TH 1460

A STUDY OF THE YORK RIVER FORMATION IN THE RIMOUSKI-MATAPEDIA AREA, QUEBEC

A study of the York River formation in the Rimouski-Matapedia area, Québec

NORTHWESTERN UNIVERSITY

A STUDY OF THE YORK RIVER FORMATION IN THE RIMOUSKI-MATAPEDIA AREA, QUEBEC

A THESIS
SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
for the degree
MASTER OF SCIENCE
Field of Geology

By
WILLIAM GREY AYRTON
Evanston, Illinois
June, 1962

W. G. Ayrton.

TABLE OF CONTENTS

ILLUSTRATIONS

PAGE

ACKNOWLEDGEMENTS

The field work for this study was done while the writer was employed by the Quebec Department of Mines. Special acknowledgement is due to Dr. Jacques Beland of the Quebec Department of Mines, who supervised this study in the field, and who provided the writer with the benefit of his considerable field experience in Gaspe.

Dr. E.H.T. Whitten of Northwestern University guided and advised the writer during the preparation of this thesis. Professors L.L. Sloss and E.C. Dapples of Northwestern University, and Dr. E.K. Walton, visiting professor from the University of Edinburgh read the manuscript and offered many helpful suggestions. Professor A.J. Boucot of the Massachusetts Institute of Technology identified the fossil collections. John Pressley, technician at Northwestern University cut thin-sections. To all of the above, the writer wishes to express his appreciation.

Particular acknowledgement is due to my wife, without whose assistance and encouragement this thesis would have been long delayed.

CHAPTER I

INTRODUCTION

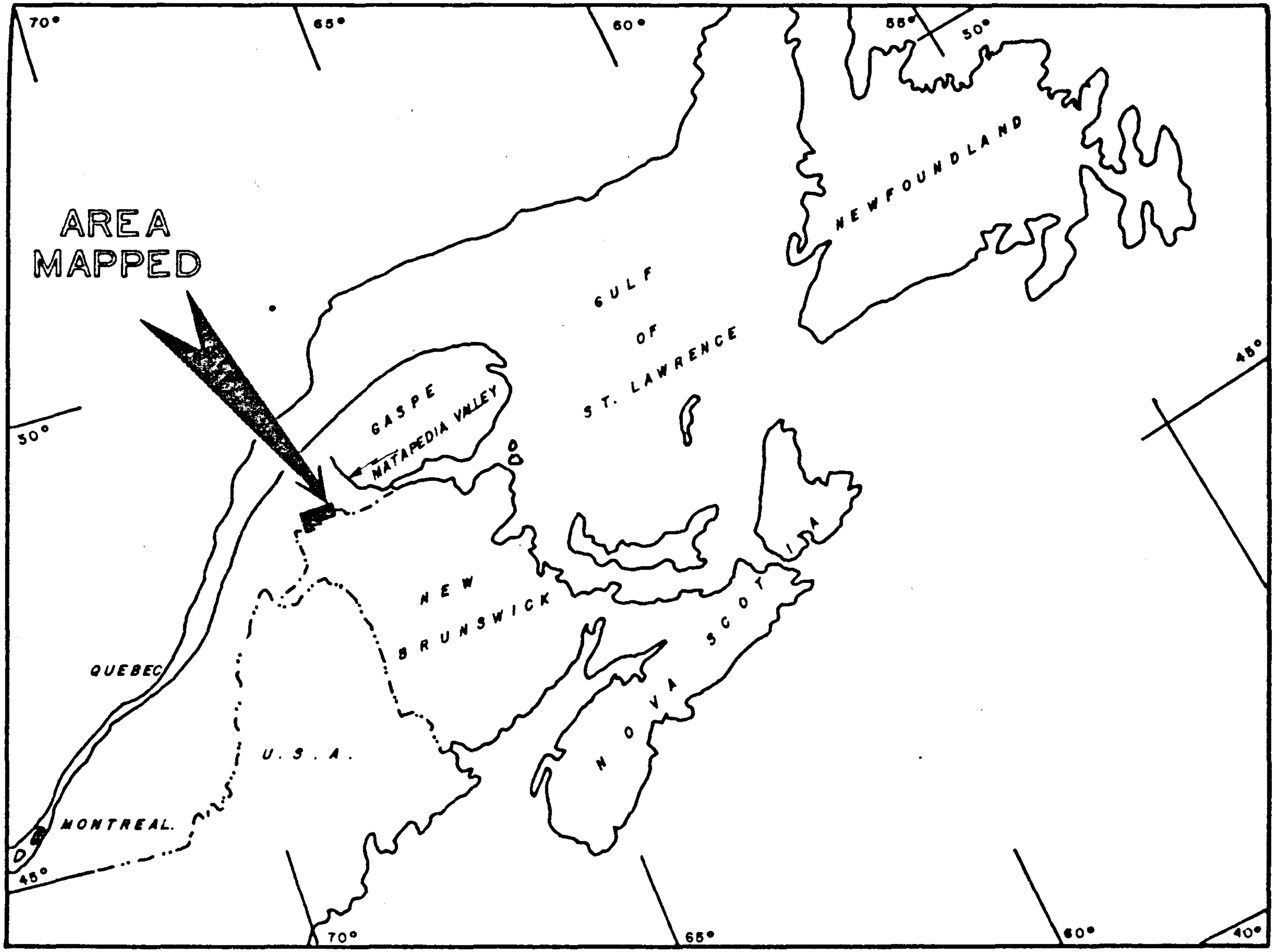
1. GENERAL STATEMENT

This study is primarily concerned with the petrology, stratigraphy and structure of the York River Formation, the lowest unit of the Gaspe Sandstone Group (Devonian). The area chosen for study is in the southwestern part of the Rimouski-Matapedia area of southeastern Quebec (Map 1).

The distribution of lithology, the tectonic framework of sedimentation and the environment of deposition are also examined. Fossils were collected but no attempt is made to make a detailed paleontological study.

2. FIELD WORK

A combination of thick glacial till, dense forests, and the location of the area along a main drainage divide, results in a lack of continuous exposure and difficult mapping. The writer became familiar with some of the regional



MAP I. LOCATION OF RIMOUSKI - MATAPEDIA AREA.

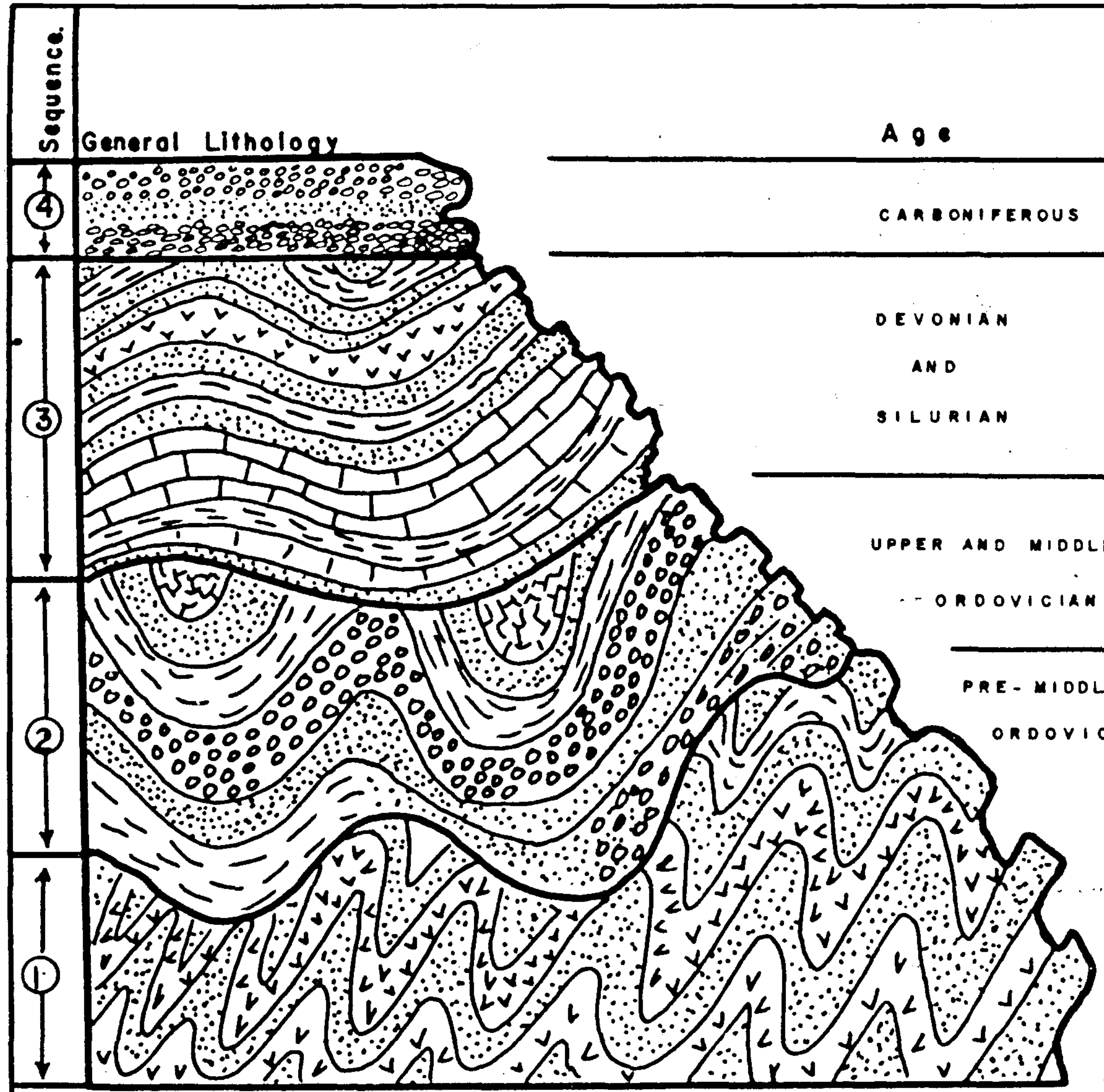
and stratigraphic problems while mapping similar rocks east of the present area in 1958. Four weeks were spent mapping the York River Formation in the Rimouski-Matapedia area in 1959. Access to this area is fairly good, by gravel roads. Advance topographic maps, 2" to 1 mile, prepared by the Department of Mines and Technical Surveys, Ottawa, were used together with aerial photographs taken by the Royal Canadian Air Force. The photographs were not particularly useful because of the dense forest cover. Many of the roads have been constructed recently and are not shown on the photographs. The best exposures occur in cuts along the roads; the streams cut through the thick glacial till and for the most part are still clogged with this material. Many streams were traversed using pace and compass methods, but in general did not provide much rock exposure.

Jean Claude Dube and Denis Gagne were field assistants.

3. GENERAL GEOLOGY OF GASPE

The Gaspe Peninsula and the Rimouski-Matapedia area are part of the northeastern end of the Appalachian mountain system on the continental mainland. The rocks comprise folded and faulted Paleozoic sedimentary strata intruded by granites, diorites, dolerite dikes and serpentinites. The regional structural trend is approximately parallel to the arcuate outline of the peninsula.

The rocks of the sedimentary column can be divided into four sequences, separated by three striking angular unconformities (Fig. 1). The term "sequence", used in the sense defined by Wheeler (1958, p.1051), "is a preserved stratal assemblage which is unconformably separated from underlying and overlying rocks". The oldest sequence consists of the Maquereau Group, the Shickshock Group and the Murphy Creek Formation, all of which are pre-Middle Ordovician. The Maquereau Group, which crops out only in southeast Gaspe, comprises metamorphosed unfossiliferous graywackes and greenstones, whereas the Shickshock Group, which crops out in northwest Gaspe, comprises mainly hornblende-chlorite schists; McGerrigle (1954) has interpreted the latter as metamorphosed basic to intermediate volcanics. The fossiliferous limestones and shales of the Murphy Creek Formation (Upper Cambrian) crop out in eastern Gaspe. The stratigraphic relationships between these three isolated units is as yet unknown.



Age	Examples of lithologic units (not necessarily in stratigraphic order)
CARBONIFEROUS	BONAVENTURE CONGLOMERATE
DEVONIAN AND SILURIAN	GASPE SANDSTONE GROUP LAKE BRANCH FORMATION YORK RIVER FORMATION GASPE LIMESTONE GROUP GRANDE GRÈVE FORMATION CAPE BON AMI FORMATION FORTIN GROUP CHALEURS BAY GROUP ETC.
UPPER AND MIDDLE ORDOVICIAN	MATAPEDIA GROUP NORMANSKILL FORMATION DEEPKILL FORMATION MICTAW GROUP ETC.
PRE-MIDDLE ORDOVICIAN	MAQUEREAU GROUP SHICKSHOCK "SERIES" MURPHY CREEK FORMATION

FIG. 1. GENERALIZED DIAGRAMMATIC SECTION SHOWING STRATIGRAPHIC AND STRUCTURAL RELATIONSHIPS IN GASPE.

The second sequence includes the Middle and Upper Ordovician strata. This series of closely folded conglomerates, sandstones, shales, slates and limestones is unconformable on the first sequence. This unconformable relationship is best seen outside the thesis area in southeastern Gaspe, where conglomerates of the Middle Ordovician Mictaw Group overlie the Maquereau Group (Ayrton, 1960).

Overlying the second sequence, with angular unconformity, are folded Silurian and Devonian strata, generally referred to as the Gaspe Limestone and Gaspe Sandstone Groups. Volcanics are present in this sequence. Crickmay (1932) believed that the unconformity separating the second and third sequences is evidence of the Taconic Orogeny, which caused deformation of the Northern Appalachians during the Late Ordovician.

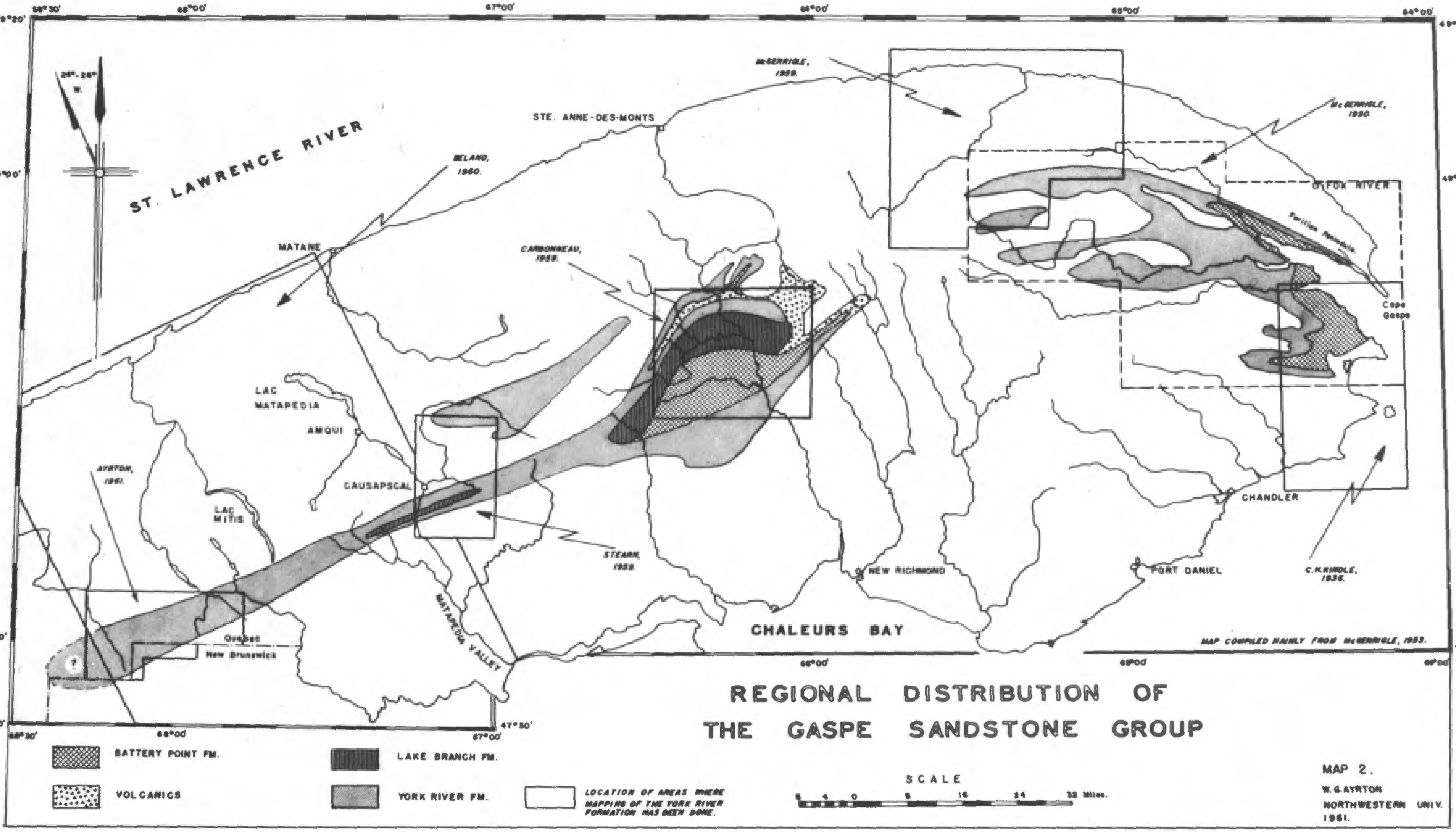
The third sequence is unconformably overlain by subhorizontal Carboniferous red non-marine conglomerates and sandstones of the fourth sequence, (Alcock, 1935, p. 89). This third regional unconformity is attributed to the Acadian Orogeny, the last major orogenic episode to affect the Northern Appalachians (McGerrigle, 1950, p.105).

