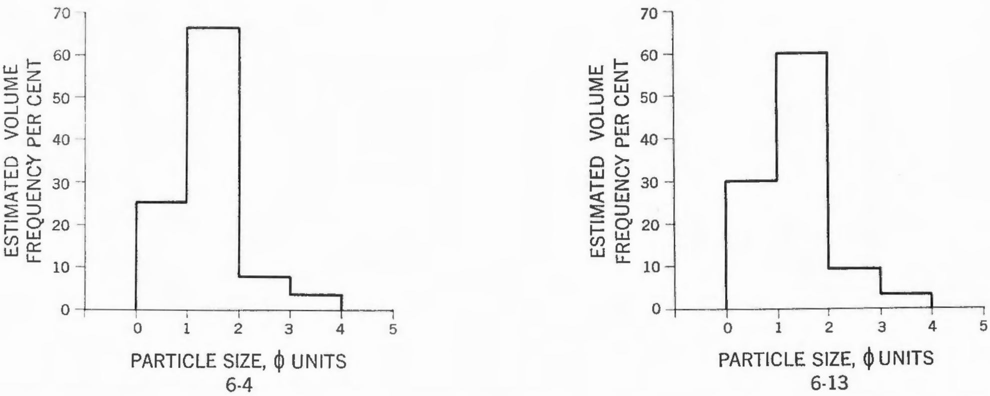

FIGURE 6. Size histograms for two Wishart sandstones, showing the estimated volume per cent distribution of detrital grains.

Size frequency distributions for two Wishart sandstones were calculated from thin section measurements (Appendix A); histograms of the distributions are shown in Figure 6. For both samples the mode is in the 0.25-0.5 mm class, and the size range is restricted to four classes. The distributions are skewed towards the coarser grades.

Origin and Depositional Environment

Sandstones of the Wishart Formation are mature orthoquartzites, which have probably passed through several cycles of sedimentation. The abundance of detrital chert is indicative of at least some reworking. Because wind is more effective than water in the rounding of sand grains (Twenhofel, 1945, p. 59; Kuenen, 1960, pp. 50-52), the Wishart sands may have undergone extensive wind transport prior to deposition.

Table XVI

Modal Compositions of Some Wishart Sandstones

(Volume per cent, based on 800 points for each specimen)

Specimen No.	Unit	Quartz Grains	Chert Grains	Chert Cement	Muscovite	Opaques	Tourmaline	Zircon	Average Roundness	Average Sphericity	Median Diameter	Sorting Coefficient S_0	Classification (Pettijohn, 1957)
58-6-3	3	90.5	—	2.0	2.9	4.6	*	*	0.7	0.8	0.67	1.32	Orthoquartzite
58-6-4	3	91.7	—	1.4	5.1	1.8	*	*	0.6	0.8	0.64	1.18	Orthoquartzite
58-6-16	13	85.2	2.7	10.7	*	1.4	*	*	0.9	0.9	0.62	1.15	Orthoquartzite

*Less than 0.2 per cent

Grains show rounding equal to rounding of the well-known St. Peter Sandstone, for which aeolian abrasion prior to deposition has been invoked by both Dake (1921, p. 223) and Thiel (1935, p. 612).

Excellent sorting of the Wishart sands strongly suggests deposition in a littoral or aeolian environment. Many modern aeolian and beach sands (Udden, 1914, pp. 703, 714-719) show similar distribution. The sands were probably derived from parts of the Marion Lake Formation that were exposed either by local upwarp and erosion or by virtue of non-deposition of volcanic rocks and Denault dolomite in the source area. Size distributions of the Marion Lake sandstones do not include larger size grades than those of the Wishart sandstones, and some samples of the Marion Lake sandstones are even finer grained than the Wishart samples. However, it is not unreasonable to postulate source rocks of Marion Lake age that were coarse-grained lateral equivalents of the Marion Lake sandstones exposed in the map-area. Wishart sands exhibiting the best rounding and sorting occur near the top of the formation, and possibly were derived by reworking of older Wishart units.

Conglomerate

Description

The lower chert pebble conglomerate (*see* Table XV) is best exposed on the south shore of the northwest arm of Marion Lake. It forms lenticular beds, less than 10 feet thick, containing subangular to rounded pebbles of greenish grey chert, white vein quartz, and grey to white arkosic quartzite. The pebbles, 0.5 to 3 cm in diameter, compose about 30 per cent of the rock, and are set in a medium-grained protoquartzite matrix. Sand grains of the matrix are very well rounded, highly spherical, and less than 1 mm in diameter. Quartz is abundant, but there are a few sand-sized fragments of chert. Pebbles and sand grains are cemented by a very fine grained muscovite intergrowth containing irregular patches of chert. Pyrite and leucoxene are the most abundant opaque minerals. Detrital zircon grains and euhedral crystals of apatite, less than 0.01 mm in diameter, are minor accessory minerals.

The upper chert pebble conglomerate, which is about 10 feet thick, outcrops on the small island in the northwest arm of Marion Lake, and on the north shore of the lake, a mile southwest of the island. In both places, marked grain gradation can be seen. Angular and rounded pebbles of jasper and chert, as much as 5 cm in diameter, occur near the base of the conglomerate, but only scattered granules occur near the top. The pebble-sized fragments of jasper and chert compose less than 40 per cent of the grey-black, rusty weathering conglomerate. The matrix consists of intimately intergrown chert, stilpnomelane, ankerite, and a green acicular mineral (minnesotaite?). Pyrite, hematite, limonite, amorphous carbon, and apatite are minor constituents.

On the east side of the island, several small outcrops of cream-buff, rusty weathering conglomerate containing as much as 50 per cent ankerite occur at the top of the upper conglomerate. Well-rounded sand grains of quartz and chert compose more than 15 per cent of the rock, and light grey subangular chert pebbles compose most of the remaining 35 per cent. Opaque minerals are virtually absent, but apatite is abundant.

Origin and Depositional Environment

The lower Wishart conglomerate resembles the Marion Lake conglomerates in composition, lenticularity, and lack of sorting, and, like them, is perhaps best interpreted as a fluviatile deposit. Roundness of sand grains in the matrix was probably inherited from the previous cycle. The abundant quartzite pebbles support this opinion, and their arkosic composition suggests the Marion Lake Formation as the probable source.

Notable in the upper Wishart conglomerate is the open framework and continuous decrease in size of pebbles from bottom to top of the 10-foot unit, features suggestive of density current origin. However, because framework components are exclusively chert and jasper, and because the unit is a single occurrence associated with shallow water sandstones showing no evidence of turbidity current origin, near-shore slumping of lithified chert and jasper beds into an environment of ironstone deposition is more likely. Once introduced into unconsolidated iron-rich muds, little if any transport would be required to cause differential settling of framework particles, resulting in open framework and size gradation.

Siltstone

Description

The siltstones and cherty siltstones of the Wishart Formation are closely associated rock types. Both are tough, thinly bedded, and appear light grey to pale greenish buff on both fresh and weathered surfaces. The cherty siltstones tend to break with a conchoidal fracture. Bedding in the siltstones is marked by slight differences in grain size, and in the cherty siltstones it is accentuated by alternation of chert-rich and silt-rich laminations. Most of the silt grains are well rounded, less than 0.05 mm in diameter, and exhibit undulatory extinction. Muscovite, in amounts up to 10 per cent, is present in all specimens. The muscovite occurs as shreds less than 0.01 mm long, parallel to the bedding. Rhombic crystals of siderite, extensively pseudomorphed by limonite, are commonly strung out parallel to bedding. The rhombs average 0.05 mm in diameter, enclose clastic quartz grains, and show distinct euhedral outlines. The lowermost cherty siltstone contains traces of apatite strung out parallel to bedding.

The ankeritic siltstones are characterized by a powdery, yellowish brown limonitic rind on weathered surfaces. Fresh specimens are tough, massive, and light grey. Slight effervescence is produced by cold 20-per-cent hydrochloric acid. Indices of refraction for the carbonate mineral in several samples were determined as $N_O = 1.72\text{-}1.75$ and $N_E = 1.52\text{-}1.54$, indicating ferrodolomite to ankerite composition (Winchell, 1951, p. 114). Dolomite structure was verified by X-ray diffraction. The ankerite grains, which compose about 30 per cent of the ankeritic siltstones, are neutral to pale brown in thin section, and lack lamellar twinning. They are anhedral, and most are less than 0.01 mm in diameter. These grains are intimately intergrown with chert, forming a fine-grained matrix for the quartz silt. Angular to poorly rounded fragments of collophane are present in some specimens. The fragments, which are up to 0.5 mm in diameter, are altered in part to clusters of clear hexagonal crystals less than 1 micron in diameter. The crystalline alteration is probably either dahllite or apatite. Muscovite flakes less than 0.01 mm long are minor constituents in most specimens.

Origin and Depositional Environment

Fine lamination of the Wishart siltstones indicates deposition below wave-base, but because of association with well-sorted sandstones of probable shallow water or aeolian origin, no great depth of water is inferred. The fine-grain size and intimate intergrowth of the ankerite and chert suggest chemical origin for these minerals. The silt grains, however, are clearly detrital, and therefore clastic as well as chemical sedimentation must have taken place.

Krumbein and Garrels (1952) have shown the importance of Eh and pH in precipitation of chemical sediments. According to their studies, siderite will precipitate in a slightly reducing environment with a pH range of 7.0 to 8.0. No data are given for ankerite, but presumably conditions for its precipitation would be similar to those required for siderite precipitation. Correns (1950) considered organic activity essential to primary precipitation of chert, but other workers (Van Hise and Leith, 1911, p. 516; Davis, 1918) suggested that inorganic precipitation is possible in environments to which silica is contributed by volcanism. Taliaferro (1933) combined both proposals, suggesting that volcanic activity may be necessary to sufficiently increase the silica content of sea-water to allow abundant organic precipitation of silica. Evidence of volcanism contemporaneous with Wishart sedimentation cannot be shown for Marion Lake area, but because volcanic rocks are interlayered with Wishart rocks south of Marion Lake (Wynne-Edwards, 1960), silica enrichment due to volcanism is plausible.

The siderite rhombs in the siltstones are either authigenic or metamorphic because they are euhedral and commonly enclose grains of quartz silt. Alteration to limonite is the result of weathering.

Occurrence of collophane fragments in the Wishart rocks is intriguing in that such fragments in Palaeozoic and younger rocks are commonly identified as the phosphatized hard parts of invertebrate organisms.

Correlation

Apatite in rocks of the Knob Lake Group near Schefferville was first reported by Howell (1954, pp. 50-54), who noted that it is especially abundant in the Wishart conglomerates. The present study has shown that the upper conglomerate of the Wishart Formation in Marion Lake map-area also contains apatite. In addition, several units of the Fleming and Wishart Formations near Schefferville contain abundant ankerite and occur in similar stratigraphic positions to ankerite-rich units of the Wishart Formation in Marion Lake map-area. Apatite and ankerite together may well prove to be diagnostic of Fleming and Wishart sedimentation.

Howell (1954, pp. 21-23) also found apatite in "cherty argillite", which he regarded as the uppermost part of the Denault Formation in the Schefferville area. This apatite-bearing argillite may actually be correlative with the apatite-bearing "cherty siltstone" regarded here, because of sharp unconformable basal contact with the Denault Formation, as lowermost unit of the Wishart Formation.

The possibility of "cherty argillite"-"cherty siltstone" correlation requires further investigation because if substantiated, terminology of the Knob Lake Group could be improved by including Howell's cherty argillite in the Fleming Formation. Such revision would characterize apatite-bearing strata as units of the Fleming-Wishart sequence, and would clarify relationship of the Denault and Attikamagen Formations. Howell (1954, pp. 23-24) interpreted the Denault Formation as a lenticular facies of the Attikamagen Formation, in order to explain apatite-bearing cherty argillite at the top of the Denault Formation and where the Denault Formation is missing, the top of the Attikamagen Formation. This concept is certainly not tenable for Marion Lake map-area, where Denault and Attikamagen Formations are separated by volcanic and sedimentary rocks comprising a sequence more than 6,000 feet thick.

Menihek Formation

A thick sequence of slate, shale, argillite, and quartzite lies stratigraphically above the Wishart Formation. Frarey mapped the northwestward extension of these rocks as the Howse Group, but he suggested (1954) the possibility of their equivalence to the Menihek Formation of the type section at Knob Lake. Within Marion Lake map-area, there are several places along the north shore of the northwest arm of Marion Lake where slate crops out less than 100 feet stratigraphically above the Wishart Formation. The contact is not exposed, but bedding attitudes strongly suggest conformity. Further, large-scale folds in the slate belt, accentuated by conformable basic sills, correspond closely to the large-scale folds in the Denault Formation. The rocks above the Wishart Formation are therefore here assigned to the Menihek Formation.

Description

Slate and shale compose more than 90 per cent of the Menihek Formation. These rocks are greenish grey to greyish black on fresh surfaces, and yellowish brown to light grey on weathered surfaces. Bedding is commonly obscured by cleavage, but where visible, consists of tabular laminations less than 1 mm thick. Grey, silty quartzitic layers that commonly show delicate cross-lamination are alternated with dark, finer grained micaceous layers. Detrital quartz grains, up to 0.03 mm in diameter, can be seen in thin section, but most of the minerals cannot be accurately identified by means of the microscope. X-ray analyses revealed that quartz, albite, chlorite, and muscovite are the major minerals. Small amounts of pyrite, dolomite, carbon, and iron silicates are present in most specimens, and hematite and magnetite are abundant in beds near the base of the formation. Possibly the iron-rich beds correlate with the Ruth and Sokoman Formations of the Knob Lake area.

Table XVII

Chemical Compositions of Menihek and Ruth Slates

	A	B	C	D	E
SiO_2	53.9	52.35	54.84	66.88	71.22
TiO_2	2.3	1.86	0.42	0.82	0.48
Al_2O_3	14.9	11.56	10.62	14.09	13.04
Fe_2O_3	9.0	13.09	13.39	1.96	1.39
FeO	4.57	3.98	7.50	1.41	3.09
MnO	0.1	0.15	—	—	—
MgO	4.3	—	1.79	1.52	2.36
CaO	1.3	0.34	0.52	0.53	0.42
Na_2O	2.1	1.32	0.13	0.78	1.14
K_2O	2.8	4.54	3.06	4.15	2.82
H_2O+	3.66	7.34	4.46	1.94	2.84
H_2O-		1.33	0.97	1.28	0.42
CO_2	0.00	—	—	—	—
P_2O_5	0.2	0.25	0.11	0.10	0.13
C	—	1.78	2.18	4.24	0.86
Total	99.1	99.89	99.99	99.70	100.21

A Sample of the lower part of the Menihek Formation, Marion Lake area. Sample 6-19
Analyst: G. Bender, Geol. Surv., Canada

B,C Samples of Ruth slate, Knob Lake area
Analyst: W. H. Herdsman, Glasgow

D,E Samples of Menihek slate, Knob Lake area
Analyst: W. H. Herdsman, Glasgow

In Table XVII, chemical composition of a sample from the lower part of the Menihek Formation in the map-area is compared with compositions of two Ruth Formation samples and two Menihek Formation samples from the Knob Lake area (Gross, 1951, p. 51). The slate from Marion Lake map-area more closely resembles the Ruth slates in having low silica and high total iron contents, but differs from them in having higher soda, lime, and magnesia contents. The titania content is unusually high in (A) and (B). Specimens taken from the upper part of the Menihek Formation in the Marion Lake area are more siliceous than the slate submitted for analysis (A), and X-ray analyses do not reveal the presence of abnormal amounts of iron oxides. The chemical composition of the upper part of the Menihek Formation in Marion Lake map-area would therefore more closely approximate in composition the type Menihek slate at Knob Lake (D, E). This substantiates the suggestion that the rocks mapped as "Menihek" in the Marion Lake map-area correlate with the Ruth-Sokoman-Menihek sequence of the type locality.

Argillites of the Menihek Formation are similar in composition to the slates and shales, but lack well-developed lamination. Fine- to medium-grained, grey, massive quartzites form widely scattered lenticular beds. The quartzites, commonly cross-bedded, are composed mostly of quartz and minor muscovite and chlorite. Some quartz grains exhibit detrital outlines, and the micaceous minerals commonly occur in clusters, which may represent distorted shale fragments. The original sandstones were probably protoquartzites, according to Pettijohn's classification (1957, p. 291).

Origin and Depositional Environment

Delicate lamination and fineness of grain in the Menihek shales and slates indicate a relatively quiet water environment of deposition. The quartzites, however, are well sorted and crossbedded, suggesting deposition in a turbulent environment. Sedimentation may have been controlled by water depth, sand being deposited when wave-base was depressed to the depositional interface. Introduction of the sandy units to a deep basin by turbidity flow is another possibility, but maturity of the quartzites and lack of graded bedding stand against such origin.

High titania content of the Menihek rocks may have resulted from unusual concentration of titanium-bearing minerals in the sedimentary environment, addition of titania during intrusion of the sills, or metasomatic transfer during regional metamorphism. The high titania content could also reflect contemporaneous vulcanism with release of titania to the waters of the basin in which Menihek strata were deposited.

Murdock Group

The Murdock Group is separated from the Knob Lake Group by a northwesterly trending fault, and crops out east of the fault in a belt less than a mile wide. Chlorite-biotite-quartz schists and chlorite-albite-actinolite schists compose most of the Murdock Group, but massive intrusive rocks are locally abundant.

Description

The fine- to medium-grained chlorite-biotite-quartz schists are dark green to greenish grey on fresh surfaces, and rusty brown to pale green on weathered surfaces. Some outcrops show relic bedding averaging 0.5 to 3 mm thick, but it is commonly obscured by cleavage. Typical specimens contain approximately 35 per cent quartz, 30 per cent biotite, 25 per cent chlorite, 5 per cent muscovite, and 5 per cent albite.

Because untwinned albite may have been mistaken for quartz, the feldspar to quartz ratio may be somewhat higher. Minor actinolite, magnetite, and granular, colourless to pale yellow epidote are present in some thin sections, and one specimen contains more than 25 per cent carbonate. The quartz and feldspar grains are equant and less than 0.1 mm in diameter. The biotite occurs in shreds up to 0.2 mm long, and exhibits yellowish brown to greenish brown pleochroism. The chlorite laths are less than 0.1 mm long, and are pleochroic from neutral to pale green.

The chlorite-albite-actinolite schists have fine-grained, greenish grey fresh surfaces and grey to brown weathered surfaces. Some outcrops show relic pillows and pyroclastic textures. Typical specimens contain approximately 45 per cent actinolite, 30 per cent albite, 15 per cent chlorite, 10 per cent clinozoisite, and minor sphene, magnetite, and leucoxene. Both actinolite and chlorite are pale green and slightly pleochroic. The albite occurs as clear, anhedral grains, and the clinozoisite forms granular clusters. Sphene, magnetite, and leucoxene compose as much as 10 per cent of some specimens.

The massive rocks are fine to medium grained, and are composed mostly of saussuritized plagioclase and uralitized pyroxene. They are tough, greenish grey, rusty weathering rocks, which closely resemble the gabbros associated with the Knob Lake and Doublet Groups.

Origin

Relic bedding in the chlorite-biotite-quartz schists indicates a sedimentary origin. The mineralogy of these rocks suggests derivation from immature pelitic sediments or tuffs. Relic pillow structures and pyroclastic textures in the chlorite-albite-actinolite schists demonstrate derivation from volcanic rocks, and the mineralogy suggests an original basaltic composition for the altered rocks.

Frarey (1954) reported outcrops of conglomerate, containing pebbles of chert and iron-formation, at the base of the Murdock Group in Willbob map-area. He cited this occurrence as evidence for an unconformity between the Knob Lake and Murdock Groups. The Murdock conglomerate was not observed in Marion Lake map-area, but because of the relationship observed by Frarey, the Murdock Group is here regarded as younger than the Menihek Formation.

Similar mineral content of Murdock and Doublet rocks suggests that Murdock rocks might be schistose equivalents of the Doublet rocks, but attitude determinations in Willbob map-area (Frarey, 1954) show that the Murdock Formation is a monoclinal sequence facing northeast. Because lowermost Doublet volcanic rocks in Marion Lake map-area also face northeast, equivalence of Doublet and Murdock Groups would require repetition by major faults for which there is no evidence.

Doublet Group

Rocks of the Doublet Group underlie about half of Marion Lake map-area. A sedimentary sequence less than 3,000 feet thick comprises the lower part of the group; a volcanic sequence more than 10,000 feet thick comprises the upper part. The volcanic rocks occupy a belt that terminates about 10 miles south of Roymart Lake, but which extends more than 80 miles northwest of the map-area.

Sedimentary Rocks

Beds of quartzite, slate, and argillite constitute the basal sequence of the Doublet Group. These rocks are best exposed north of Link and Moss Lakes, and on the limbs of the folds that flank Lac La Touche. A few thin slaty and tuffaceous beds are intercalated with the volcanic rocks, but are not shown on the map.

Quartzite

Description

Most of the quartzites are massive, fine- to coarse-grained, light grey to greenish grey rocks which weather white to rusty brown. Bedding is commonly obscure or absent, but in some of the fine-grained quartzites, black shaly partings mark distinct planar beds ranging from 1 to 5 mm in thickness. Planar crossbeds, which form units as much as 2 cm thick, occur in some of the quartzites, and delicate undulatory structures, with amplitudes of 1 to 2 mm and wave lengths of 5 to 15 mm, were observed in fine-grained quartzites that outcrop half a mile north of Moss Lake. These undulatory structures occur on bedding surfaces and may be ripple-marks. They are very small-scale features, but Bucher (1919, p. 158, Table III) recorded modern ripple-marks with amplitudes as little as 1 mm and wave lengths of 11 to 20 mm.

Quartz sand grains compose 55 to 65 per cent of the quartzites. The grains are smoky, pale blue, or clear and glassy, and few are larger than 1 mm in diameter. Boundaries are delicately sutured owing to mutual interpenetration of adjacent grains, but detrital outlines, marked by dusty rings within the serrated margins, can commonly be seen. Some grains exhibit high sphericity, but most are ovoid or lenticular; a few have length-to-width ratios of more than 3:1 (Pl. I C). Slightly clouded grains of detrital plagioclase (mostly oligoclase) compose 2 to 5 per cent of the quartzites, and most specimens contain a few detrital grains of microcline.

Chlorite and biotite, the most abundant micaceous minerals, occur as shreds less than 0.1 mm long, strung out along the margins of the detrital grains. The chlorite

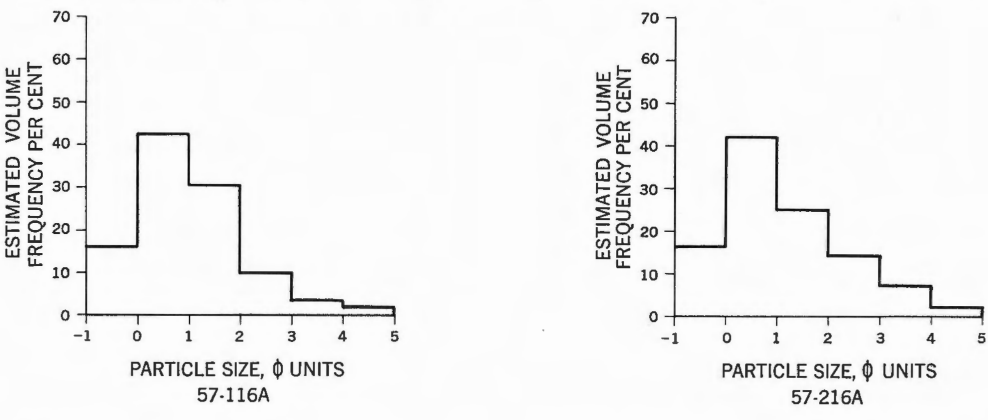

FIGURE 7. Size histograms for two Doublet quartzites, showing the estimated volume per cent distribution of detrital grains.

Table XVIII

Modal Compositions of Some Doublet Quartzites
(Volume per cent, based on 600 points for each specimen)

Specimen No.	Quartz Grains	Quartzite Fragments	Chert Grains	Shale Fragments	Plagioclase	Microcline	Chlorite	Biotite	Muscovite	Zircon	Opaques	Epidote	Average Roundness	Average Sphericity	Median Diameter	S_0, Sorting Coefficient
57-116A	60.1	14.5	2.7	1.0	9.2	2.1	3.7	6.1	*	*	*	*	0.5	0.6	0.82	1.76
57-210A	55.1	15.2	—	1.9	13.8	—	10.9	—	1.7	*	0.4	*	0.6	0.5	0.37	1.33
57-216A	62.9	15.3	—	—	12.7	—	3.8	4.7	0.4	*	0.2	*	0.5	0.6	0.80	1.58

*Less than 0.2 per cent

Table XIX

Chemical Composition of a Doublet Quartzite[1]

SiO_2	83.8	CaO	0.9
TiO_2	0.2	Na_2O	2.0
Al_2O_3	6.5	K_2O	0.2
Fe_2O_3	0.7	H_2O	1.22
FeO	3.25	P_2O_5	0.0
MnO	0.0	CO_2	0.10
MgO	1.5		
		Total	100.4

[1]Sample 57-210A
Analyst: G. Bender, Geol. Surv., Canada

is pleochroic from light green to olive-green, and the biotite is pleochroic in reddish or greenish browns. Pyrite, epidote, muscovite, leucoxene, iron oxides, and small, well-rounded zircons are accessory minerals. The rock fragments include fine-grained quartzite, chert, and shale. The chloritic shale fragments are commonly smeared out along cleavages, and some of the fine-grained quartz in the matrix may have been derived by marginal granulation of quartzite fragments. The strong undulatory extinction exhibited by the quartz, and the numerous fractures in the rocks, support this view.

The modal compositions of three quartzites are shown in Table XVIII. According to Pettijohn's classification (1957, p. 291), the rocks are lithic sandstones. The chemical composition of a typical Doublet quartzite (Table XIX) shows that, as in lithic sandstones from others areas (Pettijohn, 1957, p. 319), magnesia exceeds lime and soda exceeds potash.

Histograms of size frequency distributions for two Doublet quartzites, calculated from thin section measurements (Appendix A) are shown in Figure 7. The samples have coarse modal classes (0.5-1 mm) and are skewed towards the coarse size grades. Sorting is much poorer than for Marion Lake and Wishart sandstones (Pl. I). Because there is evidence of crushing and recrystallization, the data probably are not very accurate; original distributions probably included coarser grades.