Volcanics are associated mainly with the first and third sequences. Intrusive igneous rocks are found, but are not widespread. A large granitic body intruded Ordovician strata in north-central Gaspe, and two bands of serpentinites can be outlined roughly. Dikes and sills of rhyolite, diorite and dolerite are common throughout the peninsula.

4. PREVIOUS WORK

No previous work has been done within the area mapped by the writer. Since the Gaspe Sandstone Group and the York River Formation in particular, crop out along the length of the Gaspe Peninsula, a considerable amount of work has been done elsewhere on these units (Map 2).

Much of the early work has been concerned with establishing lithologic units, outlining their areal distribution and determining their geologic age. Prominent among early workers was Sir William E. Logan (1845, 1846, 1863), who first outlined the two major lithologic units of Devonian age, namely the Gaspe Limestone Group and the Gaspe Sandstone Group. The early literature is extensive and deals almost



REGIONAL DISTRIBUTION OF
THE GASPE SANDSTONE GROUP

MAP 2.

W. G. AYRTON
NORTHWESTERN UNIV.
1961.

entirely with eastern Gaspe; a complete historical survey of these publications is beyond the scope of this thesis. However, the development of the terminology pertaining to the Devonian strata and the various interpretations of geologic age are related in Table I. McGerrigle (1950) published an excellent compilation of the work up to 1950.

Western Gaspe, in contrast to eastern Gaspe, was examined by only a few workers prior to 1950. The rocks of the Matapedia Valley were first examined by Logan (1863), who described strata which he believed correlative with the Gaspe Sandstone Group of eastern Gaspe. These rocks were critically reexamined by Alcock (1935), who described their lithology and general stratigraphic relationships.

Since 1950, quadrangle mapping by the Quebec Department of Mines has continued to outline the areal distribution of Devonian strata and attention has been focused on petrography, stratigraphy and variations in lithology. (McGerrigle, 1950, 1953, 1959; Carbonneau, 1959; Stearn, 1959a & b; Beland, 1960.)

Beland (1960) mapped an area immediately west of the Matapedia Valley, and data from the writer's preliminary field map were incorporated in Beland's report.

CHAPTER II

GEOLOGY OF THE SOUTHWESTERN RIMOUSKI-MATAPEDIA AREA

1. STRATIGRAPHY

A summary of the units studied, lithologic descriptions, stratigraphic relations, etc., is included in Table 2 on the following page, and a generalized map (Map 3) is also included of the geology of the Heppel Syncline.

The oldest rocks examined comprise the St. Leon Formation of Silurian age (Crickmay, 1932). This unit is overlain by the Lower Devonian Cape Bon Ami and Grande Greve Formations, which comprise the westward extension of Logan's (1845) Gaspe Limestone Group. Overlying the Grande Greve Formation is the York River Formation (Lower Devonian), which represents the westward extension of Logan's (1845) Gaspe Sandstone Group found in eastern Gaspe. The Fortin Group (Lower Devonian) underlies the York River Formation in the southern part of the area, and is considered by the writer to be correlative with the Cape Bon Ami and Grande Greve Formations which crop out in the northern part of the area.

AGE			LITHOLOGIC UNIT	LITHOLOGIC DESCRIPTION	STRATIGRAPHIC RELATIONS	LOCATION OF TYPE SECTION	THICKNESS
SYSTEM	SERIES	STAGE					
?	?	?	LAKE BRANCH FM.	Massive red arkosic sandstone and siltstone, occasional beds of green sandstone. Beds rarely exceed two feet in thickness. Plant fragments, cross-bedding, intraformational conglomerates, mudcracks, ripple marks.	Gradational contact with York River Fm., transition zone of nearly 400 feet. (1)	No formal type section Best exposure on Carriere Rouge Brook 3 miles south of Causapscal. (4)	4000' (4)
LOWER DEVONIAN	Ulsterian	Onesqueth	YORK RIVER FM.	Interbedded greenish-gray, feldspathic graywacke sandstones, siltstones and shales. Abrupt changes in lithology. Beds up to 3 feet thick of massive, medium-grained sandstone common. Small scale cross-bedding in siltstone. Unit is non-calcareous except for a few fossiliferous horizons.	Gradational contact with Grande Greve Fm. on north side of Heppel syncline. Bottom of unit is the last thick (1 foot) non-calcareous bed of sandstone. Sharp conformable contact with Fortin Group on south side of Heppel syncline.	No formal type section Best seen on Little Four Mile Brook (4)	10-18,000'
		Deerpark	FORTIN GROUP	Dark Gray slates, siltstones and sandstones. Fine-grain texture, pronounced slaty cleavage. Bedding difficult to see, ¼" - ½" beds of siltstone appear lighter than dark slate. Rocks are calcareous at top of unit. Subject to deep weathering. Sometimes phyllitic in appearance.	Underlies the York River Fm. on south side of Heppel syncline. Thought to be stratigraphically equivalent to Grande Greve and Cape Bon Ami Fms. found on north side of syncline.	No formal type section. First mapped in Fortin Twp. (3)	UNKNOWN.
		Helderberg	GRANDE GREVE FM.	Interbedded, medium gray, calcareous sandstones and siltstones. Beds ½" - 1" sharply outlined, but have wavy appearance due irregular thickness of sandstone lenses. Well cleaved. Sandstone predominates at top of unit, siltstone is more abundant at base.	Underlies York River Fm. on north side of Heppel syncline. Gradational contact with Cape Bon Ami Fm.(4) Thought to be stratigraphically equivalent to Fortin Group found on the south side of Heppel syncline.	Forillon Peninsula.	2,600'
			CAPE BON AMI FM.	Gray, well cleaved, interbedded soft-silty and argillaceous limestones Weathers brown to a depth of several feet. Thinly bedded (½").	Gradational contact with St. Leon Fm. Thought to be stratigraphically equivalent to Fortin Group found on the south side of Heppel syncline.	Forillon Peninsula	1,900'
SILURIAN	Ludlow		ST. LEON FM.	Interbedded green, calcareous siltstones and fine-grained sandstones. Beds up to 2 feet in thickness. Very finely laminated, dark gray, calcareous siltstone present near the top of unit, also 3" bed of volcanic sandstone. Weathers light brown. Convolute bedding.	Bottom of unit not seen, but overlies Sayabec Fm. about 9 miles to the north of area mapped at Lac des Eaux Mortes. (2a)	St. Leon-le-Grand, Pinault Twp.	7300 (2b)

Table 2. Summary of the Stratigraphy of the Rimouski-Matapedia Area.

1. Carbonneau. 1959.
2. Beland
   a. written commun., 1961
   b. 1960
3. McGerrigle, 1946.
4. Stearn, 1959b.

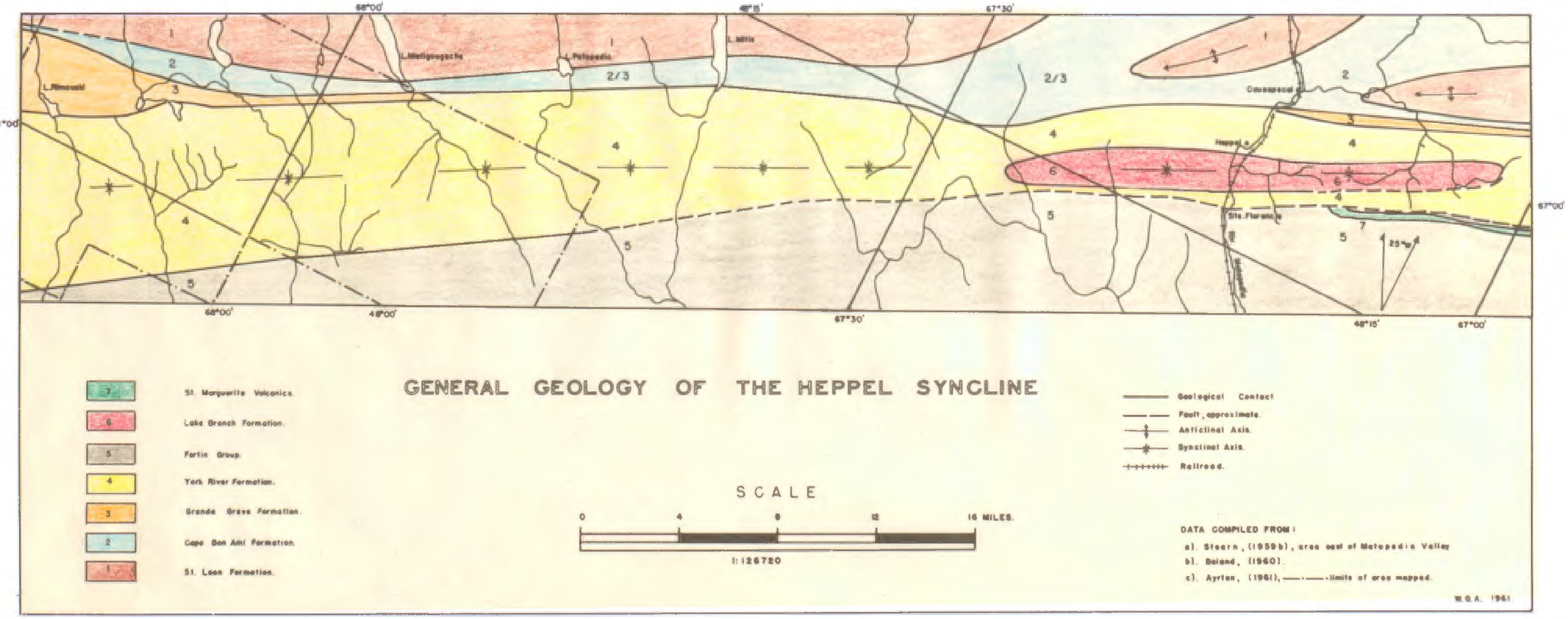
The Lake Branch Formation (Devonian), (Stearn; 1959b) is included in the stratigraphic column because it conformably overlies the York River Formation approximately 16 miles northeast of the area mapped. Consideration of the structure, stratigraphy and sedimentation of the Lake Branch Formation is essential to regional interpretation.

St. Leon Formation

The term St. Leon Formation is used by the writer to refer to those gray and green calcareous siltstones and fine-grained sandstones which underlie the Cape Bon Ami Formation within the area mapped.

This formation was only examined briefly to establish the contact relationships with the overlying Cape Bon Ami Formation. It has been examined in considerable detail by other workers east of the area mapped (Crickmay, 1932; Stearn, 1959 a & b; Burk, 1959, and Beland 1960).

The St. Leon Formation crops out over much of the area to the north of the Heppel syncline (Beland, 1960), but has not been identified south of the syncline. The type section is located near the village of St. Leon le-Grand,



GENERAL GEOLOGY OF THE HEPPEL SYNCLINE

DATA COMPILED FROM:

a). Stearn, (1959b), area east of Matapedia Valley

b). Boland, (1960).

c). Ayrton, (1961), —·— limits of area mapped.

W.G.A. 1961

MAP 3

Pinault Township, Electoral District of Matapedia (Crickmay, 1932), approximately 16 miles northeast of the area mapped.

The base of the formation was not seen, but about 9 miles to the north of the area mapped, Beland (written communication, 1961) observed the St. Leon Formation conformably overlying the Sayabec Formation at Lac des Eaux Mortes. Graptolites found by Beland (1960) and Stearn (1959b) in the St. Leon Formation indicate a Ludlovian age, or Late Silurian in the North American terminology.

No thickness measurements were made within the area mapped. Beland (1960) estimated a maximum thickness of 7,300 feet to the north of the present area. From Associated Developments Causapscal No. 1 well, drilled during 1958, (Lot 20, Range I, Lepage Township, 2½ miles northwest of Causapscal) Beland calculated a minimum thickness of 6,365 feet (Stearn, 1959b, p.19).

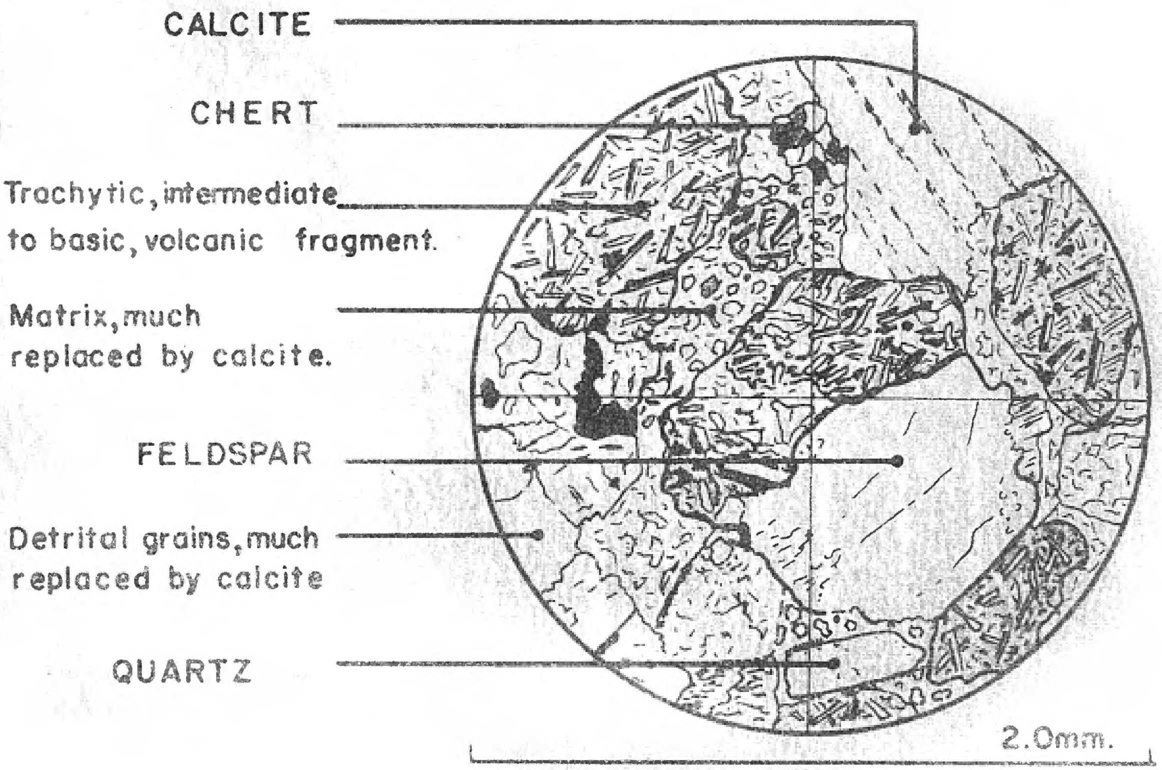
The St. Leon Formation comprises interbedded calcareous sandy siltstones and fine-grained sandstones, which are dark greenish gray in color 5 GY 4/1 (G.S.A., 1951).

The bedding is usually well displayed, with sandstone beds up to 2 feet in thickness alternating with thinner beds of siltstone. A distinctive zone of very finely laminated, dark gray calcareous siltstone is present near the top of the unit. Convolute bedding was found in several outcrops, indicating some deformation while the rocks were still in a plastic state. The St. Leon Formation, in overall nature, is much more resistant to weathering than either the Cape Bon Ami or Grande Greve Formation. It weathers to a light brown color. Nodules of dark gray, very calcareous siltstone, 3 inches in diameter were found scattered through gray sandy siltstone at one outcrop.

A three inch bed of volcanic sandstone composed of at least 20 percent rounded fragments of fine grained andesite exhibiting trachytic texture was found near the top of the St. Leon Formation (Fig. 2). The rest of the detrital fraction is composed of quartz, chert, plagioclase, potash feldspar and some individual crystals of calcite, cemented by iron-stained carbonate. It is interesting to note that Stearn (1959b p.17), working 25 miles to the northeast, also found a two inch bed of tuff near the top of

FIG. 2.