Origin and Depositional Environment

Fair sorting, crossbedding, and possible ripple-marks of the Doublet quartzites suggest shallow water deposition. Similar lithic sandstones are interpreted as continental or shallow marine deposits (Krynine, 1940; Siever, 1949; Pelletier, 1958). According to Pettijohn (1957, p. 62), lithic sandstones belong to the realm of paralic sedimentation, which implies intense terrigenous alluviation. The mineral and chemical compositions of the Doublet quartzites reflect immaturity, in keeping with this concept. The quartzites are therefore interpreted as derivatives of sands that were subjected to a short but vigorous transport and deposited in a fluviatile, lacustrine, or shallow marine environment.

Slate and Argillite

Description

The Doublet slates are sooty black, grey to rusty weathering rocks. Paper-thin beds are visible on the weathered surfaces of some specimens, but cleavage commonly masks the bedding. Only quartz, which occurs as grains less than 0.01 mm in diameter, can be definitely identified in thin section. Other mineral grains are only a few microns in diameter, and are felted together in an extremely fine grained intergrowth. X-ray diffraction patterns of several specimens show the presence of abundant quartz and muscovite, and minor chlorite, plagioclase, and iron oxides. The chemical composition of a typical Doublet slate is shown in Table XX. The sample has a normal silica content, but is notably high in ferrous iron and low in lime.

Table XX

Chemical Composition of a Doublet Slate[1]

SiO_2	57.6	CaO	0.2
TiO_2	0.4	Na_2O	1.2
Al_2O_3	15.2	K_2O	3.8
Fe_2O_3	1.2	H_2O	4.22
FeO	13.48	P_2O_5	0.0
MnO	0.0	CO_2	0.09
MgO	3.2	C	0.23
		Total	100.0

[1]Sample 57-119A
Analyst: K. Hoops, Geol. Surv., Canada

Origin and Depositional Environment

Because the Doublet slaty rocks are interbedded with the Doublet quartzites, a common depositional environment is suggested. However, fine grain size and delicate lamination of the slates indicate deposition in relatively quiet water. Structures indicative of shallow water origin have been noted for the quartzites, and the slates are therefore interpreted as representative of shallow water sedimentation during periods of quiescence.

Volcanic Rocks

Description

Typical volcanic rocks of the Doublet Group are dark green to greenish grey and weather light grey to pale yellowish green. Most specimens are very fine grained and massive, but many show faint to well-developed flow cleavage, and those in fault zones exhibit prominent fracture cleavage.

Pillows are present in more than 80 per cent of the mapped outcrops. Most pillows are less than 6 feet long and many are less than 3 feet, but several more than 20 feet long were observed north of Ryan Lake. According to Wilson's classification (1941) most of the pillows are balloon- and loaf-shaped, but mattress- and bun-shaped pillows are abundant. The pillows fit closely together and the shapes commonly provide a reliable indication of flow tops. Most pillow selvages are 1 to 3 cm thick, and are commonly darker, but weather lighter, than the pillow interiors. Cavities in the upper parts of pillows also provide a top and bottom criterion, and proved to be an invaluable aid to mapping. Sauvé (1957, pp. 44-46) reviewed the theories of origin for pillow cavities and concluded that pillow voids can form by contraction during cooling, sagging of the lower parts of the pillows, agglomeration of gas bubbles, capture of extraneous water, draining out of liquid lava, or some combination of these processes. Most cavities are empty, but in places where quartz veins are abundant (particularly north of Moss Lake and west of Lac Gauthier), the cavities are commonly occupied by quartz. Quartz and minor chert also occur in pillow interspaces.

Few flow thicknesses can be accurately determined because the scoriaceous tops weather more rapidly than the central and basal parts of the flows, forming valleys identical in appearance to valleys controlled by strike joints. On several hill-tops in the northern part of the map-area, however, complete cross-sections of flows, 50 to 230 feet thick, are exposed. Three of these flows were traced on the ground for a distance of more than 3 miles, and in this interval were seen to maintain very uniform thicknesses. Flow tops marked by parallel valleys can be traced for even greater distances on aerial photographs.

Porphyritic flows containing abundant pillows outcrop on the north shore of Lac Gauthier, on the east shore of Lac Charny, and north of Lac La Touche, where two distinct layers can be traced around the nose of a major syncline. The porphyritic flows are characterized by glomeroporphyritic clots of altered plagioclase, as much as 3 cm in diameter, which evidently are of intratelluric origin, because some of them occur in the devitrified selvages.

A few thin layers of tuff and volcanic breccia are intercalated with the flows south of Ryan Lake, northwest of Lac Gauthier, and north of Lac La Touche. The tuffs are schistose chloritic rocks, which contain a few water-worn volcanic pebbles. The volcanic breccia consists of irregular, angular, pale green to buff fragments, less than 4 inches long, in an aphanitic, greenish black, chloritic matrix.

Excellent columnar joints can be seen in some of the massive flows, and a steeply dipping 120 foot-thick flow that outcrops 3 miles north of Lac La Touche shows well-developed two-tier jointing consisting of upper tier columns 6 to 15 inches in diameter and lower tier columns 10 to 30 inches in diameter.

Plagioclase in the volcanic rocks occurs as laths less than 1 mm long. In massive specimens, the laths are randomly oriented and form a network enclosing the other minerals, suggesting that the original texture was probably intergranular or intersertal. In specimens showing well-developed flow cleavage, original textures cannot be recognized because of mineral growth in the cleavage. Varioles, less than 0.5 mm in diameter, are abundant in the margins of some pillows.

Composition and Origin

Albite, actinolite, chlorite, clinozoisite, and sphene are abundant minerals in most of the volcanic rocks in the Doublet Group. The albite and fine, granular clinozoisite pseudomorph original calcic plagioclase, and both actinolite and chlorite replace pyroxene. Magnetite, ilmenite, leucoxene, quartz, and calcite are commonly present in small amounts. Chlorite and carbonate are abundant along shear zones. Approximate modal compositions of two meta-basalt specimens are shown in Table XXI, and the chemical composition of a meta-basalt sample from the Willbob Lake area (Frarey, 1954) is shown in Table XXII. The sample is similar in composition to Nockolds' average tholeiite (*see* Table XIII). Soda and titania contents are somewhat low, but this may be atypical for Doublet meta-basalts in Marion Lake map-area (note high albite and sphene-leucoxene contents, Table XXI). The chemical and mineralogical similarity to volcanic rocks in the Knob Lake Group should also be noted.

Table XXI

Modal Compositions of Two Meta-Basalt Samples, Doublet Group

(Volume per cent, based on 600 points for each specimen)

	57-183A	57-225A
Albite	30.3	27.3
Actinolite	47.2	45.5
Chlorite	2.5	6.8
Clinozoisite	15.2	16.3
Sphene, leucoxene	4.8	3.4
Iron oxides	—	0.7

The meta-basalts in the Doublet Group record a long period of remarkably uniform volcanic activity in the history of the Labrador Trough. Abundant pillow structures indicate subaqueous extrusion for at least 80 per cent of the volcanic rocks. Those flows exhibiting columnar jointing, and particularly the one that shows two-tier columnar jointing, may well have erupted subaerially. Because individual flows are extensive and of uniform thickness, the magma must have been very fluid. Similarity to the volcanic rocks in the Knob Lake Group suggests a common magma source.

Intrusive Rocks

Numerous sills of slightly to extensively metamorphosed gabbro, diorite, quartz diorite, peridotite, and related rocks outcrop in the western half of the map-area. Many

Table XXII

Chemical Composition of Meta-Basalt[1], Doublet Group

SiO_2	49.86	Na_2O	1.76
TiO_2	0.53	K_2O	0.43
Al_2O_3	15.07	H_2O+	3.18
Fe_2O_3	2.39	H_2O-	0.34
FeO	9.63	P_2O_5	0.20
MnO	0.37	CO_2	Tr.
MgO	6.34	S	0.15
CaO	9.64		
		Total	99.89

[1]Composite sample, Willbob area (M. J. Frarey)
Analyst: R. C. Fabry, Geol. Surv., Canada

sills appear to be more than 1,000 feet thick, but the presence of sedimentary layers between adjacent sills north of Link and Moss Lakes suggests that unexposed sedimentary layers may also occur within the bodies that have been mapped as thick tabular gabbroic units. All contacts observed in the field are sharp and parallel to the bedding of intruded sedimentary rocks. The only known discordant intrusion is the gabbro body that transects the Denault Formation.

Most of the sills are bounded by sedimentary rocks, but a few coarse-grained gabbroic layers are associated with volcanic rocks of the Knob Lake and Doublet Groups. Possibly some of the fine-grained, massive greenstones that were mapped as flows are actually intrusive rocks. The sills form prominent ridges, and, where drift cover is thin, their continuity and uniform thickness can be readily seen on aerial photographs.

Planar joints parallel to sill contacts, and compositional layering, also parallel to sill contacts, indicate emplacement prior to folding. The concordance of the sills substantiates emplacement prior to folding for had they been intruded after the folding they would have been emplaced along zones of structural weakness. Finally, shear zones within the sills, particularly near the axial planes of folds, indicate that the sills have been folded.

Gabbro

Description

The gabbro is typically a tough, massive, medium-grained rock showing well-developed ophitic to subophitic texture. It is grey to greenish grey on fresh surfaces and rusty brown to dark grey on weathered surfaces. Where contacts are exposed, gabbro in the borders is very fine grained to aphanitic. The major primary minerals, augite and labradorite, are extensively altered to actinolite, chlorite, albite, and clinozoisite. Magnetite-ilmenite intergrowths are pseudomorphed by leucoxene and chlorite. Serpentine, epidote, quartz, and pyrite are the only other important minerals.

The porphyritic gabbro outcrops north of Lean Lake, west of Marion Lake, and in the northwest corner of the map-area. Leopard rock, spotty gabbro, blotchy gabbro, and mottled gabbro are descriptive names commonly applied to this rock, which is characterized by abundant greenish white, glomeroporphyritic clots of altered calcic plagioclase in a dark green, fine-grained matrix of chlorite and actinolite. In some exposures, the subspherical clots, which range from 0.05 to 10 cm and average 2 cm in diameter, compose more than 75 per cent of the rock. The porphyritic gabbros probably are intrusive equivalents of the porphyritic volcanic rocks of the Doublet Group.

Augite and saussuritized labradorite are abundant in the central parts of the thick sills west of Moss and Marion Lakes. The augite shows faint pleochroism from neutral to pale brown, and prominent (100) parting can commonly be seen in basal sections. Some large augite crystals exhibit slight zoning, having a (+) 2V of about 60 degrees at the core and less than 56 degrees at the rim. The labradorite occurs as narrow euhedral and subhedral laths less than 3 mm long. Broad albite twin lamellae are visible, but are partly masked by clinozoisite.

In most sills, augite has been pseudomorphed by actinolite and chlorite, and labradorite by an almost opaque intergrowth of clinozoisite and albite. Single crystals of actinolite commonly pseudomorph single pyroxene crystals. The actinolite is pleochroic from neutral to pale bluish green. Optic properties include: (–) 2V = 75 to 80°; z C = 15°. The chlorite occurs in fibrous sheaths intimately associated with the actinolite, and also takes the place of magnetite in pseudomorphed magnetite-ilmenite intergrowths. Some chlorite exhibits anomalous blue interference colours, but most has a low, normal birefringence. Both types are pleochroic from pale yellow to yellowish green. Pale greenish brown serpentine forms rectangular patches, possibly an alteration of orthopyroxene, and oval patches poikilitically enclosed by augite, which probably are pseudomorphs after olivine. Clear albite rims most of the extensively saussuritized calcic feldspars. Euhedral grains of epidote, as much as 0.5 mm in diameter, occur in some gabbros, but the very fine grained clinozoisite that clouds the plagioclase grains is more abundant. Clear, anhedral grains of quartz occupy interspaces between plagioclase laths, and obviously are of primary origin. Intergrowths of magnetite and ilmenite, now replaced by leucoxene and chlorite, also form anhedral patches bounded by plagioclase laths. Small amounts of granular pyrite, chalcopyrite, and pyrrhotite are disseminated through some of the gabbros, and tiny apatite euhedra occur in the quartz-rich parts of the sills. Thin veinlets containing quartz, chlorite, epidote, calcite, and prehnite are abundant.

Table XXIII shows the modal compositions of some representative gabbroic rocks. Their mineral content is similar to that of the volcanic rocks of the Knob Lake and Doublet Groups.

Origin

Evidence has been presented to show that the intrusive rocks were introduced prior to folding. It is therefore possible that the gabbros were derived from the same magma as the volcanic rocks. The common occurrence of glomeroporphyritic feldspar clusters in both intrusive and extrusive rocks suggests consanguinity, and the mineralogical compositions are similar.

Table XXIII

Modal Compositions of Some Meta-Gabbro Specimens

	57-43A	57-110A	57-118A	57-122N	57-13N
Augite	26.8	—	—	—	—
Actinolite	—	39.5	52.0	34.2	31.4
Labradorite	25.1	—	—	—	—
Albite, Clinozoisite	15.3	38.3	34.8	44.6	49.1
Epidote	3.9	—	2.3	3.5	—
Serpentine, Chlorite	17.9	7.8	6.4	5.9	15.8
Quartz	5.3	5.2	1.8	6.7	1.6
Sulphides	2.0	1.5	—	1.5	0.9
Leucoxene, sphene	3.7	6.9	2.7	3.6	1.2
Apatite	*	*	—	*	*

*Less than 0.2 per cent

Diorite and Quartz Diorite

Minor diorite and quartz diorite occur locally in the upper parts of the gabbro sills within the Knob Lake Group and in the upper part of the gabbro sill north of Lac La Touche. These rocks are included with the gabbros on the Marion Lake geological map because of their limited extent and apparent gradational relationship to the gabbros.