ST. LEON FORMATION (Volcanic sandstone.)



the St. Leon Formation, which has a similar composition.

In addition to a distinct lithologic difference, the St. Leon Formation does not possess the well-developed closely spaced foliation so characteristic of the overlying Cape Bon Ami Formation. Poorly developed foliation, statistically parallel to the axial plane, is present within these sandstones and siltstones, but the rock rarely cleaves along the foliation planes. In thin section the foliation planes appear as thin poorly developed fractures along which there is no apparent preferred orientation of micas or quartz. A discussion of the foliation is found in Chapter II, Structural Geology.

Cape Bon Ami Formation

The name Cape Bon Ami Formation was proposed by Clarke (1908) to refer to divisions 3 to 6 of Logan's Forillon Peninsula section of the Gaspe Limestone Group. The formation has since been traced the length of the Gaspe Peninsula (McGerrigle, 1953). Stearn (1959b) recognized the Cape Bon Ami Formation and the Grande Greve Formation in the Matapedia Valley, and suggested that the term

"Causapscal formation" (Crickmay, 1933), which included both these units, be abandoned. Mapping west of Stearn's area, the writer was able to map both these formation, but only on the north side of the Heppel syncline (Map 3).

The contact with the overlying Grande Greve Formation was not seen, but it is thought by the writer to be gradational and conformable. The Cape Bon Ami Formation is conformably underlain by the St. Leon Formation over most of the area. Along the Rimouski River there is evidence of faulting, which may be responsible for the marked thinning of the Cape Bon Ami Formation (see Chapter II, Structural Geology).

The Cape Bon Ami Formation has only been recognized by the writer on the north limb of the Heppel syncline, but the hypothesis that these rocks are the lateral equivalent of the Fortin Group, which crop out on the south side of the syncline, will be presented in Chapter II, Fortin Group,

No fossils were found in the Cape Bon Ami Formation within the area mapped, but to the east, fossils collected by Stearn (1959b, p.25) and Beland (1960) indicate a Helderbergian age for the unit. The fossil collections are poor, and therefore the age of the Cape Bon Ami Formation is still questionable.

No continuous exposures of the Cape Bon Ami Formation were found within the area mapped, but an estimate thickness of 1,900 feet was computed from structural cross-sections (Fig. 11).

The Cape Bon Ami Formation is very poorly exposed in this area, due to its well-foliated and calcareous nature. Most exposures are brown and deeply weathered. Where unweathered rocks occur, as along the Rimouski River, they are dark gray N.3 (G.S.A., 1951), well-foliated limestones and silty limestones.

The bedding is best seen on weathered surfaces, and is faint on fresh surfaces. The thin, 1/10" - ½" beds of silty limestone appear lighter in color than the dark gray limestone, with which they are interbedded. These beds of silty limestone often contain small cubes of diagenetic pyrite. The silt content within the silty limestone is composed mainly of detrital quartz grains with minor amounts of muscovite. A closely spaced foliation, parallel to the axial plane, is well-developed within these rocks. In thin-section, it can be seen that the rock is cut by a myriad of anastomozing fractures which are curved around individual detrital grains and produce an "augen" or net-like texture on a microscopic scale. A discussion of the foliation is found in Chapter II, Structural Geology and the texture is illustrated in Fig. 12a.

Grande Greve Formation

The name Grande Greve Formation was proposed by Clarke (1908) to refer to the two youngest divisions (units 7 and 8) of the Gaspe Limestone of Logan (1845). Clarke's type-section on the Forillon Peninsula in eastern Gaspe proved unsatisfactory because the lithologic criteria used in separating the Grande Greve Formation from the Cape Bon Ami Formation have not been recognized elsewhere in Gaspe. McGerrigle (1950, p.64) redefined the Grande Greve Formation at the same locality, including an additional 500 feet which had previously been assigned to the Cape Bon Ami Formation The base was defined as the first "appearance of hard, cherty to siliceous limestones (or calcareous siltstones)" The upper contact is marked by the first appearance of the Gaspe Sandstone Group.

Stearn (1959b, p.26) has pointed out, that as the Grande Greve Formation is traced to the west, its lithology changes from a cherty limestone to the predominantly silty limestone found in the Matapedia Valley. This lateral change in lithology can be traced further to the west into the Rimouski-Matapedia area, where the limestones become sandy. On the basis of the stratigraphic position and the calcareous nature of the unit, the name Grande Greve Formation would still appear to be applicable. The introduction of a new term for the unit would only confuse the already complicated terminology.

The Grande Greve Formation has been recognized by the writer on the north limb of the Heppel syncline, where the unit is conformably overlain by non-calcareous sandstones and siltstones of the York River Formation. It is probable that the Grande Greve Formation is the lateral equivalent of the Fortin Group, which outcrops on the south side of the Heppel syncline (Map 3). This relationship is discussed in more detail in the following section dealing with the Fortin Group.

The thickness of the Grande Greve Formation is estimated from constructed structural cross-sections to be approximately 2,600 feet in the eastern part of the area (Fig. 11, A-A'). Folding coupled with the lack of exposure in the western part of the area, make difficult any attempt to estimate the thickness.

Very few fossils have been found in this formation in western Gaspe, and consequently the unit is not satisfactorily dated. In eastern Gaspe, McGerrigle (1950, p.73) placed the unit in the Oriskany on the basis of "rare fossils" assigned a Helderberg-Oriskany age to the Grande Greve Formation of the Matapedia Valley.

Within the area mapped, the Grande Greve Formation comprises interbedded calcareous sandstones and siltstones. The formation is seen best along the road just south of Lake Kedgewick and just north of Lake No. 2. (Map 9). The color of the sandstones and siltstones is medium gray or N. 5. (G.S.A., 1951). The bedding is well displayed on the dark brown weathered surface, where the more calcareous sandstone beds appear dark brown in contrast with the gray silty layers. Beds of both siltstone and sandstone range from ½" - 2" in thickness, thin (one-tenth inch), disrupted beds of siltstone occur within the sandstone beds. The bedding is sharply outlined and dips consistently to the southeast. However, on a small scale, the thin beds have a wavy appearance, thickening and thinning with 'flames' of sandstone (¼" - ½") which have intruded the overlying siltstone beds. These structures are similar to those seen in sediments which have been deformed while still unconsolidated.

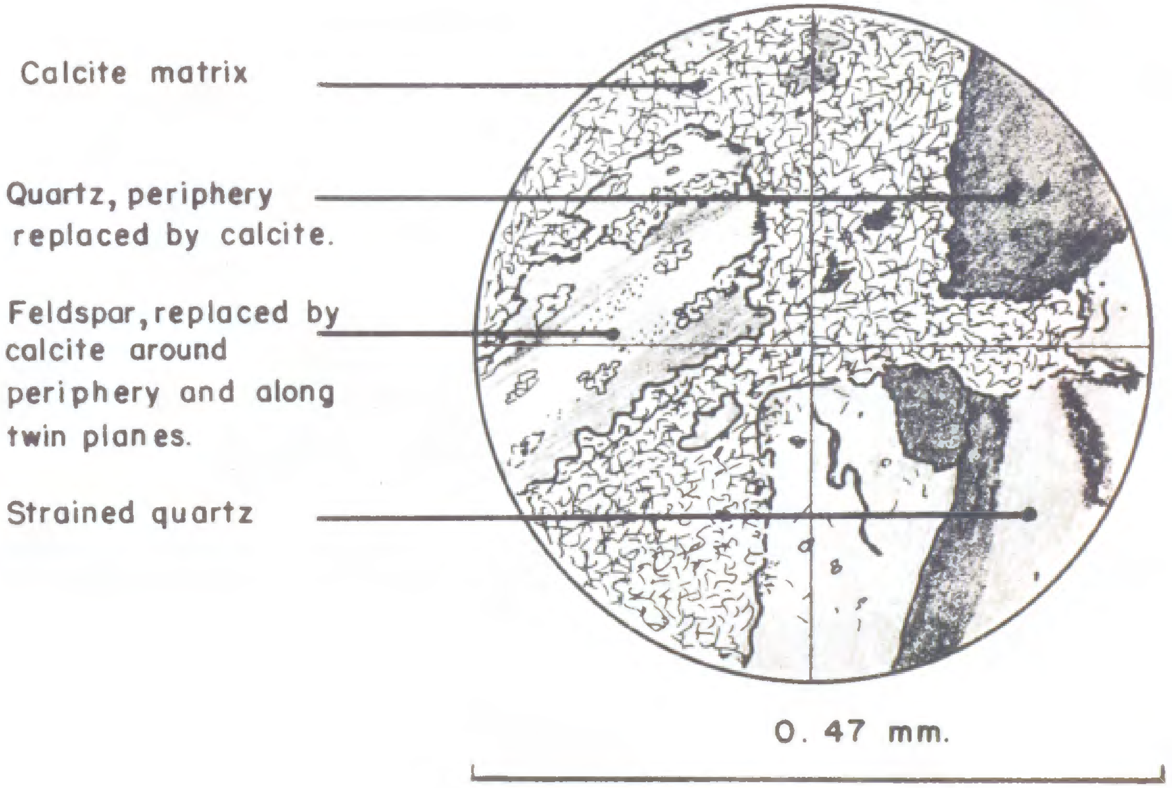
Sandstone predominates at the top of the formation, whereas siltstone is more abundant at the base. Small scale cross-bedding was observed, but no obvious graded bedding was seen probably because of the small grain size of the rocks

A closely-spaced foliation similar to that found within the Cape Bon Ami Formation is present within this unit; it is easily discernable in the field, and is statistically parallel to the axial plane. The foliation is developed to a higher degree in the siltstones than in the sandstones.

The medium to fine-grained sandstones of the Grande Greve Formation are extremely calcareous. Cement takes the form of ragged isolated patches of recrystallized calcite which almost entirely replaced the matrix (Fig. 3). The detrital grains, quartz, feldspar and chert, are

FIG. 3.

GRANDE GREVE FORMATION



corroded and embayed around their peripheries, and have clearly been replaced to varying degrees by the calcite (Fig. 3). The detrital fraction makes up 70% to 90% of the rock and the rest is composed of recrystallized calcite cement. Potash feldspar, microperthite and chert grains are extensively replaced, whereas plagioclase, muscovite and biotite are unaffected. The flakes of muscovite and biotite are often crumpled and bent around other more resistant detrital grains. The calcite is cloudy in appearance, probably because it contains small amounts of clay.

The siltstones and silty-shales have suffered less replacement than the sandstones possibly because of their relative impermeability. Solution and recrystallization of the calcite cemented the rock, while much of the detrital fraction was corroded and replaced.

Fortin Group

The term "Fortin Series" was introduced by McGerrigle (1946) to apply to a series of dark shaly slates interbedded with limestones and sandstones in eastern Gaspe. The term

"Fortin formation" is used by Cumming (1959) to refer to these rocks, whereas Carbonneau (1959) uses both "series" and "formation". Stearn (1959b) has traced the "Fortin formation" as far as the Matapedia Valley, and Beland (1960) has continued the mapping of the Fortin Group as far west as the West Branch of the Patapedia River (Map 9). The work done by the writer on this unit is confined to the contact zone between the Fortin Group and the York River Formation.

No evidence of faulting was found along this contact, although it is known to exist along the contact further to the east (Map 3). The carbonate content of these rocks is variable; at places they are completely non-calcareous, whereas at other places they react briskly with acid It is especially noticeable that along the York River/Fortin contact, the rocks of the Fortin Group are always extremely calcareous.

The calcareous nature and lithologic similarity between the uppermost beds of the Fortin Group on the south side of the Heppel syncline, and the rocks of the Grande Greve Formation on the north side is striking, particularly since both of these horizons lie directly beneath the York

River Formation. There is also a strong similarity between the rocks of the Fortin Group and those of the Cape Bon Ami Formation. Both formations are calcareous, argillaceous and well cleaved. It would therefore seem likely that the Grande Greve, Cape Bon Ami and possibly St. Leon Formations are the lateral equivalents of the Fortin Group (Fig. 4).

The position of the Fortin Group within the stratigraphic column has interested students of Gaspe geology for some time. In eastern Gaspe the structural and stratigraphic relationships are more complex than those recognized in western Gaspe. McGerrigle (1950), suggested several alternative explanations, one being that the "Fortin series" found in the southern part of his area "includes the Cape Bon Ami and Grande Greve time without maintaining the characteristics of the formations". Roliff (1952), and Cumming (1959), mapping in central and eastern Gaspe respectively, believed that the Fortin Group was the southern lateral equivalent of distinct lithologic units mapped to the north (Table I).

Stearn (1959b), suggested that his single fossil collection, made in the Causapscal area (Map 2), indicated

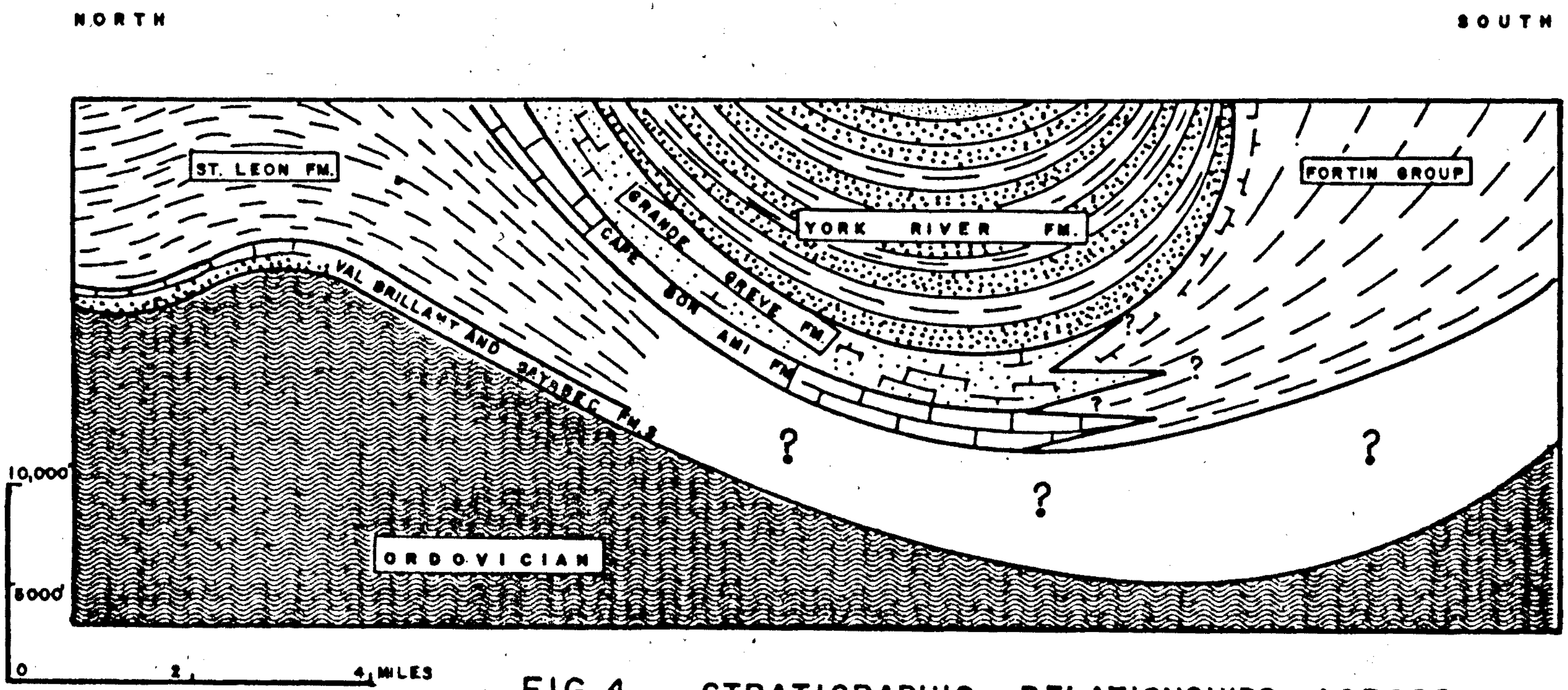


FIG. 4, STRATIGRAPHIC RELATIONSHIPS ACROSS THE HEPPEL SYNCLINE.

the equivalence of the Fortin Group to the Grande Greve and Cape Bon Ami Formations.

At this stage of geologic knowledge of the Gaspe peninsula, it is recommended that the term "Fortin Group" be retained as the unit has lithologic consistency and has been mapped the length of the peninsula. It may be possible to recognize the Cape Bon Ami and Grande Greve Formations, within what is now known as the Fortin Group, when detailed paleontologic, structural and stratigraphic information becomes available. The base of the Fortin Group was not seen.

Because of complex structure and absence of marker horizons, it is extremely difficult to estimate the thickness of the Fortin Group. Beland (1960) suggested "a few thousands of feet" and McGerrigle (1946) estimated that the thickness is about 5,000 feet at the type section. No satisfactory estimate of the thickness can be made in this area.

No fossils were found in the rocks of the Fortin Group within the area mapped. Stearn (1959b) mapping to the east has some poor paleontological evidence indicating an Oriskanian age for the unit.

The dark gray, N.3. (G.S.A., 1951) thin-bedded calcareous slates, siltstones and fine-grained sandstones of the Fortin Group are susceptible to deep weathering, and consequently are poorly exposed. The bedding is best seen on the brown weathered surface, where ¼" - 1' beds of gray siltstone appear somewhat lighter in color than the dark slates. This unit appears to be lithologically uniform, although discontinuous lenses of sandstone and conglomerate have been reported from the central part of the belt (Beland, 1960). No good marker horizons have been located within the northern part of the Fortin Group.

Foliation, parallel to the axial plane, is especially well developed within this unit, and the rocks split easily along these closely spaced planes. The remarks made about the foliation found in the Cape Bon Ami Formation apply equally well to the foliation found within the Fortin Group.

Under the microscope the calcareous slates and siltstones comprising the upper part of the Fortin Group bear a striking resemblance to rocks of the Grande Greve Formation. Calcareous cement is present in every slide examined, and the detrital fraction is composed of quartz, minor feldspar, chert, micaceous minerals and occasional rock fragments. Small squares of limonite stain, similar to staining found within the rocks of the Grande Greve Formation, are present in this unit. The calcareous cement has reacted with and embayed the quartz, chert, potash feldspar and rock fragments, but the muscovite and plagioclase remain unaffected. The silty bands are composed mainly of quartz and feldspar, and appear as very irregular and distorted beds.

York River Formation

Logan (1863), p.884) first mentioned the "sandstones of the York River", referring to strata which crop out along the York River in eastern Gaspe. Here, he collected fossils from "the York River beds". He also described (ibid. p.415) "a succession of arenaceous strata" about one and a half miles south of the Causapscal River, in the Matapedia Valley, which "represent the Gaspe sandstones". These, in effect, are the sandstones and siltstones of the York River Formation mapped by Boland (1960) and Stearn (1959a & b), and which are part of the same belt mapped by the writer.

Williams (1910, p.690) defined the "York River beds" as the basal, calcareous, marine and fossiliferous zone of the Gaspe Sandstones. In 1935, Alcock, working in the Matapedia Valley, mapped the "arenaceous strata" described by Logan, and named the unit the Heppel Formation after the village of Heppel (Map 3). E.M Kindle (1938) correlated the Heppel Formation of western Gaspe with the "York River beds" of eastern Gaspe. He gave the name Four Mile Brook member to the shales "at the top" of the Heppel Formation. Stearn (1959b, p.38) stated, "Kindle has recorded the vertically dipping section upside down for all the beds face south". Dresser and Dennis (1944, p.300) introduced the term Battery Point Formation to cover Logan's measured section of the Gaspe Sandstone Group on the Forillon Peninsula, and the "York River Formation" is referred to for the first time in the literature:

> "It is from the York River formation that the great majority of the marine fossils of the Gaspe Sandstones have been collected. Fossils are particularly abundant in certain beds in the lower half of the formation. York River beds probably make up the entire 'Gaspe Sandstone' series in the interior of the Peninsula and as far west as Matapedia Valley."

McGerrigle (1950, p. 78) redefined the York River Formation to include "all the rocks in the section having the same lithology as the general series of York River beds". The latter would appear to represent the type section of the York River Formation, but no formal type section has been described

Stearn (1959b, p.36) proposed dividing the Heppel Formation of Alcock (1935); in the following manner:

> "The present work in the Causapscal area has indicated that the Heppel sandstone can be divided into two stratigraphic units, the lower of which is lithologically similar to the York River formation and the upper, to the Lake Branch formation."

The York River Formation was defined by Stearn in essentially the same form as it is in the present paper. Stearn was able to divide the York River Formation into three informally defined members; the basal beds, the Four Mile Brook beds, and the upper beds.

The York River Formation crops out in three different belts, which are roughly parallel to the arcuate outline of the Gaspe Peninsula (Map 3). Within the area mapped, the York River Formation overlies the Grande Greve Formation on the north side of the Heppel syncline and the Fortin Group on the south (Map 3). The top of the York River Formation is not seen in this area, but concordant relationships with the overlying Lake Branch Formation have been assumed by Beland (1960), 16 miles to the east.

On the north limb of the Heppel syncline the York River Formation grades down without interruption into the Grande Greve Formation. There has been considerable discussion concerning the position of the contact. Stearn (1959b, p.32) has suggested:

> "The only logical place to draw the boundary between the York River and Grande Greve formation is at the base of the first sandstone bed or regional distribution."

This suggestion is practical, and was used by the writer in the field. It was noted by the writer that in the Rimouski-Matapedia area, the "first sandstone of regional distribution" also happened to be non-calcareous.

Stearn (1959b, p.46), reported that in the Causapscal area to the east, the Fortin Group is in contact with the York River Formation along a fault of unknown, but probably small, displacement. Beland (1960, p.13) noted that this fault continues for some distance to the west of the Matapedia Valley. No evidence of faulting was observed in the area mapped by the writer, and presumably the fault dies out between there and the Matapedia

Valley. This implies that within the area under study, the York River Formation conformably overlies the Fortin Group, and that no depositional or structural break is present

No practical division on the basis of lithology is yet possible within the York River Formation, but it is conceivable that the fossiliferous horizon near the base of the formation is the same as the Four Mile Brook unit found in the Matapedia Valley (Kindle, 1938). This correlation is rather tenuous and the horizon is not sufficiently distinct to be mapped as a member.

The thickness is not readily determined, mainly because of the paucity of exposure. There were no sections which could be measured and the problem is accentuated by the fact that the overall structural picture is still obscure. If the structure is a simple syncline with steeply dipping limbs, as suggested in Chapter II Structural Geology, a maximum thickness of 18,000 feet is anticipated.

The fossils collected by the writer and identified by Professor Arthur J. Boucot, indicate an early Onondagan (Early or Middle Devonian) age for the York River Formation.

This interpretation is based mainly on the presence of the brachiopod Amphigenia in collections AA-67-6, AA-69-10 and AA-70-6 (Map 5). The complete list of fossils is included in Table 3.

There has been much discussion over the age of the Gaspe Sandstone Group, and of the York River Formation in particular. An attempt has been made to relate the various interpretations to a chronologic scale using the type section of the Devonian in New York as reference (Table 1). A good review of the reasons behind some of these interpretations is given in McGerrigle (1950, p.87 and 1946, p.44). The diverse conclusions reached by many workers, mainly in eastern Gaspe, have been based primarily on conflicting ages assigned to the rocks on the basis of either brachiopods or mollusks. McGerrigle (1946, p.44) pointed out that, in Eastern Gaspe, the brachiopods suggest an Early Devonian Oriskany age, while the mollusks, particularly the pelecypods, suggest a Middle Devonian Hamilton age. If the age indicated by the brachiopods is the correct one, then it would appear that the Gaspe Sandstone Group gets younger from east to west, as the brachiopods in the west indicate an Early Onondagan age.

The rocks of the York River Formation are brown-weathering, greenish-gray, 5 GY 4/1 (G.S.A., 1951) medium to fine-grained graywacke sandstones, interbedded with green and gray siltstones and greenish-gray shales.

The sandstones occur in massive beds, usually about two to three feet thick, whereas the siltstones occur in beds from 1" to 4" thick. Commonly, finely laminated siltstones are interbedded with shale in thin-bedded sequences, and in the area mapped, sandstones appear to be slightly more abundant than siltstones and shales. However, much of the unit is hidden and it is probable that the less resistant siltstones and shales underlie much of the covered area.

The sandstone is composed of sharp angular fragments of quartz, feldspar and chert, and is cemented by an argillaceous matrix. The quartz grains are mostly frosted, cloudy and dirty gray in color, some are milky; a few are clear, show good conchoidal fracture and are unfrosted. Angular plagioclase grains are twinned, and good cleavage faces may be seen. The potash feldspar is kaolinized and is present as pporly defined white and gray grains. Pink feldspar (microcline?) was observed in minor amounts. The chert is present as black grains, which are somewhat better rounded than the quartz or feldspar. Muscovite is present as crumpled, bent flakes, and there are small amounts of biotite.

The sandstones are predominantly non-calcareous, although several somewhat calcareous fossiliferous horizons are present within the unit. Plant fragments which appear as carbonaceous organic remains devoid of any cellular structure are common. The weathered surface of the sandstones is usually white, due to the alteration of the feldspar and the argillaceous matrix; on occasion it has a brown to orange tint caused by limonite staining. Effects of weathering are apparent to depths of approximately one inch.

A striking feature is the abrupt variation in lithologic character within the formation; thick sandstone beds (Plate Ia) alternate with thin-bedded sequences of siltstone and shale (Plate Ib) with monotonous regularity. The fissility of the shales and siltstones is low, probably due to the high siliceous content. Small-scale cross-bedding is found within the siltstones but was never observed in the massive sandstones. Graded bedding was

PLATE I

a) White weathering, massive dark green graywacke sandstones of the York River Formation

b) Finely-bedded, dark green siltstones of the York River Formation often suspected by the writer, but due to the prevailing small grain size, 'tops' determinations were never recorded with any certainty.

Thirty-five thin sections of the sandstones, siltstones and shales of the York River Formation were examined. Twelve out of twenty-six thin-sections of individual sandstone horizons were selected according to a statistically random design; each thin-section number was written on a separate piece of paper, put in a hat, and the first twelve to be picked were point-counted. The sandstones are of similar mineralogic composition, and there does not appear to be any well-defined areal variability within the area mapped. The location of the samples is shown on Map 8 (Appendix) and their minerologic compositions are given in Table 7 (Appendix).

A pilot study was made to determine the number of grains that should be counted, in order that an accurate and representative estimate of the mineral composition of each thin section could be obtained. This study is included in the Appendix. The results of twelve mineralogical determinations have been plotted on Gilbert's Sandstone Classification triangle (Fig. 5), (Williams, _et al_. 1958, p.292).

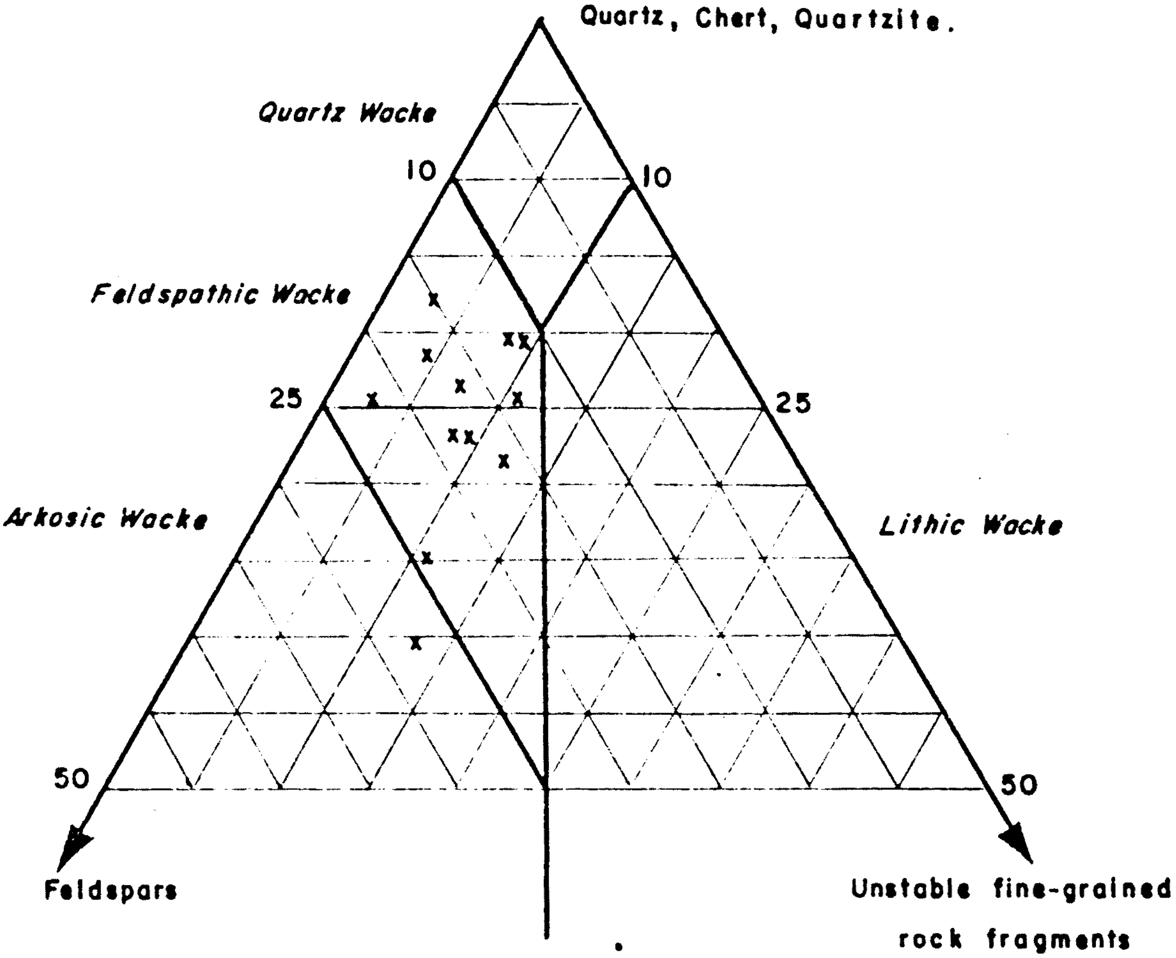


FIGURE 5.

Triangular diagram showing the mineralogical composition of twelve sandstones from the YORK RIVER FORMATION. (Triangular diag. after Williams *et al.*, 1958, p. 292.)

RESULTS TAKEN FROM THIN-SECTIONS X-50-1,2,3,4,5,6,7,8,10,11,12,13.

Since every sandstone examined consists of more than 10% argillaceous matrix, the "wacke" triangle has been used. All but one sample falls within the "feldspathic wacke" field, and this latter falls within the "arkosic wacke" field, however, it lies very close to "feldspathic wacke".

Gilbert (ibid, 1958, p.293) defined a graywacke as a rock consolidated by a dark-colored, firmly indurated matrix of slate or argillite composition, containing abundant fine-grained mica or chlorite. Therefore, the term "graywacke sandstone" adequately describes the sandstones of the York River Formation.

In thin-section the quartz grains are highly angular, having a roundness of approximately 0.2 and a sphericity of 0.5 (Krumbein and Sloss 1951, p.81). The size of the quartz grains ranges from 0.35 mm. (length of the long axis) down to those sizes included in the matrix (less than .02 mm). At least 50% of the grains are within the 0.35 mm to 0.25 mm. range, and therefore the rock is classified as a medium-grained sandstone.

The majority of the grains are in point-contact with a lesser number of concavo-convex contacts; welded contacts are rare and it is suspected that all of those seen were within fragments of quartzite. The quartz grains have kept their original detrital shape and do not appear to have been deformed or significantly altered. Any physical deformation has apparently been minimized because of the "padding" mechanism provided by the argillaceous matrix. Slight periferal alteration is noticeable in some grains, their edges being slightly embayed or pitted when in contact with the matrix. Sixty to seventy percent of the quartz grains exhibit strain shadows. A small number of quartz grains have worn overgrowths, suggesting that part of the detrital material may be composed of second-cycle sediments (Fig. 6).

All the feldspar examined is believed to be detrital as no evidence of authigenic growth was seen. Eight of the twelve thin sections were etched with hydrofluoric acid and stained with sodium cobaltinitrite following the technique described by Chayes (1952); this proved helpful and time saving as far as the grain counts were concerned. Approximately 70% of the total feldspar is highly altered; it exhibits no observable twinning, appears as cloudy and embayed grains with indistinct outlines, and is thought to be altered potash feldspar. The turbid nature of these grains is most likely due to the development of minute flakes of kaolinite, chlorite and sericite within the potash feldspar. The remaining 30% of the total feldspar comprises recognizable microperthite, microcline and plagioclase, all three of which have clear outlines which contrast strongly with the turbid grains of altered potash feldspar. The plagioclase feldspars are predominantly sodic, consisting of individual grains of albite (?), oligoclase or andesine. In general, the feldspars have a roundness of 0.1 and a sphericity of 0.6 (Krumbein & Sloss 1951, p.81).