Description

The diorites and quartz diorites commonly show the same texture and structure as the gabbroic rocks, but are lighter in colour, ranging from greenish grey to light grey, and some are coarser grained. Albite composes as much as 60 per cent of these rocks, but clinozoisite is minor, suggesting alteration of relatively sodic plagioclase. A typical diorite and a typical quartz diorite have the following composition:

	Diorite %	*Quartz Diorite* %
Albite	45	55
Actinolite	30	10
Chlorite	10	
Clinozoisite	5	5
Quartz	5	25
Sphene	2	
Magnetite	2	3
Apatite	1	2

The quartz diorites commonly show micrographic intergrowths of quartz and feldspar, and some contain small amounts of sericitized microcline.

Origin

Occurrence of the diorite and quartz diorite at the tops of gabbro sills strongly suggests differentiation in place. Evidence for separate intrusion is lacking, and similarity of texture, structure, and mineral content support the differentiation hypothesis.

Baragar has convincingly demonstrated differentiation in place for similar sills in Ahr Lake map-area, about 60 miles northwest of Marion Lake. His discussion (1960) is well documented by chemical and mineralogical data.

Ultramafic Rocks

The ultramafic rocks that outcrop on ridges near Lac La Touche form part of a meta-peridotite belt that terminates in Marion Lake map-area, but which extends northwest more than 60 miles. Distribution of the ultramafic rocks indicates concordance with the Doublet rocks and the associated gabbro sills. Compositional layering and planar strike joints are parallel to contacts, and several conformable contacts are exposed. Most of the ultramafic rocks near Lac La Touche probably form discrete sills, but their distribution with respect to the associated gabbroic rocks suggests that in a few places they may form the lower parts of differentiated sills. The 1,500-foot-thick tabular body that borders Lac La Touche must consist of at least three sills, because two layers of sedimentary rock crop out within it. The individual sills could not be mapped, however, because of thick glacial drift.

A body of ultramafic rock also crops out a few miles southeast of Lac Rucelai. No contacts are exposed, but its restricted occurrence suggests unconformable relationship to the Doublet metavolcanic rocks. It may be a sheared and recrystallized facies of the Lac La Touche meta-peridotite belt, but its occurrence at the faulted border of the Labrador Trough suggests separate intrusion.

Description

The meta-peridotites near Lac La Touche are extremely tough, fine to medium grained, and massive. They have greenish black fresh surfaces and orange-brown to dark brown weathered surfaces. Olivine is present in the central parts of the sills, but in most places is completely replaced by serpentine. Tremolite is abundant at the borders of the ultramafic sills, and because of its resistance to weathering, stands out in relief with respect to the enclosing serpentine.

Modal compositions of two ultramafic rocks are shown in Table XXIV. Original textures are well preserved, and excellent pseudomorphs of olivine are visible in thin section. The olivine, which composed as much as 70 per cent of the original rocks, is partly to completely replaced by antigorite, serpophite, and magnetite. The pseudomorphs are 0.25 to 3 mm in diameter, and although most are equant and rounded, some are distinctly tabular. Remnants of olivine grains can be seen in specimens from the central parts of the sills. The antigorite is fibrous and has apparently grown inward from the margins of the olivine grains. Patches of tremolite needles commonly occur in the pseudomorph cores, and the magnetite occurs as rounded euhedral grains less than 0.1 mm in diameter, strung out along networks in the antigorite. Pale green, near-isotropic serpentine (serpophite) is abundant in most specimens.

Tremolite composes more than 60 per cent of specimens from border zones of the sills. It occurs as equant grains, as much as 2 cm in diameter, which are probably pseudomorphs after pyroxene. Most of the tremolite is colourless, but some shows

Table XXIV

Modal Compositions of Ultramafic Specimens

(Volume per cent, based on 800 points for each specimen)

	57-254A	57-259A
Antigorite	59.2	35.1
Serpophite	12.0	9.3
Tremolite-actinolite	14.3	41.3
Brown hornblende	8.0	5.9
Chlorite	3.9	1.2
Magnetite	2.6	7.2

faint green pleochroism, indicating that it is actinolitic. Brown hornblende, a minor constituent of most ultramafic specimens, shows strong pleochroism from colourless to reddish brown. Marginal alteration to tremolite is common. A fibrous pink to yellowish chlorite that shows anomalous blue interference colours is present in small amounts.

The ultramafic rock southeast of Lac Rucelai consists mostly of tremolite and serpentine. It lacks the pseudomorphic texture so well shown by the ultramafic rocks near Lac La Touche, showing instead a well-developed nematoblastic texture.

Dyke Rocks

A few diabase dykes were observed in the gneissic terrane east of Lac Alonce. These are tabular bodies, 1 foot to 25 feet thick, which occupy vertical, northwest-trending fractures in the gneiss. Their margins are aphanitic and melanocratic, but the central parts of the thicker dykes are fine to medium grained, mesocratic, and show well-developed diabasic texture. The coarser grained rocks exhibit a grey and green mottling on fresh surfaces; weathered surfaces are buff to greyish brown.

Plagioclase composes more than 50 per cent of the dyke rocks. It shows progressive normal zoning from An_{55} to An_{30}, and is commonly clouded by fine-grained sericite. Titanaugite, serpentine, chlorite, actinolite, biotite, magnetite, and a fine-grained, moderately birefringent mineral (bowlingite?) are the other constituents. The serpentine and bowlingite (?) pseudomorph olivine, and, in places, remnants of the olivine can be seen; small amounts of chalcopyrite and pyrite are present. The modal composition of one specimen is shown in Table XXV.

Table XXV

Modal Composition of a Diabase Specimen[1]

(Volume per cent, based on 800 points for each specimen)

Plagioclase	54.7
Titanaugite	10.8
Serpentine, bowlingite(?)	13.3
Chlorite, actinolite	11.4
Biotite	1.9
Magnetite	7.6
Sulphide minerals	0.3

[1]Specimen 58-4A a mile east of Lac Alonce

Diabase dykes that cut rocks of Knob Lake Group near Schefferville show a mineral content similar to that of the dykes near Lac Alonce. A thin section of a diabase specimen (FA-307-61) collected near Mary Jo Lake, and lent to the author by W. F. Fahrig, differs mostly from the Lac Alonce specimens in having abundant fresh olivine and only a minor amount of bowlingite (?) and serpentine. The plagioclase is zoned with approximately the same range of composition, and the pyroxene has similar optical properties.

Chapter III

STRUCTURAL GEOLOGY

The western two thirds of Marion Lake map-area is underlain by rocks of the Labrador Trough, and the eastern one third by gneisses and amphibolites. Folds and major faults in the Labrador Trough trend northwest and are truncated by the gneisses. Because of this structural discordance, a major fault must separate rocks of the Trough from the gneisses and amphibolites. Another prominent fault separates the Knob Lake Group, in which fold axes plunge steeply northwest, from the Murdock and Doublet Groups, in which fold axes plunge gently southeast. Marion Lake map-area can, therefore, be divided into three structurally distinct units. For convenience, the three units will be referred to as the Southwestern Block, the Central Block, and the Eastern Block (Fig. 8). Two geological cross-sections (on Map 1174A) show the structural interpretation.

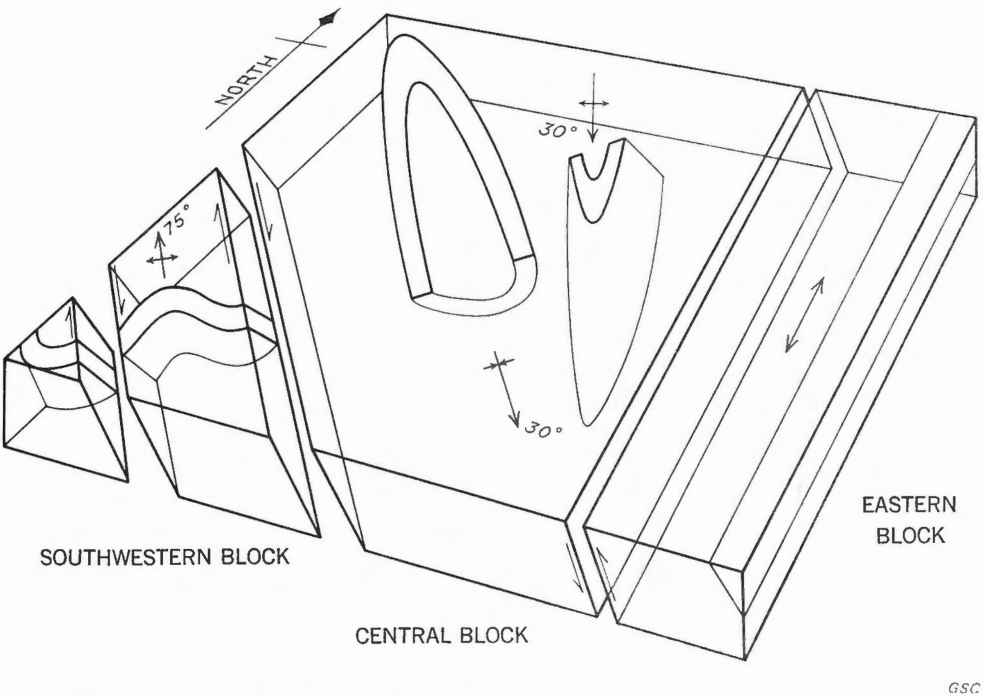

FIGURE 8. Transparent block diagram showing the three structural units in Marion Lake map-area. The basic structural elements are shown schematically.

Southwestern Block

Rocks of the Knob Lake Group are structurally characterized by fold axes that plunge steeply northwest. The outcrop pattern outlines a large syncline and anticline, and small-scale structures, which are congruent with these large folds, have been observed in many outcrops.

Folds

Folds in the Knob Lake Group are accentuated by the gabbro sills northwest of Marion Lake and by both sills and flows near Mountain and Keco Lakes. Noticeable, however, is the disparity between outcrop patterns of the Marion Lake Formation and the overlying strata (Knob Lake flows and Denault, Wishart, and Menihek Formations). On the west shore of Marion Lake, the Knob Lake flows and Marion Lake Formation are only a few hundred feet apart; a mile west of the shore, they are separated by more than 2 miles. Gabbro occupies the wedge between them. Undetected faults may be present, but laccolithic intrusion of the gabbro affords a more likely explanation. Configuration of the gabbro and its conformable relationship to the enclosing strata suggest intrusion accompanied by arching of overlying formations with respect to the Marion Lake Formation.

Drag-folds are abundant in the Menihek Formation, and many of them are congruent with the large-scale folds. However, drag-folds have also developed along shear zones, and care must be taken to relate them to the correct large-scale structures.

Faults

Most faults shown in the accompanying geological map can be recognized in aerial photographs as strong lineaments marking straight shallow valleys along the fault zones. The sheared and fractured rock in the fault zones is rarely exposed because of thick drift in the fault-controlled valleys. Prominent lineaments for which no evidence of faulting was observed in the field are shown on the map by means of a separate symbol.

The fault separating the Knob Lake and Murdock Groups has been mapped for more than 50 miles northwest of Marion Lake map-area (Frarey, 1952), and extends about 15 miles southeast, where it is truncated by the eastern boundary fault (Wynne-Edwards, 1960). Near-vertical drag-folds and near-horizontal slickensides indicate transcurrent movement with right-hand offset. Another transcurrent fault with right-hand offset passes through Keco Lake, and parallels the above-mentioned fault. Shear surfaces within both fault zones dip steeply northeast. Because the northwest-trending folds indicate northeast-southwest compression, substantial reverse movement may also have occurred in these fault zones.

Cleavage and Lineation

Flow and fracture cleavages[1] are well developed in the Attikamagen and Menihek rocks, and fracture cleavage is prominent in the siltstones of the Marion Lake Formation.

[1]The terms flow and fracture cleavage are used according to the usage of De Sitter, 1956, pp. 98-100.

The flow cleavage in most places trends northwest and is steeply dipping. Because the axial planes of large folds have the same attitude, this cleavage is presumed to be related to folding (De Sitter, 1956, p. 99) and is probably an axial plane cleavage. Flow cleavage in highly folded areas is gradational with fracture cleavage in less deformed rocks, showing that it developed from fracture cleavage, but in many places a second fracture cleavage transects the flow cleavage. Too few instances of this later fracture cleavage were observed to determine whether it is also related to folding. In many places, cleavage and bedding intersect to form a lineation that plunges steeply northwest. Because this lineation parallels axes of folds, it is a b-lineation (Sander, 1926, p. 328). Cleavage is absent in the Marion Lake sandstones, in the Denault Formation, and in the gabbros, but fracturing subparallel to axial planes is common.

Joints

Sets of planar joints are well developed in the gabbro sills. Joints parallel to the sill contacts are most prominent, but several sets perpendicular to the contacts are also present. Because of this relationship, the joints are an aid in structural mapping.

Cross joints (ac-joints) are present in parts of the Attikamagen Formation, and are particularly well developed in the slates that outcrop on the east shore of the southwest arm of Marion Lake. Joints are also conspicuous in much of the Menihek Formation, and commonly there are two sets subperpendicular to the bedding. In places, these joint sets intersect at about 60 degrees, forming large rhombic slabs which, in the steeply dipping beds, tend to be upthrust as a result of frost action.