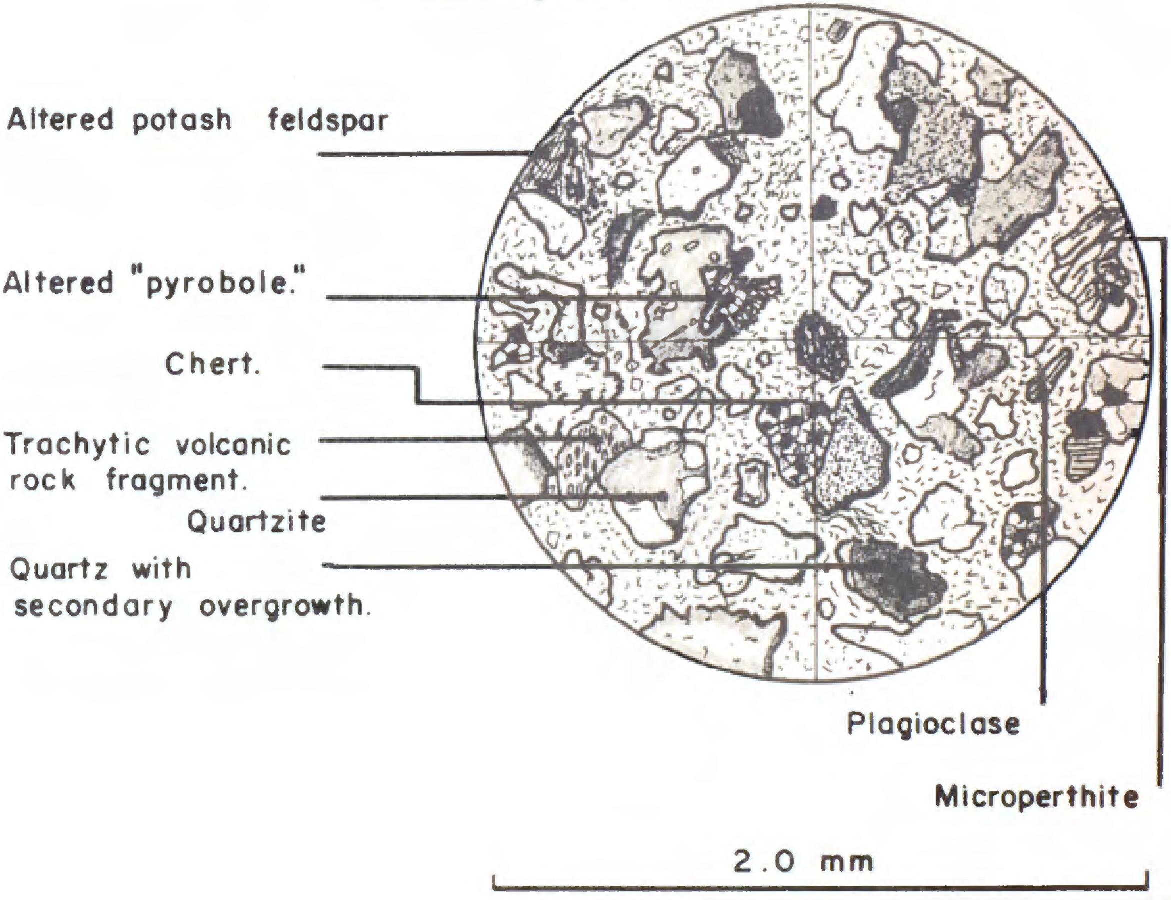
Chert, a minor component, has an average roundness of 0.1 and a sphericity of 0.5. The grain boundaries are vague when the chert is surrounded by matrix and it is difficult to differentiate between detrital grains and siliceous matrix.

The rock fragments are highly altered and are rarely identifiable. The majority of those identified are rounded fragments of acidic and intermediate volcanic rocks which show trachytic texture. There are also a few fragments of quartzite but no fragments of limestone or shale were observed. Finely disseminated magnetite (?) and ilmenite (?) grains are present in small amounts in every thin section examined.

The matrix is dark-colored and firmly indurated. It is made up of finely comminuted quartz, feldspar, kaolinite. sericite, muscovite and an abundance of chlorite, which occur together to form a microcrystalline aggregate. Some iron oxide and organic material are also present. The matrix appears to have been formed from the original argillaceous detritus, which recrystallized diagenetically, dependent on time and depth of burial. The development of chlorite is an indication of diagenetic replacement, low grade metamorphism, or possibly both. Silicification is also responsible for partial cementation of the rock, and, where present, the matrix is anisotropic and resembles chalcedony. Since the rock has a very low permeability it is suggested by the writer that the silica cement is an alteration product rather than an addition by precipitation from solution. The mica is considered by the writer to be primary as it occurs as crumpled, elongate flakes, wrapped

FIG. 6. YORK RIVER FORMATION

(medium grained sandstone.)



around other detrital grains, indicating compaction. Rare zircon and small fragments of amber colored garnet are easily recognizable; a few scattered grains of glauconite and tourmaline are also present, their rarity is attributed to the immature state of the sediment. Some calcareous cement is present at the horizon represented by sample X - 50 - 2 The cement, replaces feldspar and quartz as is evidenced by the embayed outlines of the grains.

In review, therefore, the sandstones of the York River Formation are dark greenish-gray, hard, medium-grained feldspathic graywackes.

Siltstones and shales probably make up at least 50% of the York River Formation. Petrographically, the siltstones are very similar in general appearance and mineral composition to the sandstones. They have a high detrital quartz content, with feldspar and chert present in approximately the same quantities as in the sandstones, the main difference is in the composition of the matrix. There is considerably less chlorite and siliceous cement than was seen in the sandstones; sericite and especially biotite are present in higher proportions. The biotite has a preferred orientation parallel to the bedding and is crumpled and bent as in the sandstones. The sericite appears to have a random orientation interpreted as authigenic crystal growth in place.

The siltstones are both massive and laminated; the laminations are alternating bands (0.3 mm - 1.0 mm) of silt-sized and clay-sized particles.

The shales are composed mainly of flakey micaceous minerals, mainly muscovite and sericite. Although they are not particularly fissile in hand sample, a definite parallel orientation of the micaceous minerals can be seen under the microscope. Pettijohn (1957 p.351) has mentioned this type of parallelism and states:

> "Many of the individual crystals do not lie exactly parallel to the bedding. In all sections cut normal to that structure most micaceous minerals will be approximately parallel to the bedding. Because such minerals have the slow ray vibrating parallel to their cleavage they show parallel extinction. Thin sections that are cut normal to the bedding therefore show an aggregate positive elongation and mass extinction very much as if the slide were cut from a single crystal."

The shales are also laminated, but the silty layers are thin and lens-like and tend to taper out, as do fine layers of black organic material. Silt-sized grains in the shales are predominantly quartz, whereas feldspar is almost completely absent. There is no visible chlorite, but considerable amounts of orange, waxy, translucent material, which may be organic or possibly ferric iron stain, is present.

Foliation, statistically parallel to the axial plane, is weakly developed within the York River Formation; since many of the beds dip at angles of 80-90 degrees, the foliation is parallel to bedding in most cases. The foliation is not observable in handsample in most of the medium-grained sandstones, but may show as weakly developed fractures when the rock is examined in thin section (Fig. 12c). A more complete discussion of the foliation is included in the following section on Structural Geology.

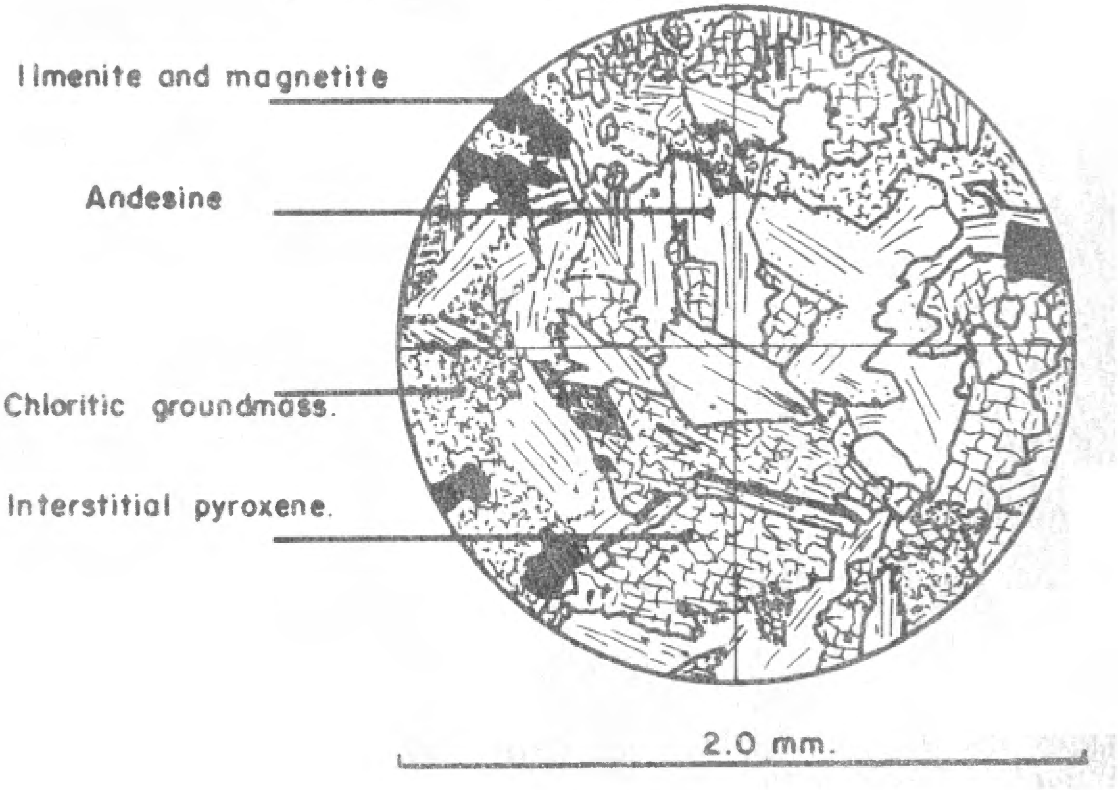
2. INTRUSIVES

A diorite dike has intruded the St. Leon Formation at the crest of the northernmost anticline shown on Map 9. The intrusion is at least 300 feet long and approximately 150 feet wide, paralleling the N.50.E trend of the fold axis. From observations made in the field, it is believed by the writer to have a vertical dip. No contact metamorphism was seen, except for a small amount of pyrite enrichment within the calcareous siltstones in a zone less than two feet thick.

The rock is fine-grained and weathers rusty brown. Tiny laths of white plagioclase feldspar, enclosed in a green groundmass, are visible in the hand-sample. The later crystallizing pyroxene occupies interstices between euhedral lath-shaped andesine crystals, as masses of optically continuous material giving the rock a holocrystalline, subophitic texture (Fig. 8). Bladed intergrowths of ilmenite and magnetite are present as skeletal crystals, and the ilmenite is partially altered to leucoxene.

In mineralogical composition, the rock contains approximately 60% andesine, 15% pyroxene (clinopyroxene is

FIG. 8. DIORITE DIKE



most abundant, but orthopyroxene is also present), less than 5% ilmenite and magnetite, and 20% alteration products. Considerable chlorite formed by the alteration of plagioclase is present as radiating, fibrous, irregular patches. The plagioclase is also sericitized to a small extent. Interior parts of some pyroxene grains have been altered to chlorite.

3. STRUCTURAL GEOLOGY

The Devonian and Silurian rocks of this area were deformed at the close of the Devonian period, during the Acadian orogeny. The main deformational features produced were folding, development of foliation and faulting. Since the rocks of the area are poorly exposed, only limited structural interpretation may be made. The Heppel Syncline, the main structure within the area, can be traced at least 40 miles to the east, and is named after the village of Heppel in the Matapedia Valley (Map 3). The York River Formation, which outcrops in the center of the Heppel syncline, is found for a distance of 14 miles to the southwest (Beland, written communication, 1951). This formation has a width of 6 to 7 miles perpendicular to the dominant axial trend.

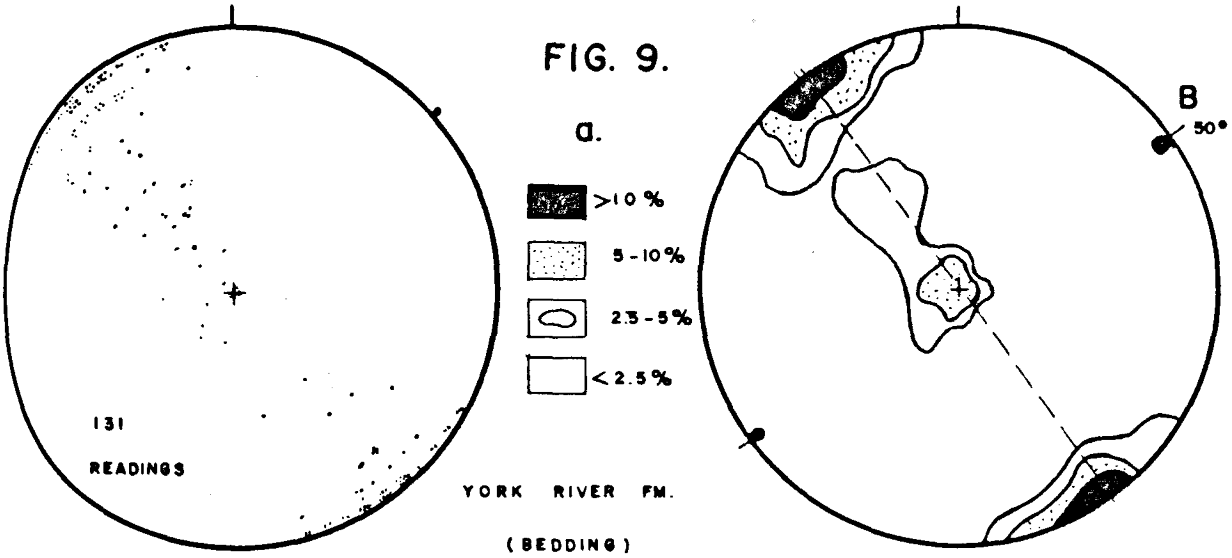
No flexures were seen in the field, nor were any well-defined "b-lineations" (lineations parallel to the fold axis) observed, but bedding and foliation directions were recorded where possible (Appendix, Table 8). The normals (π - poles) to these bedding and foliation planes have been plotted on stereograms (π - diagrams), using the lower hemisphere of a Schmidt stereographic projection.

The style of folding can be deduced only by quantitative geometric consideration of the data. Within the York River Formation, steep to vertically dipping beds are common, accompanied by horizontal and on occasion overturned strata. Small folds with gently dipping limbs have been mapped on the north limb of the Heppel syncline (Map 9), no closure was observed, indicating that they are open folds.

On Fig. 9a, the spread of the π - poles to bedding planes, (131 readings) lie statistically on a single great circle, indicating "cylindroidal folding". A fold can be described as cylindroidal if it has a fold axis defined as follows: ". . . the nearest approximation to the line which when moved parallel to itself in space generates the fold". (Clark and McIntyre, 1951.) Weiss, (1951) has pointed out that a π - diagram for an ideally cylindroidal fold shows all poles lying on a single great circle of the projection. It should also be noted that this single great circle also results from a single axis of folding. The fold axis trends N. 50° E. and is essentially horizontal, although the girdles

FIG. 9.

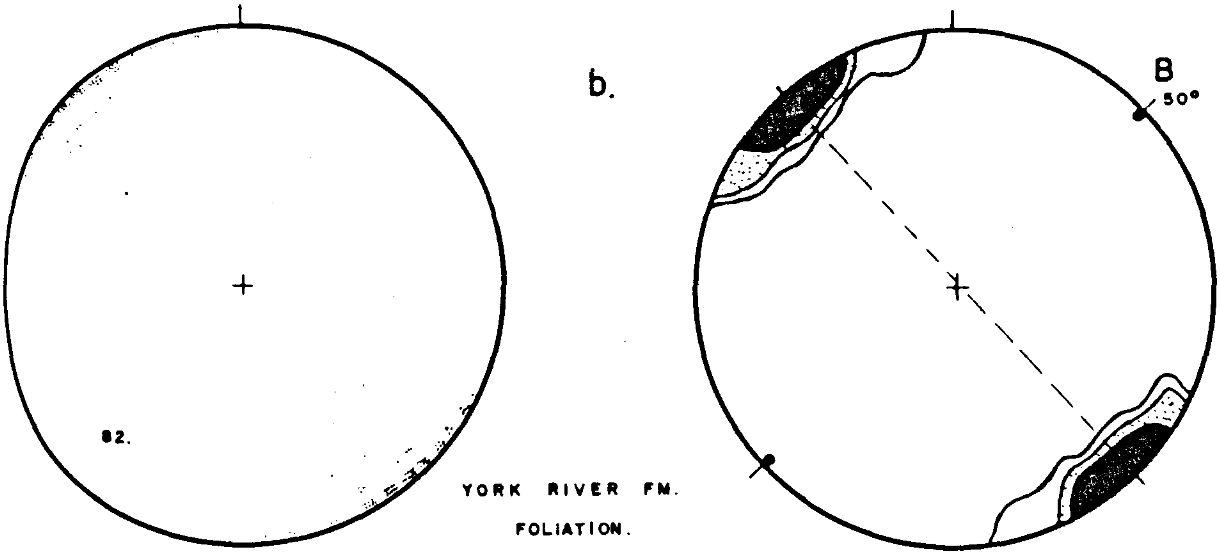
a.