Joints are abundant in the Denault Formation, and sufficient joint-bedding relationships were observed to note that the joints are typically subperpendicular to bedding, regardless of position of the beds in folds. The joints may therefore have developed when the strata were essentially flat-lying, by analogy with the conclusions of Schmidt (1957) for folded carbonate rocks in central Alberta.

Central Block

Large-scale folds, longitudinal faults, and shear zones are abundant in the Doublet Group. Most of the Murdock Group is highly schistose, and no large-scale folds were recognized.

Folds and Flow Cleavage

Axes of the numerous folds in the Doublet Group trend northwest to north-northwest, converging towards the southeastern part of the Central Block. Axial planes dip steeply northeast to east, and the limbs of some folds are locally overturned towards the southwest. Most fold axes plunge gently southeast, but axes of the folds between Lac Rucelai and Lac Godefroy are essentially horizontal. Most of the plunging folds can be recognized and traced on aerial photographs, but the horizontal folds are recognized only by reversals in dip where the upper sides of flows can be identified. Flow cleavage or schistosity is well developed in the volcanic rocks of the Doublet Group. This cleavage is subparallel to axial planes of folds and commonly contains elliptical chlorite smears that are elongate in "a". The relationship of cleavage, lineations, and folds is identical to that described by Cloos (1950, p. 8) for South Mountain anticlinorium in Maryland.

Faults and Fracture Cleavage

Major faults within the Doublet Group, which are marked by shear or fracture zones as much as 300 feet wide, commonly occupy straight, shallow valleys, and show as lineaments on aerial photographs. They converge, as do the folds, towards the southeastern part of the Central Block. Fracture cleavage, which is prominent in most fault zones, dips northeast at lesser inclination than the flow cleavage. Intersection of flow and fracture cleavages commonly forms a b-lineation that parallels fold axes. In many fault zones, vertical transport is indicated by slickensides on the fracture cleavage surfaces. Chlorite is abundant in the shear zones, and in some its growth parallel to shearing has resulted in development of a secondary schistosity, which masks the regional schistosity.

Eastern Block

Foliation

A well-developed foliation, which is the most prominent structure in the Eastern Block, is steeply inclined in most places, and has a remarkably uniform northward trend within the outcrop belt. Its strike parallels the inferred contact of the Eastern and Central Blocks, and consistent reversals in dip suggest that it is isoclinally folded.

Foliation in the gneisses consists of alternate dark- and light-coloured layers less than 1 cm thick. Where subparallel flakes of biotite are abundant in the dark layers the gneisses tend to fracture in flaggy slabs, but in most outcrops the gneiss breaks along irregular surfaces unrelated to the gneissosity. Lenticular mineral aggregates, mafic schlieren, and tabular bodies of melanocratic gneiss interlayered with the leucocratic gneisses accentuate the foliation in many exposures.

In the amphibolites foliation consists of interleaved hornblende-rich and plagioclase-rich layers. The layers, which are less than 2 mm thick, probably formed by metamorphic segregation. Some of the amphibolites exhibit a crude fissility parallel to the foliation.

Lineation

Linear elements in the gneisses and amphibolites include crenulations on foliation surfaces, fold axes, acicular hornblende prisms, lenticular pods of mafic minerals, schlieren, and the intersection of foliation and fracture cleavage. All lineations lie in the north-trending foliation and are horizontal or plunge gently north. The concordance of lineations in the gneisses and amphibolites suggests a common structural history for the two rock types. Coincidence of fold axes with the regional lineation of the Eastern Block indicates that the linear elements mark a b-lineation.

Joints

Two joint sets are present in the Eastern Block: one set trends northwest and the other trends west; both are vertical to steeply dipping. Because the east-west joints are regionally developed within the gneisses and amphibolites and are perpendicular to the b-lineation, they probably are ac-joints, formed at the same time as the foliation and lineation. The northwest-trending joint set is best developed in the gneiss east of Lac Alonce, where diabase dykes have been intruded along some of the joints. Contraction fractures normal to the dyke walls are developed here and there, but the dykes are nowhere offset by younger fractures. A northeast-trending joint set is present in outcrops of amphibolite 2 miles east of Lac Gouffier. Perhaps the northeast- and northwest-trending joint sets form a conjugate system.

Relationship of Structural Elements

Structures within rocks in the Labrador Trough appear to be related in origin. The regional schistosity is an axial plane cleavage, which developed during folding; as fracture cleavage in fault zones offsets this schistosity, faulting must have taken place after folding. However, the faults are subparallel to axial planes of folds, and a common origin is therefore suggested. Probably forces directed from the northeast caused folding, local overturning to the southwest, and development of flow cleavage, and during late stages of deformation the faults formed as a direct result of the same southwest-directed force. Reverse movement along the northeast-dipping faults then relieved the stresses imposed on the rocks in the Labrador Trough, and fracturing in the fault zones obscured the fold-developed flow cleavage. Some transcurrent movement occurred in some of the fault zones, as shown by the right-hand offset on the fault in the southwest corner of the map-area. Major transcurrent movement along the fault between the Knob Lake and Murdock Groups may have caused juxtaposition of the blocks showing divergent plunge. Faulting at the east margin of the Labrador Trough in the map-area must have occurred after cessation of deformation of the rocks in the central and western blocks, because the structures of the rocks in these blocks are truncated at the margin by the gneissic block.

Chapter IV

METAMORPHISM

Regional Metamorphism

The slightly to extensively metamorphosed sedimentary, volcanic, and intrusive rocks in the western part of the map-area belong to the greenschist facies, and the gneisses and amphibolites in the eastern part belong to the amphibolite facies. There is no indication of progressive increase in grade of metamorphism from west to east. The greenschist rocks to the west form part of the Labrador Trough; the gneisses and amphibolites may be either basement rocks that have been elevated by faulting, or more highly metamorphosed rocks of the Trough that have been faulted against the lower grade greenschist rocks with consequent removal of the zone showing increasing grade of metamorphism.

Greenschist Facies Rocks

Both muscovite-chlorite and biotite-chlorite associations occur in the Knob Lake, Murdock, and Doublet Groups, but because the mineral assemblages are not zonally distributed, subfacies (Turner, 1948, p. 58) cannot be delineated within the map-area.

Original textures of the sedimentary rocks are well preserved only in competent formations. The quartzites, siltstones, and calcareous rocks show little more than slight recrystallization, but most of the pelitic rocks are extensively recrystallized, and show typical greenschist mineral content. Quartz-albite-chlorite-muscovite and quartz-albite-biotite-chlorite assemblages are common in the slates and phyllites, but clastic oligoclase grains are preserved in some of the sandstones. Perhaps deformation of the less competent pelitic rocks was responsible for their more extensive alteration.

Albite-actinolite-clinozoisite-chlorite-sphene assemblages in the meta-basalts and meta-gabbros have largely taken the place of calcic plagioclase-pyroxene-magnetite-ilmenite assemblages. However, the central parts of some thick gabbro sills are relatively unaltered, showing that equilibrium was not fully attained during metamorphism. Perhaps lack of penetrative deformation in the competent gabbro sills was, in part, responsible for preservation of original pyroxene and plagioclase, but because the sill margins are invariably altered, access of water was probably a more important factor.

Amphibolite Facies Rocks

The gneisses and amphibolites consist essentially of plagioclase (An_{28-42}), blue-green hornblende, biotite, quartz, epidote, and sphene, a mineral assemblage that is typical of the amphibolite facies. Some of the amphibolites contain as much as 8 per cent augite, suggesting a somewhat higher degree of metamorphism, but because abundant hornblende, epidote, and sphene are in equilibrium with the pyroxene, these rocks also belong to the amphibolite facies.

Contact Metamorphism

Intrusion of the sills has had little apparent effect on the country rock, but this may be due to masking of contact metamorphic effects by the regional metamorphism. All contacts observed in the field are sharp, and the mineral content of the intruded rocks at the contacts is identical to that of the intruded rocks remote from the contacts. A fine-grained, weathering-resistant zone less than 2 inches thick commonly occurs in the country rocks at the contacts, and probably formed as a result of local increase in temperature during intrusion.

Several outcrops of siltstone in the Marion Lake Formation show a peculiar mottling consisting of scattered patches rich in chlorite and muscovite. The patches are less than 0.5 cm in diameter and commonly coalesce to form irregular networks parallel to bedding. The spaces between the mottles are invariably bleached, and the chlorite-muscovite content of mottled beds does not differ significantly from that of mottle-free beds. Occurrence of the mottled beds near gabbro sills suggests that the mottling is a contact phenomenon.

Tremolite zones at the margins of several ultramafic sills near Lac La Touche probably formed by contact metamorphism. No analyses are available to demonstrate chemical differences, but the abundance of tremolite suggests a silica content higher than that of the serpentine-rich parts of the sills. Perhaps silica was derived from the sedimentary rocks that enclose all sills in which the tremolite zones were observed.

Fault Zone Metamorphism

Regional cleavage commonly is obscured by fracture cleavage in the fault zones, and in some places a secondary schistosity has developed parallel to the shearing in the fault zones. Chlorite and carbonate minerals, particularly ankerite, are abundant in the fault zones. Carbonatized rocks east of Lac Charny and Lac Buzançois mark zones of extensive shear, which are probably faults. Some specimens contain as much as 30 per cent ankerite.

Age of Metamorphism

Metamorphism of the bedded rocks in the central and western parts of the map-area obviously took place after emplacement of the gabbro sills but prior to faulting at the eastern margin of the Labrador Trough, because the high grade gneisses and amphibolites to the east show no signs of retrograde metamorphism. Folding of the bedded rocks may well have coincided with metamorphism, for these two phenomena are commonly synchronous. Development of metamorphic minerals in the regional cleavage, which in turn is related to the regional folding, lends strong support to this possibility.

Metamorphism of the Eastern Block is related to the origin of the gneisses and amphibolites. These rocks may be: (1) Basement rocks that were unaffected, because of spatial separation prior to uplift along the boundary fault, by the processes responsible for metamorphism of the bedded rocks within the Labrador Trough. (2) Basement rocks that recrystallized during the period of metamorphism affecting the Labrador Trough and that were subsequently uplifted along the boundary fault. (3) Bedded rocks of the Labrador Trough, which were subjected to more intense metamorphism and brought into juxtaposition against the lower grade metamorphic rocks by subsequent faulting.

According to the potassium-argon method of absolute age determination, biotite from a sample of gneiss collected near the east shore of Lac Alonce is 1,875 m.y. old[1]. This age is considerably less than that of biotite from known basement rocks west of the Labrador Trough (2,365 m.y.)[1], but this by no means eliminates origin (1) above, because the basement rocks are probably of several ages. Of the few rocks from the Labrador Trough that have been dated, the geographically nearest sample (Menihek slate, near Schefferville) contains muscovite with age 1,420 m.y. (Quirke, *et al.,* 1960, p. 323). If this is a representative date for metamorphism of rocks in the Labrador Trough, it lends support to origin (1). Further support for origin (1) is provided by ages of 1,660 and 1,860 m.y. (Lowdon, 1960), determined by the lead isotope methods for authigenic galena in stromatolitic dolomite from Cambrian Lake map-area. These dates should approximate the period of sedimentation, which, obviously, must pre-date metamorphism of the sediments in the Trough. However, augen-gneiss, flanking the eastern part of the Trough in Lac Herodier map-area and interpreted by Fahrig *(in* Lowdon, 1960, p. 29) as metamorphosed strata of the Labrador Trough, has yielded biotite dated at 1,935 m.y. Within limits of precision for the K/A method of dating, this age may be concordant with the age of the Lac Alonce sample, suggesting origins (2) and (3) as alternatives for Marion Lake map-area. However, the younger dates from the Labrador Trough, if accurate, tend to refute origins (2) and (3), unless several periods of metamorphism are postulated.

[1]Determinations by Geological Survey of Canada (Lowdon, 1960).

Chapter V

GEOLOGICAL HISTORY

Downwarping of the basement initiated sedimentation in the linear belt now known as the Labrador Trough. Sediments derived from bordering highlands formed the basal Seward conglomerates and arkoses, which are not exposed in the map-area but which do outcrop farther south. Continued erosion reduced elevation of the borderlands, and deposition of the fine-grained Attikamagen clastic rocks ensued. Variations in oxidation potential and organic activity resulted in local deposition of black shales. Uplift along the west side of the Labrador Trough resulted in renewed deposition of arkoses and conglomerates, now part of the Marion Lake Formation. Some rock fragments in these sediments were derived from the underlying Seward and Attikamagen Formations. Slight fluctuations in sea-level caused shifts of the strand line across a low-lying plain, allowing deposition in shallow marine, littoral, fluviatile, and perhaps aeolian, environments. A period of volcanic activity followed, resulting in extrusion of basaltic flows, but probably no major changes in environment occurred. The extensive carbonate deposition that produced the Denault Formation took place in a shallow water to intertidal environment. Algae modified the environment, played a major role in sediment fixation, and may have precipitated much of the dolomite. Some erosion of the Denault Formation occurred before influx of the Wishart clastic sediments. The beds of Wishart sandstone indicate periods of time sufficiently long for attainment of the remarkable textural and compositional maturity that they exhibit. Iron sedimentation started during the deposition of the Wishart Formation, perhaps as a result of change in climate, or perhaps because of contemporaneous volcanism. Deposition of the Menihek Formation probably occurred in somewhat deeper water in a reducing environment.