YORK RIVER FM.

(BEDDING)

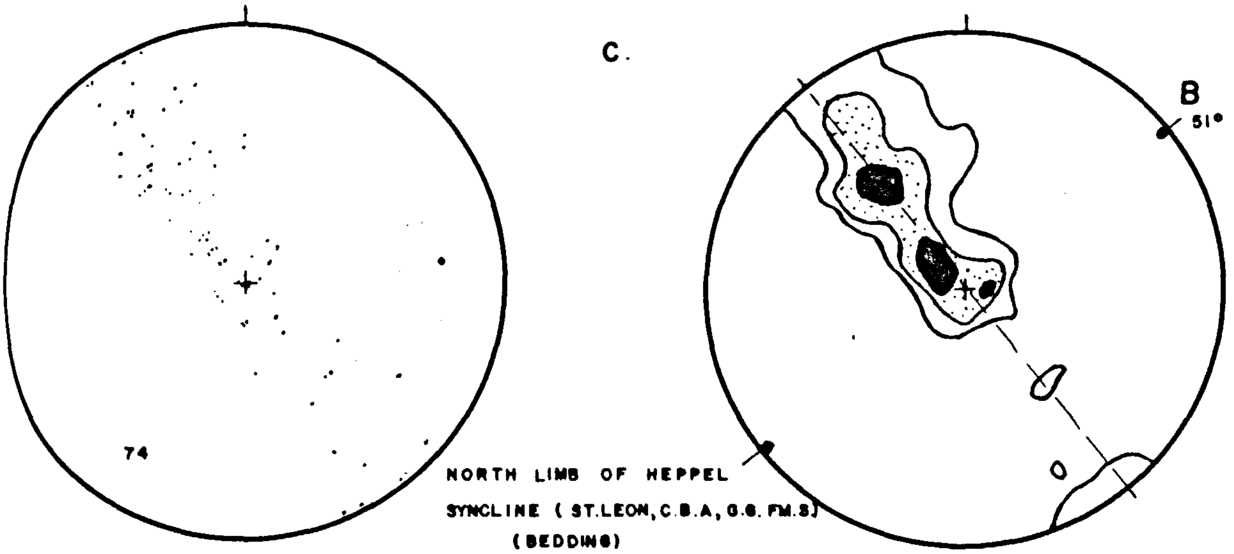
b.



YORK RIVER FM.

FOLIATION.

c.

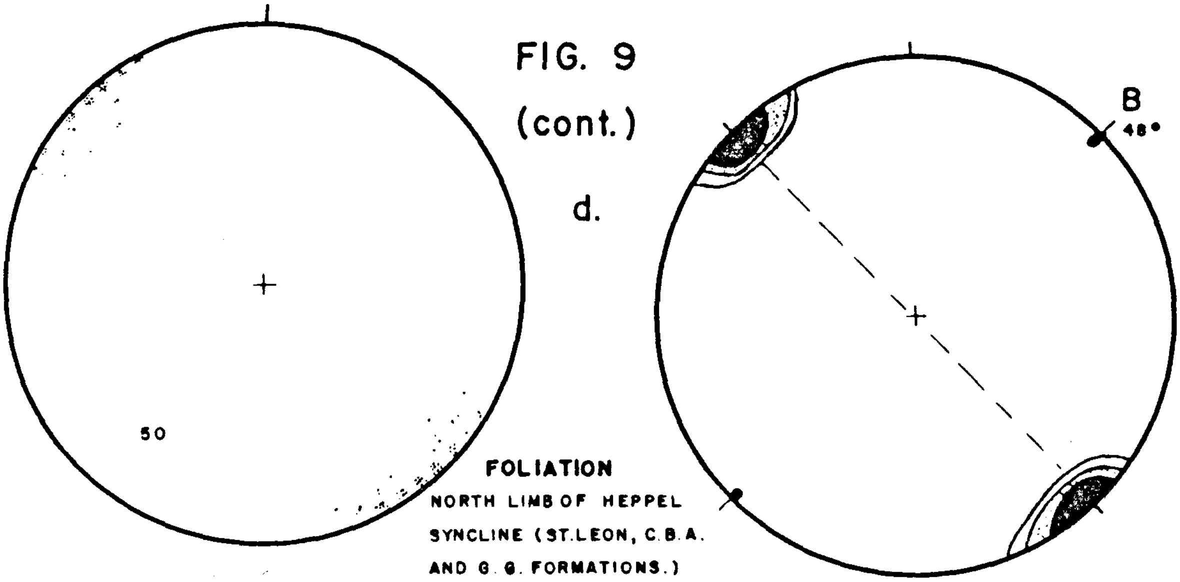


NORTH LIMB OF HEPPEL SYNCLINE (ST.LEON, C.B.A, G.G. FM.S) (BEDDING)

PLOTTED ON SCHMIDT NETS.

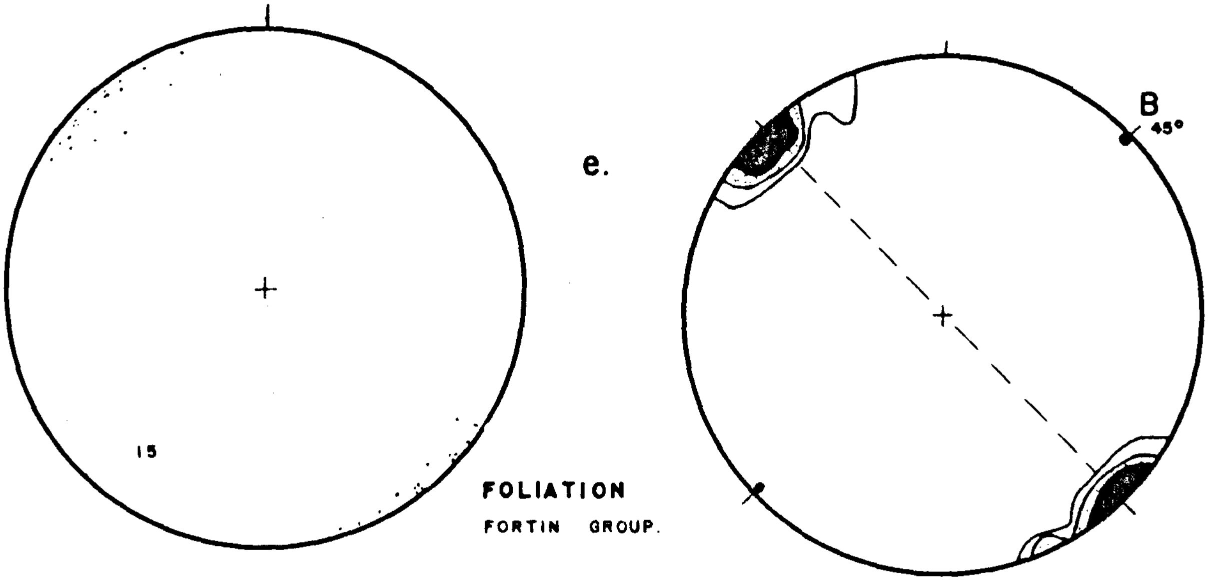
FIG. 9
(cont.)

d.



FOLIATION
NORTH LIMB OF HEPPEL
SYNCLINE (ST.LEON, C.B.A.
AND G.G. FORMATIONS.)

e.



FOLIATION
FORTIN GROUP.

■ > 30%

░ 20-30%

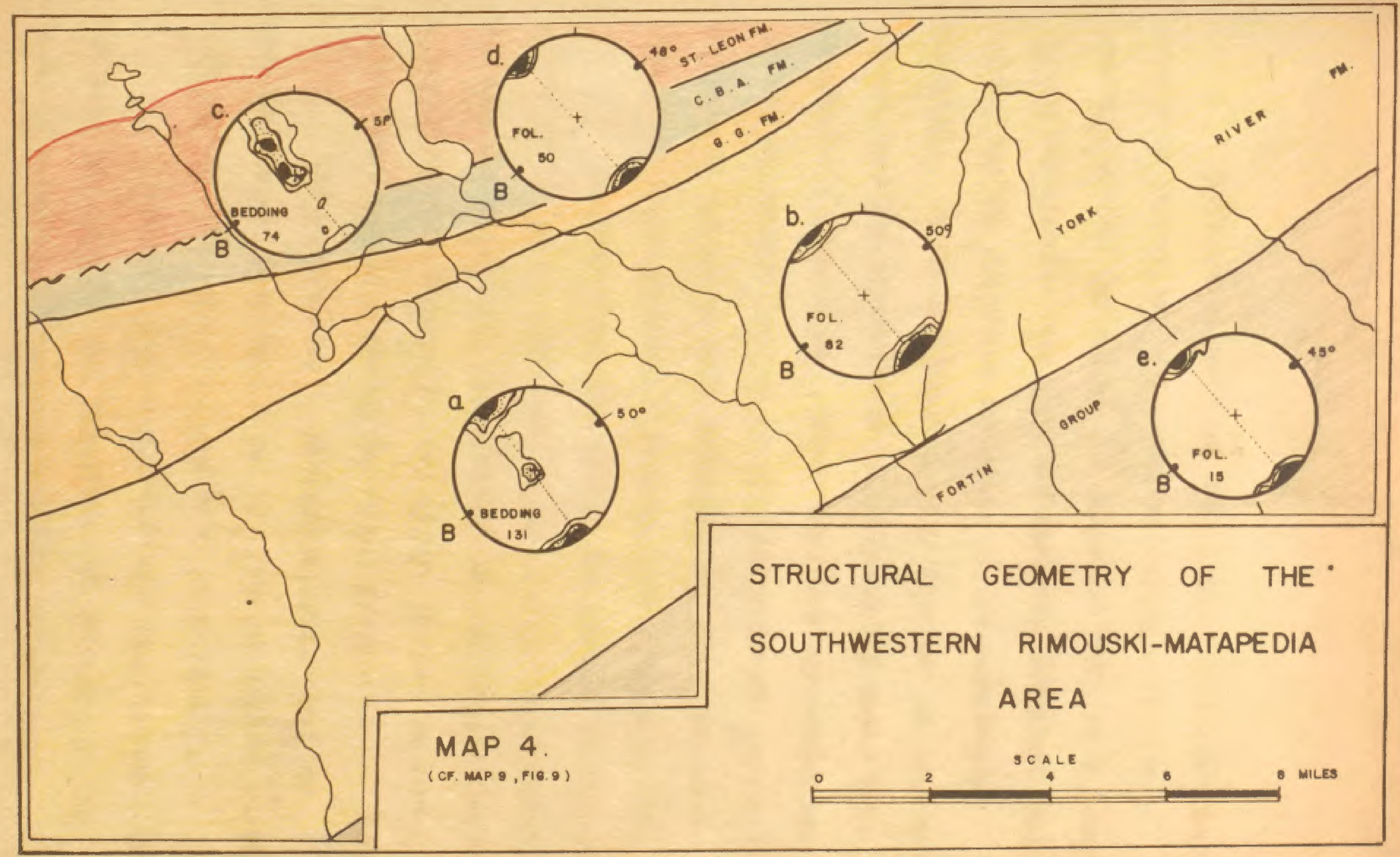
▭ 10-20%

☐ < 10%

in Fig. 9a and 9b both suggest that there may be a plunge of a few degrees to the northeast. Gently plunging canoe folds are present both to the north and east of the area mapped (Beland, 1960; Stearn 1959b).

The π - diagram for foliation mapped in the York River shows axial symmetry with two well defined maxima indicating the plane of symmetry (Fig. 9b). This plane of symmetry is assumed to be the axial plane of the fold; it strikes at N 50 E. and has a vertical dip.

On the north limb of the Heppel syncline, the Grande Greve, Cape Bon Ami and St. Leon Formations are exposed. The attitude of the strata is in general not as steep as that observed within the York River Formation. There is also structural evidence of an anticlinal structure in the extreme northern part of the area. On Fig. 9c the poles to the bedding planes (74 readings) are again statistically distributed along a single great circle, indicating a similar style of folding as that found within the York River Formation. In Fig. 9 c the fold axis trends at N.51 E. and has no plunge, the foliation π - diagram (50 readings) however indicates that the axial plane strikes at N.48 E. and has a vertical dip. (Fig. 9d).



STRUCTURAL GEOMETRY OF THE SOUTHWESTERN RIMOUSKI-MATAPEDIA AREA

MAP 4.

(CF. MAP 9, FIG. 9)

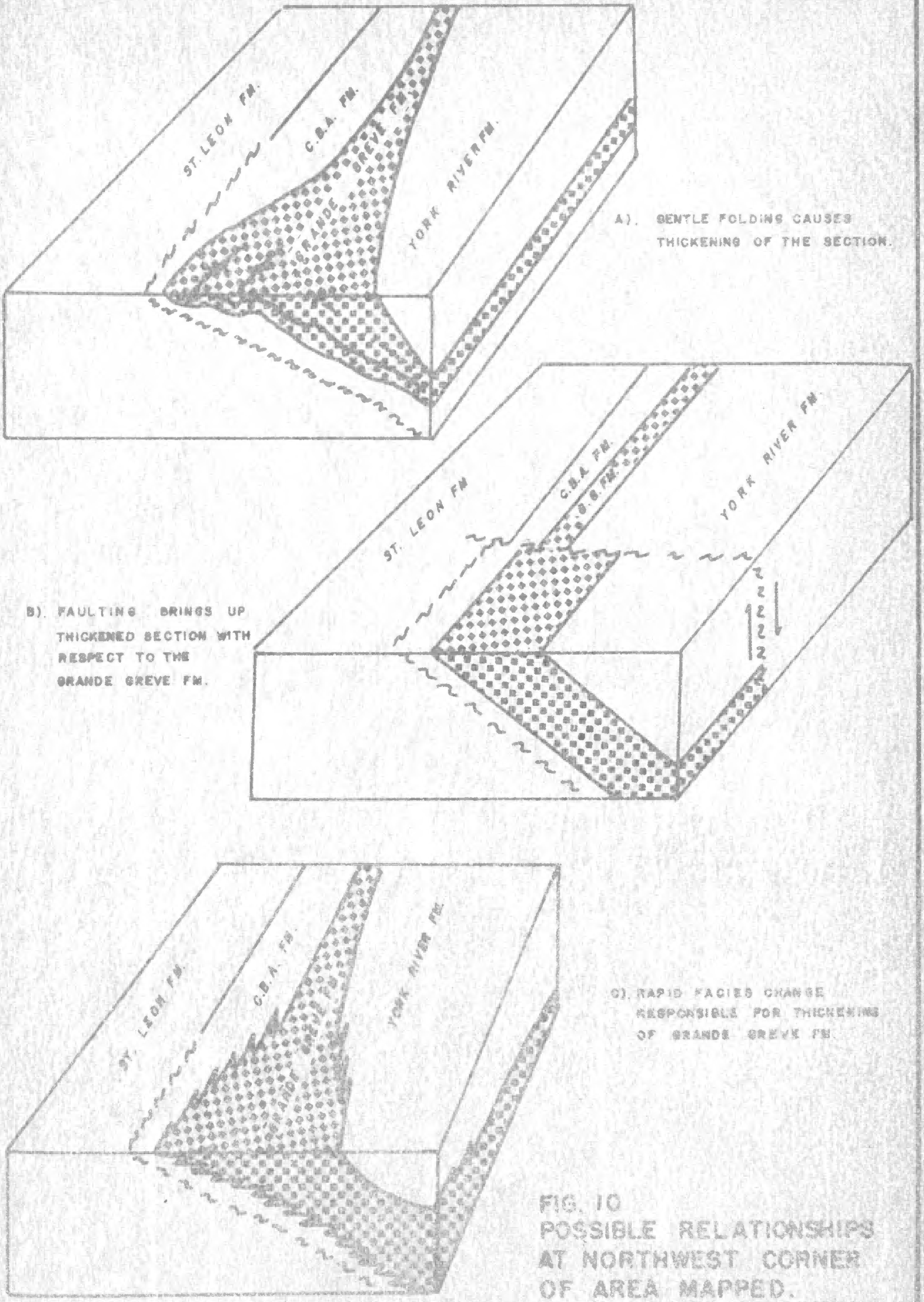
Because of the time available, the writer was unable to investigate in detail the complex structure existing within the slates and shales of the Fortin Group. During deformation this unit had markedly different competence from the graywacke sandstone of the York River Formation Folds with amplitudes of six feet or less are common, and the structure of these rocks has never been successfully unravelled Marker horizons are absent and bedding directions are not always easily found. The slatey cleavage is extremely well developed and shows the same consistent trend observed elsewhere within the area (Fig. 9e).

The main structure within the area is considered by the writer to be synclinal, a view supported by minor crossbedding directions found within the siltstones and shales of the York River Formation, and by the outcrop pattern of the overlying Lake Branch Formation further to the east (Map 3). The possibility nevertheless exists that the observations may have come from the limbs of several smaller folds rather than from the limbs of a large fold.

A fault of unknown attitude and displacement, which truncates the Cape Bon Ami Formation, is believed by the writer to exist in the northwestern part of the area.

Evidence for this fault is found along the Rimouski River (Map 9) where northwest dipping St. Leon strata are found in close proximity to the Cape Bon Ami contact and where beds of the latter dip to the southeast. The fault appears to merge with the normal stratigraphic Cape Bon Ami/St. Leon contact about 3 miles to the east of the Rimouski River.

The outcrop belt of the Grande Greve Formation is considerably wider between Lac John and the Rimouski River. Three possible relationships to explain this widening are represented diagrammatically in Fig. 10. Gentle folding in the western part of the area is possibly responsible for the widening, although the unit is also gently folded at Lac John, with no apparent widening. A thickened section of the Grande Greve Formation may have been brought up or down along faults, although no evidence for the latter has been observed. The third, and possibly the most likely explanation is that the western area represents a region of rapid facies change, and here the base of the Grande Greve Formation is time-equivalent to the top of the Cape Bon Ami Formation to the east of Lac John.



A). GENTLE FOLDING CAUSES THICKENING OF THE SECTION.

B). FAULTING BRINGS UP THICKENED SECTION WITH RESPECT TO THE GRANDE GREVE FM.

C). RAPID FACIES CHANGE RESPONSIBLE FOR THICKENING OF GRANDE GREVE FM.

FIG. 10
POSSIBLE RELATIONSHIPS AT NORTHWEST CORNER OF AREA MAPPED.
(CF. MAP 7.)

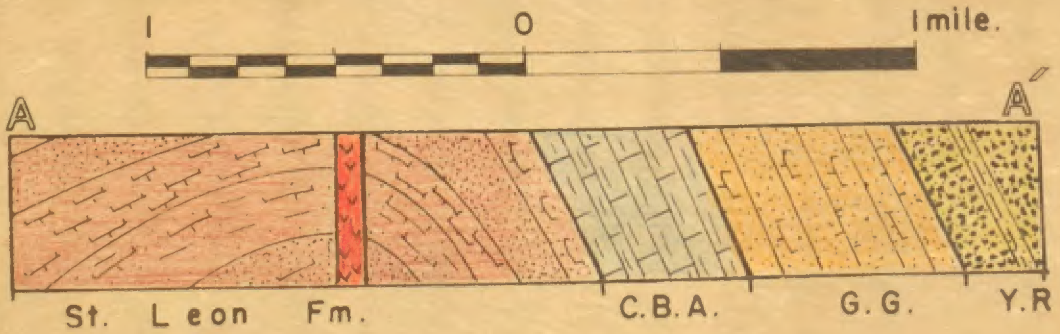
LEGEND

🟥	**DIABASE DIKE.**
🟨	**YORK RIVER FORMATION** Nòn calcareous graywacke ss., sls & sh.
🟧	**GRANDE GREVE FORMATION:** Calcareous ss. & sls.
⬜	**CAPE BON AMI FORMATION:** Gray silty ls.
🟫	**ST. LEON FORMATION:** Gray and green calc. sls. and fine grain ss.

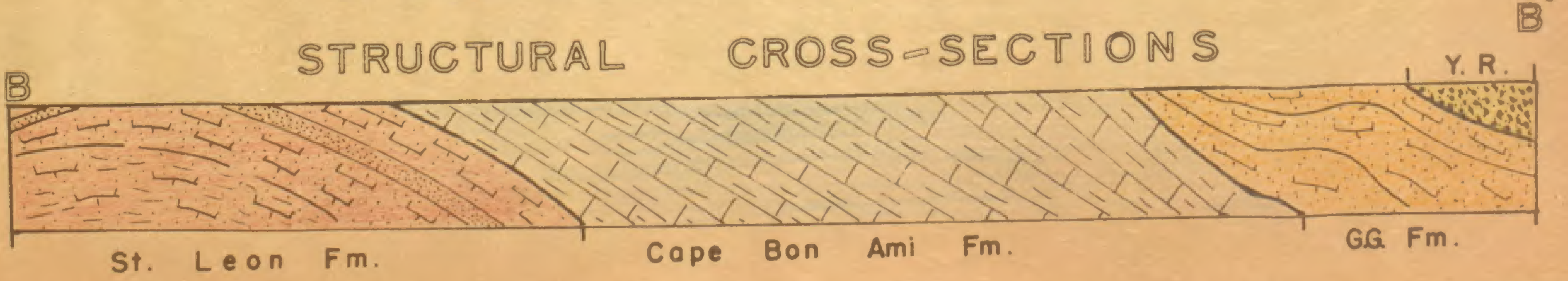
▥	Diabase dike.
▒	Medium grained sandstone.
░	Fine grained sandstone.
▤	Silty sandstone.
▦	Calcareous sandstone.
▦	Silty limestone.
▤	Calcareous siltstone.

FIG. 11:
(c.f. Map 9.)

Scale: $1'' = \frac{1}{2}$ mile



STRUCTURAL CROSS-SECTIONS



No evidence was seen of any faulting along the York River/Fortin contact, although the presence of a fault has been shown to exist to the east of this area (Map 3) (Beland, 1960; Stearn, 1959 a & b).

The term foliation is used in the sense defined by Fairbairn (1949, p.5), where he stated, "parallelism of planar elements gives rise to foliation". Well-developed closely-spaced foliation surfaces, statistically parallel to the regional axial plane, are present within the Cape Bon Ami and Grande Greve Formations, as well as the Fortin Group; the foliation is only weakly developed in the St. Leon and York River Formations. There is no apparent regular change in the development of foliation in any direction across the area mapped. The degree of foliation developed is primarily controlled by the lithology of each unit. Foliation is well developed within the silty limestones, the siltstones and the shales, but is very poorly developed within the sandstones.

Under the microscope the fine-grained rocks show a well-developed foliation which has the form of a myriad of anastomosing very fine fractures, curved around individual detrital grains, producing a net-like texture within the rock.

The distance separating adjacent fractures appears to be controlled by the size of the grain around which the fractures curve. (Fig. 12a.). In hand-sample the foliation surfaces have a lustrous appearance, however in thin-section layers of preferrentially oriented phyllosilicates are not obvious.

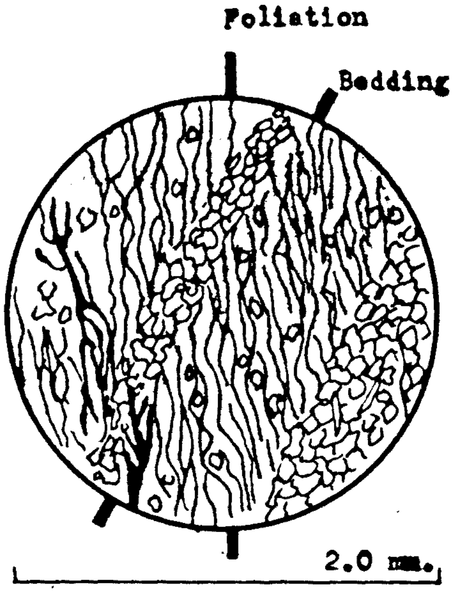
The foliation is poorly developed and often irregularly spaced within the sandstones (Fig. 12c). The fractures do not transect grains but curve around them. Where sandstone and siltstone are interbedded the foliation planes tend to be deflected or even disappear completely (Fig. 12b).

In trying to classify this type of foliation the important question of "scale" must be considered. On the scale of the hand-sample, the fine-grained rocks appear to have been uniformly affected by the foliation, but on the scale of the thin-section every particle of the rock has not been affected (Fig. 12b). The foliation appears as a series of closely-spaced planes, along which movement has probably taken place. It is difficult to ignore the presence of lustrous foliation surfaces found in hand-sample, and it is the opinion of the writer that the term 'slip

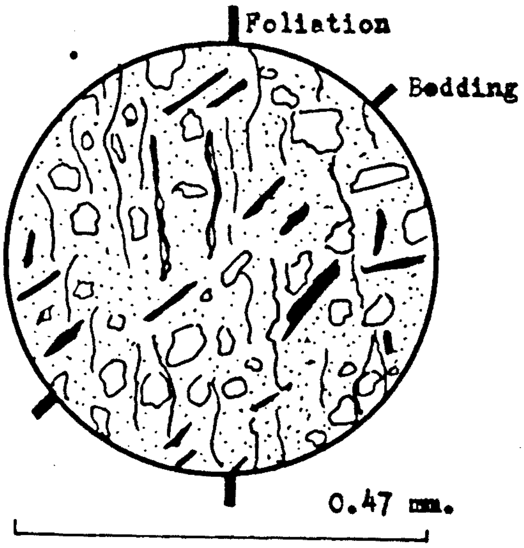
FIGURE 12.

EXAMPLES OF FOLIATION

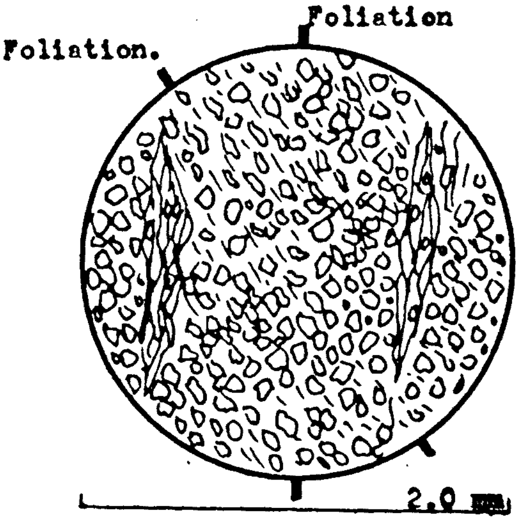
a. Well developed foliation in fine-grained siltstones of the Cape Bon Ami Fm. N.B. foliation planes rarely cross-cut coarse beds.



b. Weakly developed foliation in laminated siltstones of the York River Fm. Non-continuous fractures. Mica (in solid black) is aligned parallel to bedding.



c. Fine-grained sandstone of the York River Formation; clusters of weakly developed fractures cross-cut preferred orientation of quartz and micaceous minerals. Sample not oriented in field and one foliation direction is thought to represent bedding.

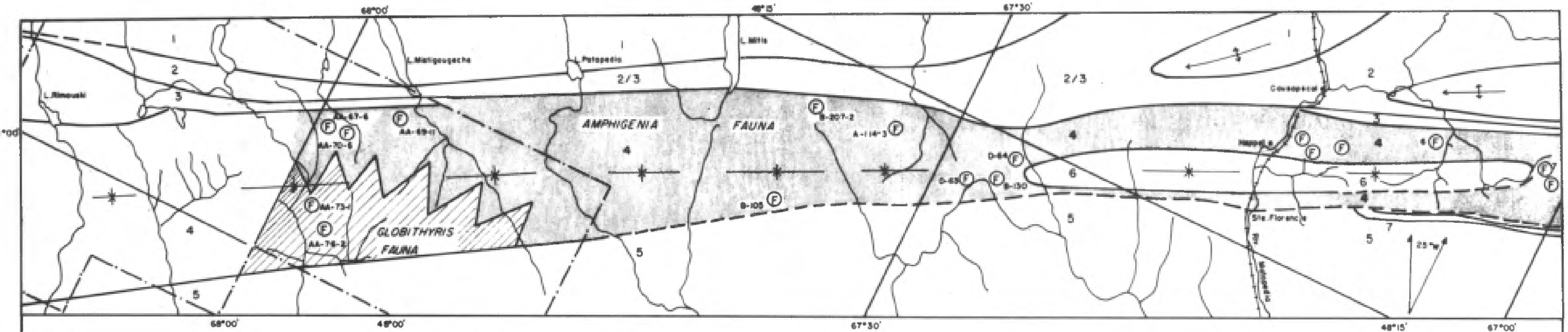


foliation" is applicable for this structure (equivalent to "slip cleavage" as defined by Billings, 1954, p.339).

4. PALEONTOLOGY OF THE YORK RIVER FORMATION

The York River Formation is not particularly rich in fossil content, but identifiable forms have been found within the sandstones at a number of localities (Map 5). The identifications were made by Professor Arthur J. Boucot of the Massachusetts Institute of Technology, and a list of the fauna found within the area mapped is shown in Table 3. The fossil locations of Beland (1960) and Stearn (1959b) have also been shown on Map 5.

Two distinct faunal assemblages are present within the area mapped. The fauna of the northern limb of the Heppel syncline is characterized by the brachiopod Amphigenia, a genus hitherto found only in strata of Schoharie and Onondaga age. The southern limb of the syncline contains an impoverished fauna characterized by the brachiopod Globithyris. Boucot (1953, p.14) interpreted this fauna, which is not found in the middle or southern Appalachians, as a unique facies fauna. The situation of these two distinct faunal assemblages is similar to that found by Boucot (1953) in the Tomegan Member of the Moosehead Formation in Maine. No evidence of the Globithyris



APPROXIMATE REALMS OF THE AMPHIGENIA AND GLOBITHYRIS FAUNAS

7	St. Marguerite Volcanics.
6	Lake Branch Formation.
5	Fortin Group.
4	York River Formation.
3	Grande Greve Formation.
2	Cape Bon Ami Formation.
1	St. Leon Formation.

SCALE

0 4 8 12 16 MILES

1:126720

Ⓕ	Fossil Location
——	Geological Contact
— —	Fault, approximate
‡	Anticlinal Axis
✳	Synclinal Axis
++++++	Railroad

DATA COMPILED FROM:

a) Stearn, (1959b), area east of Matapedia Valley

b) Beland, (1960)

c) Ayrton, (1961), —·— limits of area mapped

W.G.A. 1961

MAP 5.

fauna is found in the fossil collections of either Beland (personal communication, 1960) or Stearn (1959b). Within the area mapped by the writer, one collection, AA-70-6, contains a mixed fauna of both Globithyris and Amphigenia.

Boucot (1953) believed that the depauperate Globithyris fauna, which is in such marked contrast to the normal marine fauna of the Lower Devonian, suggested a specialized environment, and indicated that the zone of the littoral or sub-littoral would provide such an environment. There is no apparent change in the lithologic character of the York River Formation to indicate the presence of two distinct environments.

The geographic distribution of these two distinct facies faunas is difficult to interpret, mainly because it is not known whether the faunas represent life or death assemblages. The restricted Globithyris fauna may have developed in response to a specialized environment as suggested by Boucot (1953) or possibly it may have been transported to the site of deposition without being mixed with the normal marine fauna. It is the opinion of the writer that the geographic distribution may have been in part controlled by turbidity currents, but it is still enigmatic how the segregation of the two faunas was achieved.

Carbonized remains of very poorly preserved plants are common throughout the unit. No identification of these particular samples was possible, but Dawson (1871) has identified many excellent specimens of Psilophyton from the Gaspe Sandstone Group in Eastern Gaspe, and it is probable that the same flora is preserved in the Rimouski-Matapedia area.

There is a paucity of fossils within the York River Formation, and it is difficult to give a definite reason for this lack of life. Many possibilities can be considered, for example the turbid environment within the basin may not have been a suitable place for animals to live. Alternatively, salinity, temperature, depth of water, amount of light or food supply may also have been responsible for inhibiting life.

TABLE 3.