Rocks of the Murdock Group represent a period of volcanic (dominantly pyroclastic) activity. Sediments of the Doublet Group were deposited in shallow waters, and although the environment may not have differed greatly from that when the Knob Lake strata were deposited, the Doublet sands were not subjected to extensive abrasion and sorting as were the sands of the Marion Lake and Wishart Formations. Volcanic activity ensued, accompanied by intrusion of the abundant sills of the map-area.

Force directed from the northeast resulted in folding about northwest-trending axes in the Labrador Trough. Cleavage and reverse strike-faults formed during the same period, accompanied by metamorphism to the greenschist facies. The east side of the Trough was later faulted, resulting in uplift of the gneisses and amphibolites, which may be either basement rocks or highly metamorphosed rocks of the Labrador Trough.

Chapter VI

ECONOMIC GEOLOGY

Numerous gossans mark the locations of sulphide deposits in the map-area. Some gossans are more than 2,000 feet long, but the sulphide bodies from which they were derived are commonly less than 100 feet long. The transported gossans extend downhill from their source and many of them form stream beds. Pyrite is the most abundant sulphide, but chalcopyrite and pyrrhotite are commonly present. The sulphide minerals are mostly disseminated, but also occupy fractures in the host rocks, which for almost all the deposits are slates of the Menihek Formation or Doublet Group. Shear zones and the contacts between slates and mafic sills are the most common sites of mineralization. Because the slates normally contain finely divided sulphide minerals, it is possible that the sulphide deposits originated by concentration of sedimentary sulphides mobilized as a result of thermal metamorphism (caused by intrusion of the sills) and dynamic metamorphism (within shear zones). The mafic sills, which also contain disseminated sulphides, may have been the source of the sulphides.

Veinlets of cross-fibre asbestos occur in the serpentinite bodies near Lac La Touche and in the tremolite-serpentine body southeast of Lac Rucelai. Most of the asbestos is hard and non-flexible, and fibres of commercial grade were not observed.

Quartz veins as much as 10 feet thick outcrop west of Lac Gauthier and along the chain of lakes northeast of Moss Lake. Traces of disseminated pyrite and chalcopyrite are present in some of these veins.

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APPENDIX A

Calculation of Grain-size Distribution, in Volume Per Cent Frequency, from Thin Section Data

The grain-size distribution of a poorly indurated sedimentary rock is most easily determined by sieve analysis of a representative sample. However, for well-indurated samples, this method cannot be used unless the constituent grains can in some way be separated. For carbonate-cemented quartz sandstones, acid treatment is sufficient for disaggregation, but for rocks in which the cement is identical in composition to the framework particles, no practical method of separation has yet been devised. Alternatively, a selected size parameter can be statistically measured in thin section. Commonly the apparent long axes of grains are measured and grouped in size classes (Krumbein and Pettijohn, 1938, p. 128). The data so obtained, however, are expressed as number frequencies, and are not directly comparable with the weight frequency data obtained by sieve analyses.

The relationship between thin section data and sieve data has been considered by many workers, and mathematical correlation factors have been proposed (Krumbein, 1935; Greenman, 1951). A graphical method of translating thin section distributions to sieve distributions, described by Friedman (1958), is more convenient and possibly more accurate than the mathematical methods.

Because most sandstones in Marion Lake map-area are not amenable to sieve analysis, frequency data were obtained from thin sections of the sandstones, and the data converted to sieve equivalents by use of Friedman's graph (1958, p. 414). Frequency distributions were determined with the aid of a microprojector (Krumbein and Pettijohn, 1938, p. 374) instead of by microscope and point-counter. The procedure is as follows:

1. The microprojector is adjusted to give a suitable image of the thin section on a sheet of white paper. The scale factor is determined by placing a transparent millimetre rule over the thin section.

2. The long axes of all grains in several random fields are measured and grouped according to phi size classes. As each grain is counted, the grain image is stroked off on the field of projection. The numbers in each class are conveniently recorded with the aid of a tally counter. The data are converted to number frequency per cent.

3. The frequency of each class is weighted by multiplying by the square of the class mid-point. This step converts number frequency to apparent area frequency. On the assumption that the thin section represents a random cut through the sampled rock, the apparent area frequency is directly proportional to the apparent volume frequency ($V = A\int dx$).

4. The apparent volume frequencies are converted to per cent values and then summed to give apparent cumulative per cent frequencies for each class.

5. The apparent cumulative values are plotted on the graph given by Friedman (1958, p. 414), and the "true" cumulative values are read on the appropriate scale. The "true" volume frequencies are obtained from this set of figures, and plotted in histograms.

An alternative method, which eliminates the arithmetic computations (step 3, above), consists of projecting the thin section image on a rectangular grid, and measuring long axes of grains located at grid points. Similarly, a grid on transparent plastic can be superimposed on photomicrographs of sandstones or sawed and polished surfaces of conglomerates. These procedures are equivalent to the microscope point-counting technique, but are more convenient, quicker, and less tedious, especially if a strip gauge (Pelletier, 1960) is used for measurement of grain size.

APPENDIX B

Geological Sections in the Denault Formation

The five sections described on the following pages were measured with a 200-foot tape along lines established by Brunton compass. The tape was moved forward in 200-foot increments, and the contacts between units were recorded to the nearest 5-foot mark. The per cent exposure, measured thickness, and true thickness of each unit are tabulated in columns adjacent to the lithological descriptions. The section locations are shown in Figure 4.

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
				SECTION 1
				Top of Section
19	2,355-2,740	365	100	Siliceous dolomite: grey, orange-buff weathered; well laminated, as seen on ribbed weathered surface; fractures smoothly to give a massive-appearing fresh surface; very finely crystalline; laminations planar and persistent laterally; sparse chert nodules, ovoid in section, elongate parallel to bedding.
18	2,300-2,355	50	100	Dolomite: grey, buff-grey weathered; finely crystalline; undulatory stromatolites and minor quartz veinlets.
17	2,265-2,300	30	40	Algal unit: light grey and buff, carbonaceous dolomite; 4-7″ columnar stromatolites, differentially weathered; 1-2 cm pisolites at base; thin veinlets of quartz are abundant.
16	2,195-2,265	65	40	Dolomite: grey, buff weathered; medium grained crystalline; undulatory stromatolites; quartz interlayers near top. Bedding 90;55N.
	2,115-2,185	60	70	
	1,915-2,115	185	70	Dolomite: dark grey, buff-grey weathered; finely crystalline; irregular, undulatory stromatolites in places; veinlets and lenses of quartz abundant; a few chert nodules, and some black chert beds.
15	1,870-1,915	40	100	Algal unit: dark grey, cream-buff weathered carbonaceous dolomite; lower 25′ pisolitic; upper 15′ contains columnar stromatolites with heads 6-12″ in diameter. Intraformational conglomerate between algal heads at top of unit. Bedding 105;55N.
14	1,790-1,870	70	100	Siliceous dolomite: grey, grey weathered; massive; finely crystalline; abundant veinlets and irregular pods of quartz; some chert nodules near top.

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
14	1,540-1,790	230	100	Siliceous dolomite: dark grey, buff to brown weathered; very finely crystalline; undulatory stromatolites; scattered glassy quartz sand grains; abundant digitate stromatolites as much as 2 mm in diameter. Bedding 120;55N.
	1,380-1,540	140	100	Siliceous dolomite: grey to dark grey, buff weathered; fairly massive, medium crystalline, faint planar laminations in some exposures; a few irregular plates of quartz parallel to bedding; abundant digitate stromatolites, 1-3 mm in diameter.
	1,335-1,345	10	100	Siliceous dolomite: dark grey, buff-brown and buff-grey weathered; intraformational conglomerate; many quartz veinlets.
	1,235-1,335	95	100	Dolomite: grey, buff weathered; finely crystalline; massive; quartz lenses and layers parallel to bedding.
	1,120-1,235	110		Covered
13	1,095-1,120	25	100	Algal unit: dark grey, buff weathered carbonaceous dolomite; small columnar stromatolites 3-6″ in diameter; occur in zones separated by well-laminated, grey dolomite; some intraformational conglomerates; generally at top of zones.
12	965-1,095	125	80	Dolomite: grey, cream to dark grey weathered; fine to medium crystalline; massive; milky quartz plates parallel to bedding.
11	950-965	15	100	Algal unit: columnar stromatolites 6-10″ in diameter; differentially weathered grey and buff laminations 1-2 cm thick. Bedding 120;80NE.
10	855-950	90	100	Dolomite: grey, buff-grey weathered; well laminated; medium grained; scattered oval chert nodules and a few veinlets of milky quartz.
9	790-855	60	100	Algal horizon: 10′ of intraformational conglomerate at the base; 2-4″ hemispherical stromatolites compose most of the remainder; the upper 15′ is pisolitic (concentrically laminated subspherical bodies, 0.2-4 cm in diameter); most of the rock is dark grey, carbonaceous dolomite.
8	660-790	125	100	Siliceous dolomite; grey, cream to grey weathered; fine to medium crystalline; a few quartz sand grains and irregular pods of quartz.
	555-660	105	100	Dolomite: light grey, buff-grey weathered; finely crystalline; well laminated in places; scattered quartz layers and lenses.
	500-555	55	100	Dolomite: light grey, dark weathered; medium crystalline, massive; a few quartz layers.
6	480-500	20	100	Dolomite: grey on fresh and weathered surfaces; fine to medium crystalline; scattered black chert nodules, elongate parallel to bedding. Bedding 130;75N.
5	390-480	90	100	Dolomite: dark grey, buff-grey to dark grey

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
	340-390	50	60	weathered; undulatory stromatolites, but generally massive; many quartz veinlets parallel to bedding and fractures; chert nodules in the lower part. Bedding 115;V. Intraformational conglomerate at 465-480.
	310-340	30	30	
3	210-310	100	20	Dolomite: dark grey; dove grey to tan-brown weathered; medium crystalline; undulatory stromatolites; milky quartz pods and veinlets. Bedding 130;V. Fractures at 15;V and 65;75NW.
2	110-210	100	20	Siliceous dolomite: cream-grey, buff weathered; very well laminated, finely crystalline; planar, closely spaced bedding surfaces; a few cross-beds.
	0-110	110		Covered

Total thickness 2,580

SECTION 2

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
				Top of Section
19	2,265-2,315	40	100	Siliceous dolomite: cream-grey to grey, buff-brown to tan weathered; very finely crystalline; very well laminated; some chert nodules. Bedding 45;60N.
18	2,260-2,265	20	100	Siliceous dolomite: grey, buff weathered; fine to medium crystalline; some undulatory stromatolites; intraformational conglomerate at base.
17	2,220-2,260	30	80	Algal unit: grey, buff weathered, slightly carbonaceous dolomite; 2′ pisolitic layer overlain by columnar stromatolites, 5-8″ in diameter.
16	2,145-2,220	60	80	Siliceous dolomite: grey, buff weathered; fine to medium crystalline; many irregular plates of quartz parallel to bedding and quartz veinlets along fractures; undulatory stromatolites in upper 25′.
15	2,130-2,145	15	80	Algal unit: dark grey, buff weathered, medium crystalline carbonaceous dolomite; well laminated to massive; many pisolitic layers; digitate stromatolites at 2,005′ and 2,055′.
	2,055-2,130	70	30	
	2,005-2,055	45	70	
14	1,805-2,005	185	20	Siliceous dolomite: grey, grey to buff weathered; finely crystalline, some undulatory and digitate stromatolites and some pisolites as much as 3 cm in diameter; quartz veinlets along fractures in upper 60′. Bedding 40;55N.
	1,705-1,805	90	30	
	1,540-1,705	150		Covered
	1,330-1,540	190	50	Siliceous dolomite: tan to light grey, buff weathered; very finely crystalline; massive; minor lenses and plates of milky quartz; a few pisolites and small digitate stromatolites towards top.

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
13	1,305-1,330	25	50	Algal unit: columnar stromatolites as much as 2″ in diameter; buff to grey weathered carbonaceous dolomite. Bedding 50;60NE.
12	1,255-1,305 1,230-1,255	45 25	50 100	Siliceous dolomite: grey to pink, dove grey to buff weathered; very finely crystalline; massive to finely bedded; some undulatory stromatolites; a few quartz lenses and chert nodules.
11	1,190-1,230	40	100	Algal unit: grey, buff weathered, siliceous dolomite; lower 15′ pisolitic; upper part contains many columnar stromatolites as much as 6-8″ in diameter; some milky quartz along laminations.
10	995-1,190 970-995	180 25	40 20	Siliceous dolomite: light grey to cream, buff-grey weathered; fine to medium crystalline; well laminated to massive, with plates and veinlets of quartz; some undulatory stromatolites at 1,040-1,060′; a few chert nodules in upper part. Bedding 50;65N.
9	935-970	30	20	Algal unit: columnar stromatolites, 4-7″ in diameter and 2-4″ high; dark grey, carbonaceous dolomite, fragmental at top.
8	895-935 800-895	30 85	20 80	Siliceous dolomite: pink to light grey, cream-buff weathered; very finely crystalline; massive; a few quartz pods; some quartz sand in upper 60′.
7	720-800	70	100	Siliceous dolomite: grey, cream-buff weathered; finely crystalline; thinly laminated; small amount of quartz in veinlets and pods.
	670-720	50		Covered
6	645-670	25	50	Siliceous dolomite: light grey, buff weathered; very finely crystalline; finely laminated; a few black chert nodules; parting parallel to bedding. Bedding 40;70N.
5	600-645 500-600	40 90	50 20	Siliceous dolomite; grey to pink-buff to dark grey weathered; finely crystalline; massive to poorly bedded; a few quartz pods, and quartz veinlets along fractures in upper 40′.
3	400-500	85	80	Siliceous dolomite: same as for 110-375.
	375-400	30		Covered
	230-375 110-230	135 110	50 100	Siliceous dolomite: light grey, grey-brown weathered; fine to medium crystalline; massive to poorly laminated; partly brecciated, with patches of white quartz along fractures; irregular bedding; a few quartz pods and chert nodules; several thin layers of intraformational conglomerate. Bedding 30;60-NW.
2	0-110	95	100	Siliceous dolomite: light cream-grey, tan to orange-buff weathered; very finely crystalline; massive fractures; parting parallel to planar bedding; very well laminated; some crossbedding; well-developed joints at right angles to bedding. Bedding 35;70NW.
Total thickness 2,115				

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
				SECTION 3
				Top of Section
19	915-1,000	80	100	Siliceous dolomite: light grey, tan weathered; planar, closely spaced laminations; very finely crystalline; massive on fractured surface; a few chert nodules. Bedding 120;75 NE.
18	840-915	70	100	Dolomite: grey, buff weathered; fine to medium crystalline; 2′ intraformational conglomerate at base; upper part exhibits undulatory stromatolites.
17	810-840	30	100	Algal unit: dark carbonaceous dolomite; columnar stromatolites, 5-7″ in diameter, weathered in relief along alternate laminations of grey and buff dolomite; fragmental material between the closely packed heads.
16	510-810	295	20	Dolomite: grey, light grey weathered; medium to finely crystalline; abundant plates of milky quartz parallel to bedding and along fractures; undulatory stromatolites in the upper 90′. Bedding 115;85NE.
	440-510	70	80	Dolomite: grey, grey to buff weathered; massive; a few ovoid chert nodules and milky quartz pods; many quartz veinlets along fractures.
15	390-440	50	80	Algal unit: dark carbonaceous dolomite; 5′ basal intraformational conglomerate; columnar stromatolites above this; the largest heads, 8-10″ in diameter, are at the top; well-laminated dolomite separates successive colonies. Bedding 110;V.
14	305-360	55	80	Siliceous dolomite: dark grey, grey to buff weathered; finely crystalline; a few chert nodules and quartz pods; many quartz veinlets along fractures.
14	195-305	105	100	Siliceous dolomite: dark grey; cream to dark grey weathered; slightly carbonaceous; undulatory and digitate stromatolites compose about 20 per cent of the unit; pisolitic from 270-285. Bedding 115;80NE.
	0-195	190	100	Siliceous dolomite: light grey, cream-buff to dark grey weathered; massive, finely crystalline; a few milky quartz lenses parallel to bedding, where present; intraformational conglomerates at 85-90 and 120-135.
Total thickness 945				

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
				SECTION 4
				Top of Section
17	2,255-2,295	35	75	Algal unit: grey, light grey weathered, carbonaceous dolomite; finely crystalline; concentrically laminated pisolites 0.2-1 cm in diameter, and many digitate stromatolites in

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
				lower part; some 6-19″ columnar stromatolites at top.
16	2,040-2,255	205	75	Dolomite: grey, light grey weathered, finely crystalline; massive; a few chert nodules and thin quartz-carbonate veins; quartz lenses abundant near top. Bedding 105;55N.
15	1,965-2,040	70	85	Algal unit: concentric pisolites, 0.2-2 cm in diameter in a grey, buff weathered, fine-grained matrix; 8-10″ columnar stromatolites in upper 15′ of unit; a few digitate stromatolites in the lower part.
14	1,945-1,965 1,865-1,945	20 75	85 25	Siliceous dolomite: grey, cream-buff weathered, very fine grained; massive; undulatory stromatolites near base; several zones of pisolites and digitate stromatolites. Quartz and carbonate veins abundant. Scattered quartz lenses in central part and chert nodules near top.
	1,830-1,865	35	45	Dolomite: grey, buff weathered; finely crystalline; undulatory stromatolites; pisolites in some exposures. Bedding 100;70N.
	1,775-1,830	50		Covered
	1,720-1,775	55	75	Dolomite: dark grey, dark weathered; undulatory laminations near top; quartz veins in massive lower part; pisolites and 1″ digitate stromatolites at 1,740′; some intraformational conglomerates.
	1,675-1,720	40		Covered
14	1,590-1,675 1,535-1,590	70 50	25 100	Dolomite: grey, dove-grey to buff weathered; massive at base, some undulatory stromatolites at top; many fragmental zones, and some pisolites at 1,555′; a few chalcedony pods and quartz lenses.
	1,325-1,535	185		Covered
	1,215-1,325	95	70	Dolomite: grey, dove-grey to dull buff weathered, finely crystalline, massive; quartz stringers and pods accentuate the poor bedding. Bedding 100;70N. Pisolites in upper 10′ of exposure, 1-3 cm in diameter, concentrically banded.
13	1,205-1,215	10	70	Algal unit: dark carbonaceous dolomite; columnar stromatolites, 2-6″ in diameter.
12	1,095-1,205 1,075-1,090	90 15	25 85	Dolomite: cream-grey, tan weathered; medium to finely crystalline; massive; a few quartz lenses.
11	1,060-1,075	15	85	Algal unit: columnar stromatolites 6-8″ in diameter, overlain by intraformational conglomerate. Dolomite is tan to flesh-coloured, buff weathered.
10	1,035-1,060 975-1,035 925-975	20 55 45	85 55 85	Dolomite: grey, buff weathered, massive; a few chert nodules and quartz-carbonate stringers. Bedding 85;65N.
9	900-925	25	85	Algal unit: cream-grey, siliceous dolomite, light brown weathered, massive, columnar stromatolites 2-4″ wide in lower 15′. Subspherical pisolites in upper part.

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
8	750-900	135	75	Siliceous dolomite: dark grey, buff to dark weathered; massive; finely crystalline. A few quartz grains in some exposures. Some chalcedony pods.
8	640-750	95	40	Siliceous dolomite: grey, dove-grey weathered, finely crystalline; a few irregular pods of chalcedony, and veinlets of quartz; poor bedding. Bedding 105;65NE.
	525-640	100	20	Siliceous dolomite: grey-brown, buff-brown weathered; finely crystalline, massive; many pink and white quartz-carbonate veinlets and coarsely crystalline patches of quartz.
6	485-525	30	40	Dolomite: grey, grey-buff weathered; medium to finely crystalline. A few ovoid black chert nodules, flattened parallel to bedding.
5	350-485	120	40	Siliceous dolomite: grey, light buff to grey weathered; dark brown beneath moss; massive, finely crystalline; several flat pebble conglomerates; a few chert nodules and numerous small carbonate stringers. Increasingly carbonaceous towards top, where undulatory stromatolites are prominent. Exposures interrupted by swamps. Bedding 100;60N.
4	335-350	15	40	Siliceous dolomite and chert: dark grey to black chert fragments in a light grey siliceous matrix.
3	280-335	50		Covered
	205-280	70	20	Dolomite: grey, buff weathered, carbonaceous;
	180-205	20	30	finely crystalline; lowermost 20′ massive with a few quartz-filled fractures (35;60NW), undulatory stromatolites and pisolites in upper part. Bedding 95;55N.
2	100-180	70	30	Siliceous dolomite: cream-buff; orange-buff weathered; very finely crystalline; very well laminated; planar beds less than 5 mm thick are clearly visible on ribbed weathered surfaces, but not visible on smooth-fracturing fresh surfaces; small-scale crossbedding. Bedding 95;60N.
2	0-100	90		Covered

Total thickness 2,055

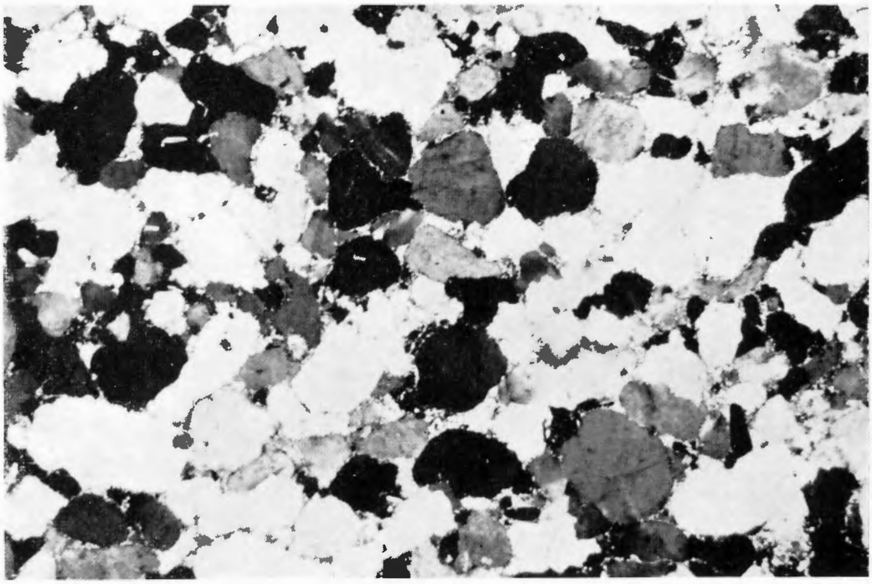
SECTION 5

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
				Top of Section
18	2,885-2,945	50	100	Dolomite: grey, grey weathered; undulatory stromatolites; finely to medium crystalline; smooth fractures.
17	2,875-2,885	10	80	Algal unit: carbonaceous dolomite; columnar stromatolites, 6-10″ in diameter; alternate buff and grey laminations.
16	2,835-2,875	40	60	Dolomite: grey, buff-grey weathered; medium
	2,740-2,835	90	20	to finely crystalline; many chert nodules and

Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
	2,715-2,740	30	80	carbonate veins; lenses of quartz near the top.
15	2,715-2,735	15	60	Algal unit: dark, carbonaceous dolomite; columnar stromatolites 8-12″ in diameter; alternate buff and light grey laminations.
14	2,650-2,715	50	60	Siliceous dolomite: light grey, grey weathered; massive; scattered chert nodules and a few irregular pods of milky quartz; quartz stringers.
	2,580-2,650	55		Covered
	2,395-2,580	175	20	Dolomite: grey, buff-grey weathered; finely to medium crystalline; undulatory stromatolites; algal pisolites at 2,250-2,255′ and 2,415-2,430′. Pisolites are subspherical, concentrically laminated, 0.2-3 cm in diameter. Bedding 90;70N.
	2,335-2,395	160	40	
	2,035-2,335	290		Covered
	1,885-2,035	145		Dolomite: same as unit 12.
13	1,875-1,885	10	80	Algal unit: buff to grey, carbonaceous, dolomite; columnar stromatolites, 4-6″ in diameter; poorly laminated.
12	1,660-1,875	215	80	Dolomite: dark grey, grey to tan weathered; medium crystalline; massive; scattered quartz stringers and lenses parallel to bedding. Bedding 85;75N.
11	1,650-1,660	10	100	Algal unit: carbonaceous dolomite; columnar stromatolites 8-10″ in diameter; alternate grey and buff laminations, differentially weathered.
10	1,400-1,650	245	100	Dolomite: light grey to buff-grey, cream-buff weathered; massive; rough weathered surface; many grey to white chert nodules; scattered irregular milky quartz pods and carbonate veinlets parallel to bedding and along fractures at 40;70NW and 155;60NE.
9	1,385-1,400	15	100	Algal unit: grey to buff carbonaceous dolomite; columnar stromatolites 4-8″ in diameter, ribbed weathered surface outlines the laminations.
	1,375-1,385	10	100	Flat pebble conglomerate: dark grey, dark weathered fragments in an arenaceous dolomite matrix.
8	1,230-1,375	145	80	Dolomite: grey to light grey, buff weathered; fine to medium crystalline; massive; scattered quartz grains; many irregular lenses of white quartz. Bedding 80;V.
	1,205-1,230	25	80	Siliceous dolomite breccia: light grey, medium-grained to finely crystalline fragments cemented by milky quartz; massive; rough weathered surface; numerous irregular quartz pods and veinlets. Most prominent fractures at 150;V.
	1,095-1,205	110	90	Dolomite: light grey, dove grey weathered; medium crystalline; scattered quartz sand grains; rough weathered surface; obscure bedding; a few irregular pods of quartz; two

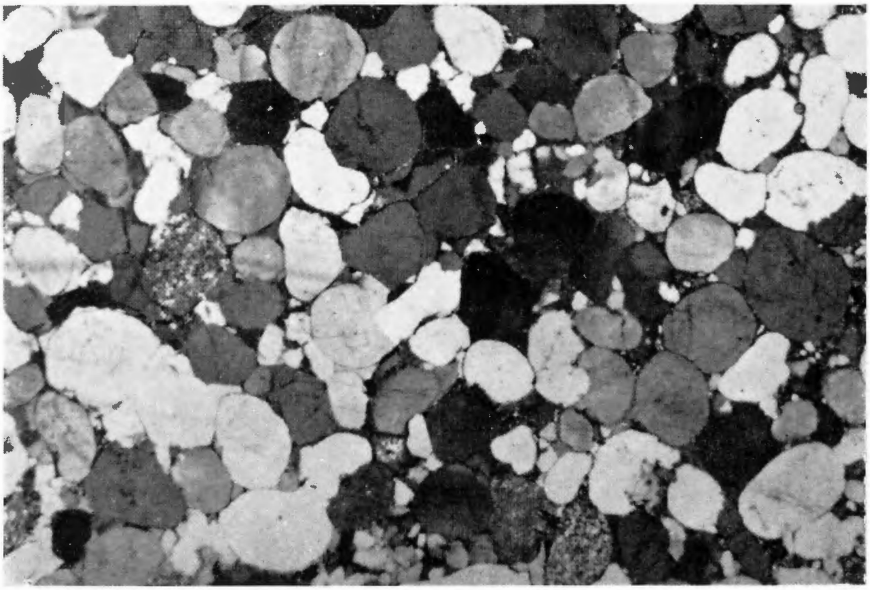
Unit	Measured Distance (Feet)	True Thickness (Feet)	Per cent Exposure	Description
				prominent sets of intersecting carbonate veinlets. Bedding 85;V.
7	1,030-1,095	60	90	Dolomite: dark grey, grey weathered; medium to finely crystalline; well laminated; a few irregular masses of milky quartz. Bedding 85;V.
6	1,010-1,030	20	90	Dolomite: dark grey, buff weathered; medium to finely crystalline; black chert; ovoid nodules elongate parallel to bedding.
5	970-1,010	40	30	Dolomite: grey to dark grey; buff to grey weathered; medium to finely crystalline; undulatory stromatolites. Bedding 50;V.
	905-970	60	30	Dolomite: grey to dark grey; tan to grey weathered; medium to finely crystalline; massive; scattered grey to white chert nodules, ovoid in section, elongate parallel to bedding; numerous quartz-carbonate veinlets less than 2 cm thick follow fracture sets at 5;60W and 120;75NE.
4	890-905	15	60	Siliceous dolomite and chert: dull black, rusty to dark weathered; much fractured and brecciated. Grades upward to green-grey, rusty grey weathered siliceous dolomite which exhibits faint bedding.
3	715-890	175	60	Siliceous dolomite: dark grey, buff to grey weathered; finely crystalline; bedding obscure; some undulatory stromatolites. Bedding 55;80NW.
2	635-715 565-635 465-565	 235	10 30 100	Dolomite: grey, cream-buff weathered; finely crystalline; well-laminated planar beds increasingly thinner and more regularly spaced towards the top. Local small-scale crossbedding. Bedding 65;86NW.
	240-465	215	0	Marion Lake
2	65-240	165	100	Siliceous dolomite: light grey, tan-buff weathered; very finely crystalline; very well laminated with ribbed weathered surface controlled by bedding; beds paper-thin to 1 mm thick, planar and remarkably persistent; local small-scale crossbedding. Bedding 60;V.
1	0-65	60	100	Siliceous dolomite: cream-grey, orange to tan weathered, very finely crystalline; planar-bedded; fair to well laminated; grid pattern of surface grooves developed by fracture-controlled weathering. Bedding 70;80SE. Fracture sets at 10;45W and 100;85SW.
Total thickness 2,860				

PLATE 1



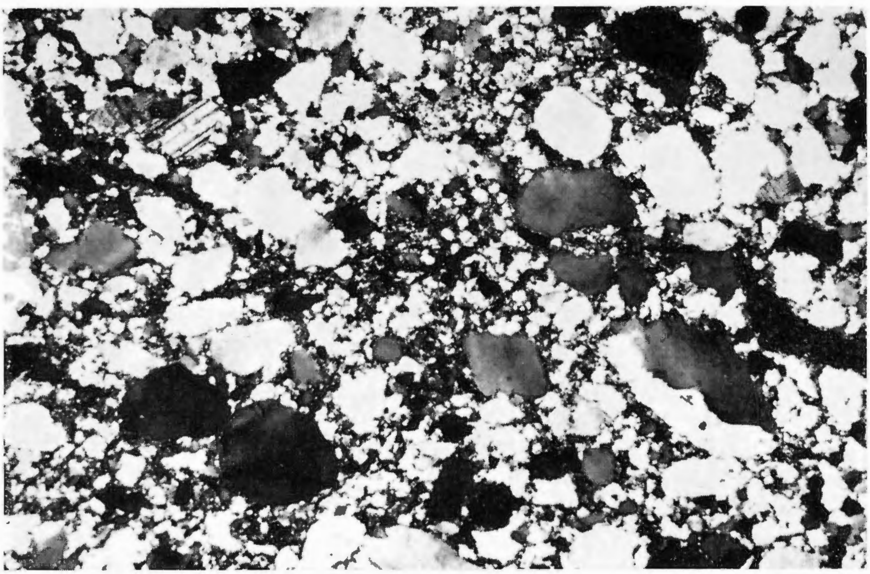
112469-A

A. Photomicrograph of orthoquartzite, Marion Lake Formation, showing well-sorted, well-rounded, subspherical grains of quartz. Note fine micas along grain boundaries, and abundance of microstylolitic interpenetration. Crossed nicols, x40.



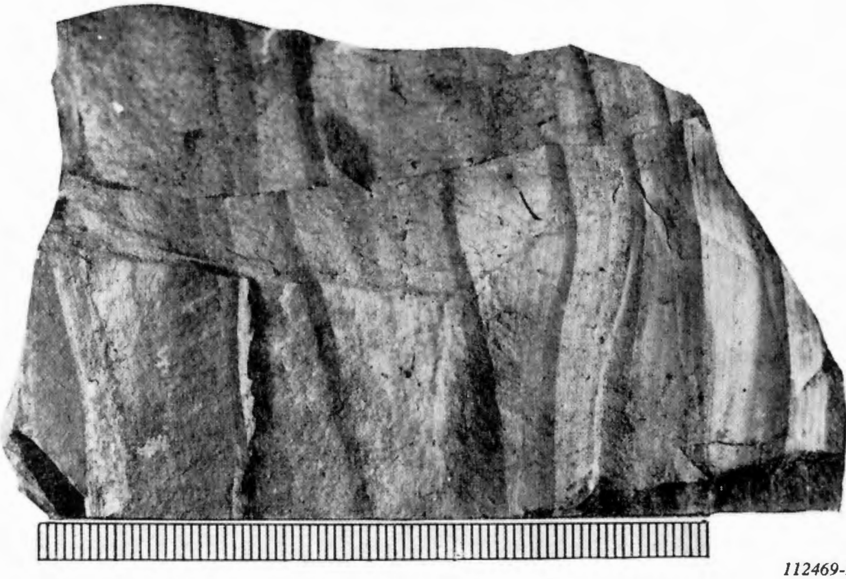
112469-B

B. Photomicrograph of upper orthoquartzite, Wishart Formation. Note excellent rounding and striking sphericity of both quartz and chert grains. Crossed nicols, x30.



112469-C

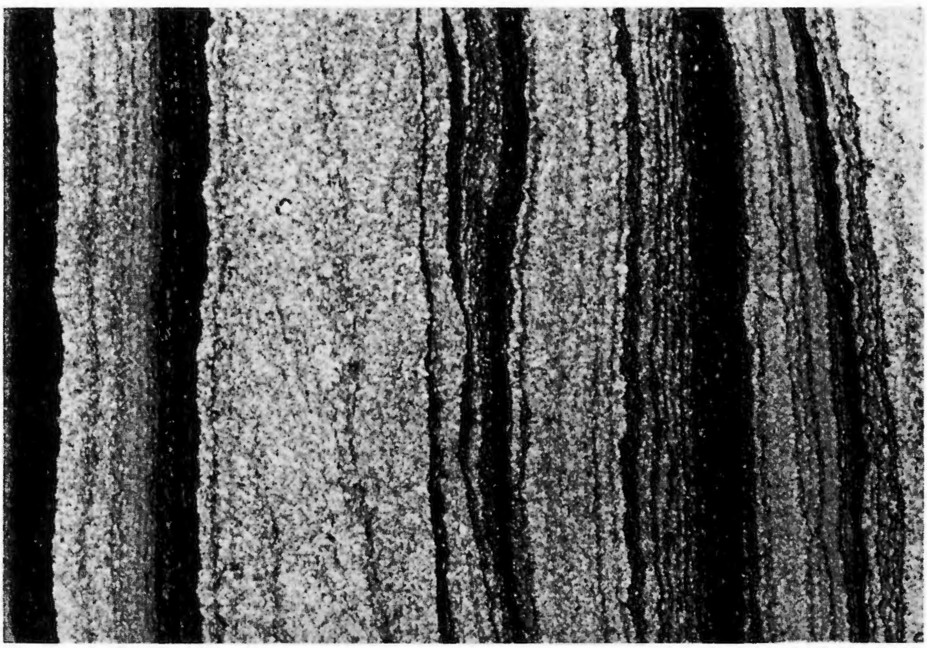
C. Photomicrograph of typical Doublet quartzite, showing poorly sorted, rounded to subangular quartz and feldspar grains. Note strong undulatory extinction and abundance of composite grains. Crossed nicols, x20.



112469-D

A. Rhythmically bedded siltstone, Marion Lake Formation, showing graded bedding and fine lamination within the graded beds. Tops of beds face right. Silty layers light grey; finer grained layers dark grey.

PLATE II



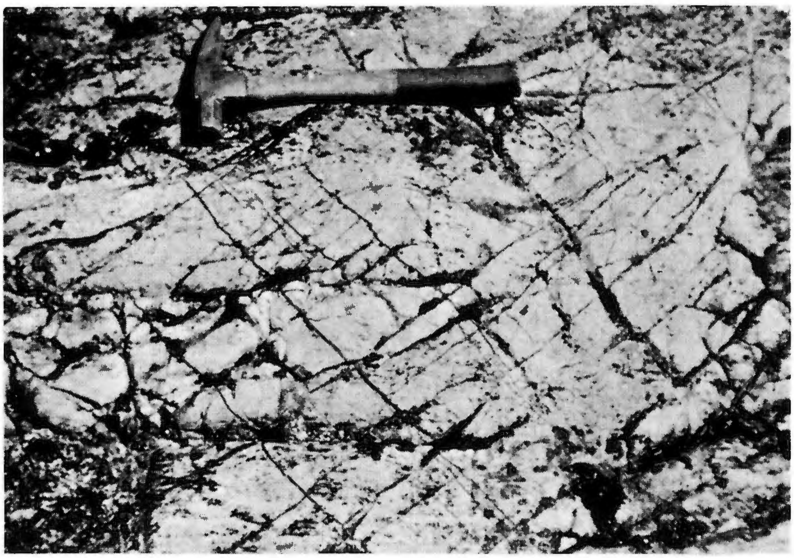
112469-E

B. Photomicrograph of rhythmically bedded siltstone, Marion Lake Formation. Tops of beds face right. Note gradations in colour and grain size. Crenulation of laminations in part due to cleavage oblique to bedding. Plane polarized light, x10.

112469-F

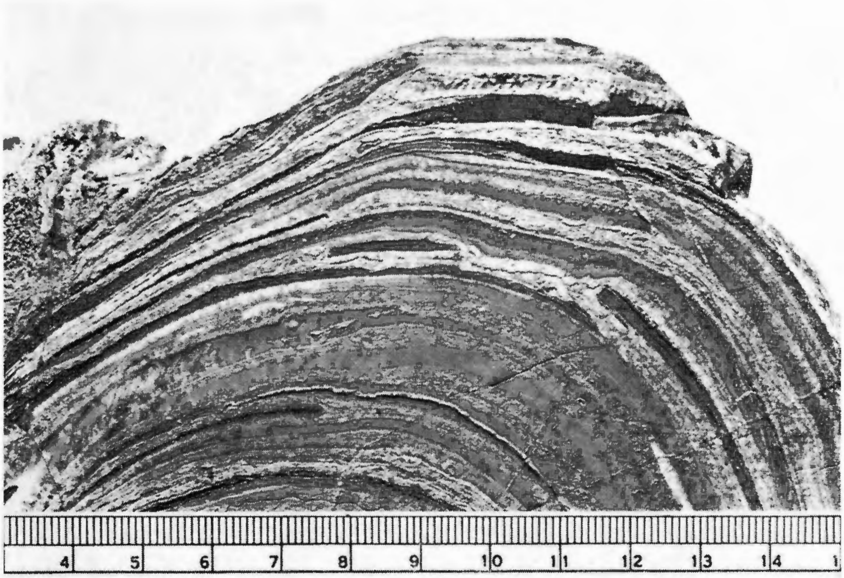
A. Laminated siliceous dolomite, Denault Formation, showing ribbed weathered surface.

PLATE III



112469-G

B. Weathered surface of massive dolomite, Denault Formation. Note prominent joint sets obliquely symmetrical to faintly visible bedding (parallel to hammer handle).



112469-H

A. Acid-etched longitudinal section of hemispherical stromatolite. Note alternation of dark carbonaceous layers and light carbon-poor layers. Truncation of several carbonaceous layers suggests vigorous wave action during growth.

PLATE IV

112469-J

B. Acid-etched longitudinal section of digitate stromatolites. Note detrital nature of interspaces and correspondence in thickness for successive laminations in adjacent 'fingers'. Note also overlying intraformational conglomerate containing carbonaceous fragments which probably were derived from algae-reinforced layers of hemispherical stromatolites. x2

112469-I

C. Weathered surface of pisolitic stromatolites. Structureless pellets are abundant in the matrix, and also form the nuclei of some stromatolites. Note abundance of fragmental pisolites (scale in millimetres).

PLATE IV

112469-K

D. Undulatory stromatolites seen in differentially weathered outcrop. Irregular white protuberances subparallel to bedding are quartz pods.

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