FAUNA OF THE YORK RIVER FORMATION

		AA-76-2	AA-73-1	AA-70-6	AA-69-10	AA-67-6
Globithyris Fauna						
Globithyris callida	**	X	X	X		
Globithyris diania	**	X	X			
Clams		X	X			
Unident Clam			X			
Amphigenia Fauna						
Brachiopods						
Acrospirifer sp.				X		
Amphigenia parva	*			X	X	X
Atrypa "reticularis"	*			X	X	X
"Chonetes" nectus	*			X	X	X
Elytha ? sp.				X		
Eodevonarid sp.	*				X	
Meristella sp.					X	
Mucrospirifer ? sp.					X	
Pholidops sp.	*				X	
Protoleptostrophia blainvillei	*			X	X	X
Rhipidomelloides cf musculosa solaris				X		X
"Schuchertella" sp.	*				X	
Stropheodonta cf. demissa	*				X	
Mollusks						
Unident pelecypod				X		
Snails					X	
Cornellites sp.	*				X	
Tetracoral				X		
Trilobite					X	

**Found also in the Globithyris fauna of Boucot (1953), in Maine

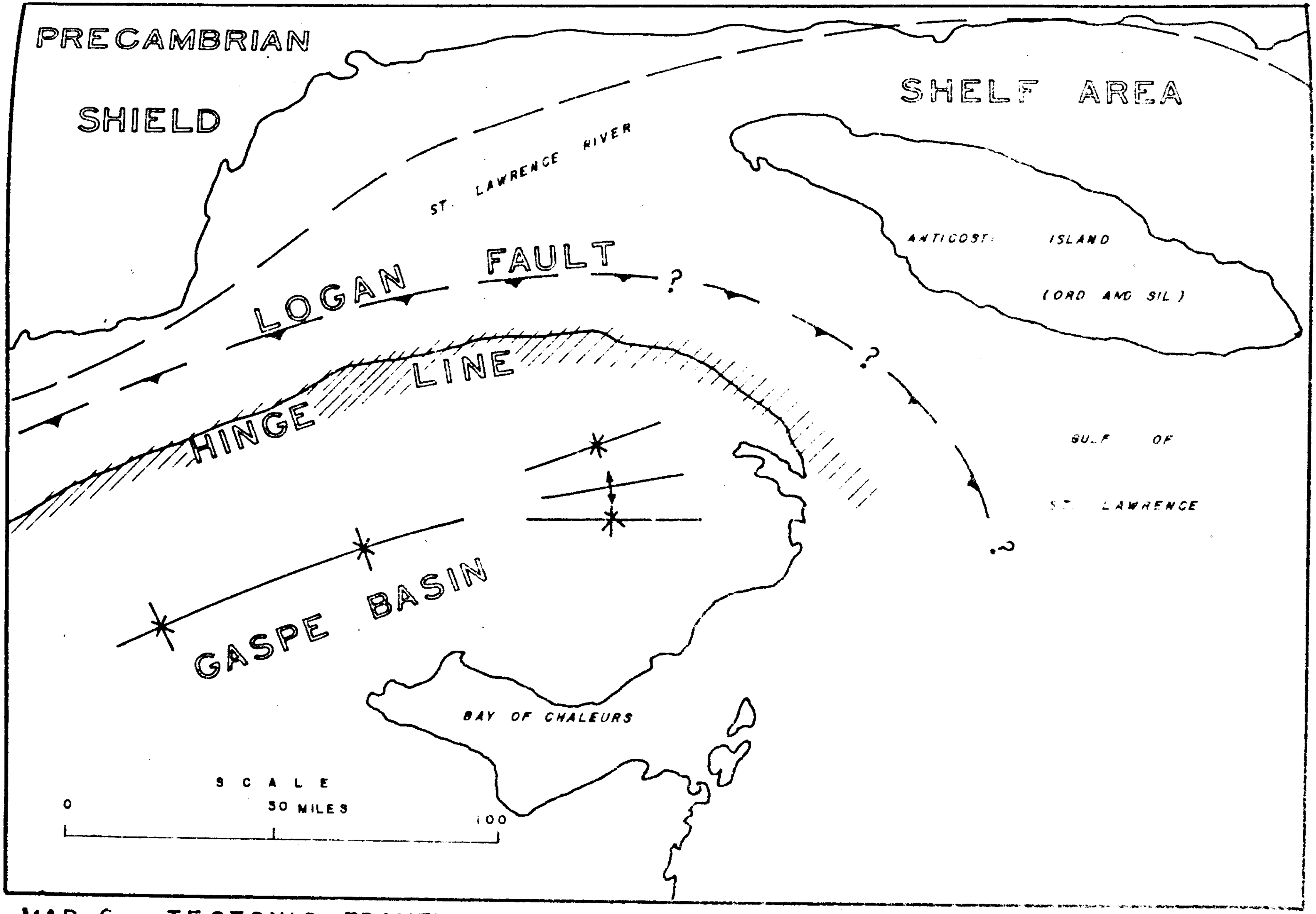
*Found also in the Amphigenia fauna of Boucot (1953), in Maine

CHAPTER III

INTERPRETATION

Tectonically, the Northern Appalachians were once part of a geosynclinal belt which, in the Devonian Period, extended from Newfoundland to Alabama. The pre-Silurian rocks of this belt were deformed in Late Ordovician time during the Taconic Orogeny (Crickmay, 1932). The northwest boundary of the Appalachians, and also the zone of severe Taconic deformation, is outlined by the Logan Fault, which Logan (1863) believed to be a major thrust. The fault can be traced as far as Quebec City, east of which it is generally believed to underlie the St. Lawrence River (Map 6). "Logan's Line", as the fault-trace is commonly called, lies to the southwest, south and southeast of the shelf areas of Anticosti Island, the St. Lawrence Lowlands and northeastern New York State respectively. The undisturbed sediments of the shelf, chiefly limestones and shales, are relatively thin and range from Cambrian to Silurian in age.

Silurian and Devonian rocks unconformably overlie Ordovician and older rocks at a number of locations within



MAP 6. TECTONIC FRAMEWORK DURING YORK RIVER TIME.

the Gaspe Basin. Southwest of Gaspe, long belts of Silurian and Devonian rocks extend into New Brunswick, Maine and New Hampshire, and synclinal remnants are also found in the Eastern Townships of Quebec, (Dresser and Dennis, 1944).

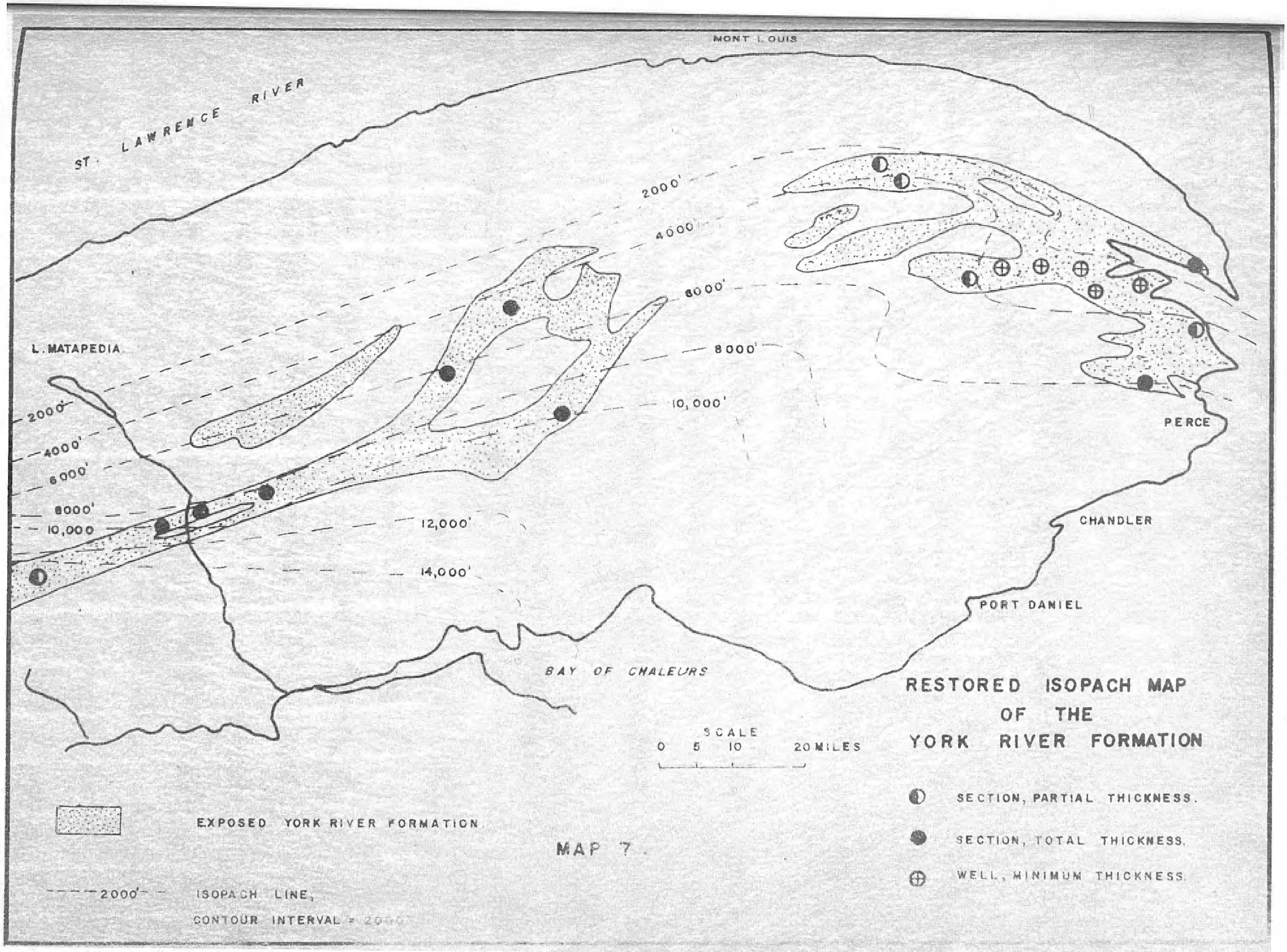
The rocks of the Gaspe Devonian are of the typical eugeosynclinal association, chiefly graywacke, dense siliceous limestone, siltstone, green shale and volcanics. There is very little record remaining of miogeosynclinal or shelf rocks of the Devonian Period, as they have either been obscured by later deformation or eroded. Because of this gap in the geologic record, it becomes increasingly difficult to interpret whether the York River sediments were derived from inside or outside the geosyncline.

By considering first the pattern of sedimentation in the Gaspe Basin, and secondly the type of sediments deposited in it, it is possible to reconstruct a partial tectonic framework of part of the Northern Appalachians during the Devonian Period.

Sedimentation continued without any major break during the Silurian and Devonian Periods, so it is of interest to consider the pattern of Silurian dedimentation.

Burk (1959) outlined two elongate troughs in which as much as 20,000 feet or more of Silurian sedimentary and volcanic rocks were deposited. These troughs were roughly parallel to the present outline of the peninsula and were separated by a less-rapidly subsiding arch. An inferred hinge zone separated the thick geosynclinal succession of Gaspe from the thin shelf sequence preserved on Anticosti Island to the northeast.

The Gaspe Limestone Group (St. Alban, Cape Bon Ami and Grande Greve Formations) was deposited during the Early Devonian, and was overlain by thick clastic sediments known collectively as the Gaspe Sandstone Group. The York River Formation was the first unit of the Gaspe Sandstone Group to be deposited. An isopach map showing restored thickness values has been constructed (Map 7), and the pattern of sedimentation is similar to the Silurian pattern (Burk, 1959). At least 10,000 feet of sediments were deposited in the Gaspe Basin, the northern part of which was roughly parallel to the arcuate outline of the peninsula. The isopach pattern suggests that the eastern end of this elongate trough received less sediment than did the western



RESTORED ISOPACH MAP
OF THE
YORK RIVER FORMATION

MAP 7.

part and that a less rapidly subsiding element apparently existed at the eastern end of the trough. The isopach pattern illustrates that the unit thickens towards the south, and that the most southerly exposures are those in which the thickest accumulations are found. It is therefore apparent that neither the shape nor the extent of the southern part of the basin can be satisfactorily outlined, as probably much of the rock record has either been covered by later Carboniferous sediments, or has been removed by erosion.

The progressive thinning of the York River Formation to the north suggests a pre-existent shelf area where thin limestones, since removed by erosion, were once deposited. No Devonian rocks have been preserved on Anticosti Island and the only evidence of Devonian strata north of the St. Lawrence River is found in the St. Helen's Island Breccia at Montreal. This volcanic breccia contains fragments of fossiliferous Lower Devonian limestone (Clark, 1952, p.81). The youngest rocks which crop out in the St. Lawrence Lowlands are of Ordovician age, so the extent of the shallow Devonian seas over the Canadian Shield is unknown.

The York River Formation has been described in detail in Chapter II, but in the light of the present discussion it is considered relevant to review some of the more important lithologic characteristics. The York River Formation is a marine deposit comprising a monotonous and regular sequence of innumberable alternating sandstone, siltstone and shale layers between which the contacts are sharply defined. The sandstones are medium-grained massive graywackes of marked petrographic consistency. The shales and siltstones are finely laminated and of similar composition to the sandstones. Much carbonized plant material is found within the sandstones, but vectorial properties such as cross-bedding and flute casts are rarely found.

The presence of finely laminated shales interbedded with massive sandstones rich in plant material is somewhat paradoxical. The former indicate undisturbed bottom conditions, presumably deep water and certainly deposition below wave-base, while the latter indicate deposition in a shallow neritic environment.

At this point it is of value to consider examples of similar deposits found in similar tectonic environments in other parts of the world. In so doing, the mode of deposition, the provenance and the environment of deposition, within the Gaspe Basin may be more clearly understood. Three deposits are here considered, the Alpine flysch, the flysch of the Polish Carpathians, and the sediments of the Ventura Basin of California. It is beyond the scope of this study to describe each of these deposits in detail, but some of the pertinent criteria and geologic inferences have been extracted from the literature, and are compiled in Table 4.

Sujkowski (1957), in an excellent paper describing flysch sedimentation stated that:

> "Many rock series outside the Alps resemble Flysch, and there is no reason why they should not be classified as Flysch."

Sujkowski's definition of flysch is given in Table 4, and it is apparent that the sediments of the York River Formation could be thus classified.

Sujkowski believed that the normal type of deposit in situ in a flysch series is represented by shales and that the sandstones are "interlopers in a strange environment". Each bed of sandstone represents a local accident which interupted the normal sedimentation and introduced foreign

TABLE 4

COMPARISON OF FLYSCH DEPOSITS

	Tercier (1947) ALPS	Dzulynski et al. (1959) Sujkowski (1957) POLISH CARPATHIANS	Natland & Kuenen (1951) Ventura Basin, California	Ayrton (1961) York River Fm., GASPE
Thickness	6,000 ft. (?)	20,000 ft.	20,000 ft.	10,000-18,000 ft.
Sandstones				
Graded Bedding		Common	Common	Suspected
Cross-Bedding	Not Present	Rare	Rare	Not Present
Av. thick. of beds		½"-6ft. (lenticular)	6"-5ft. (lenticular)	6"-2ft.
Sorting	Petrographic Consistency	Well-sorted (for size)		Petrographic Consistency
Composition	Micaceous Sandstones	Graywackes	Impure Sandstones	Graywackes
Siltstones & Shales				
Laminated		Horizontal lamination	Regular lamination	Horizontal lamination
Av. thickness		5" - 6"		6"
Cross-bedding		Common Small-Scale	Common Small-Scale	Present Small-Scale
Conglomerates	Present	Present (Lenticular)	Abundant	One 3ft. bed
Current Ripples	Scarce	Present	Questionable	None observed
Layer Contacts	Regular bedding, sharp	Sharp & clean-cut	Upward transition from shale→ss. abrupt	Sharp & clean-cut
Sedimentary Markings	Slump Structures	Flute & Load Casts, Slump Structures	Slump & drag marks Pull-apart structures	Slump Structures
Organic Remains	Lack of autochthanous dwelling fauna. Abundant carbonized plants.	Abundant in shale, ss. scarce-decayed plants	Fairly abundant, wood & leaf fragment	Few sandy fossiliferous horizons. Abundant carbonized plants.
Tectonic Environment	Geosynclinal basin, broken by steep discontinuous cordillera	Geosynclinal	Basin	Geosynclinal
Depth of Sedimentation	Marine seds. part neritic, part bathyal	Deep Water	4-5,000' shoaling to a few 100' then deposits of terrestrial origin	Deep water→basin well filled, & finally seds. of terrestrial origin.
Deposition	Problematical	Turbidity Currents	Turbidity Currents	Turbidity Currents
Rate of Sedimentation		0,8"-1.0" per 1000 yrs. Sand phase each 4000yrs.		

Definition of Flysch by Sujkowski (1957) - "The name Flysch is a facies denomination of a marine deposit composed of innumerable alternations of sharply divided pelitic and psammitic layers. Other rocks in the deposit are accidental, and in particular pure limestones are rarely present. The series commonly attain thicknesses of thousands of feet and were deposited in geosynclinal areas."

material from outside the area. This explanation is similar to that given by Natland and Kuenen (1951) for the sediments of the Ventura Basin of California. They believed that after rivers carried sediment to the sea, the silt and clay fraction proceeded immediately down the gentle submarine slope, but the sand was concentrated near shore. When these deposits of sand exceeded the angle of repose they slid seaward in a massive turbidity flow. Such conditions may well have existed in the Gaspe Basin.

The bathymetric setting within the Gaspe Basin is still far from clear but a few lines of evidence may still be followed. The marine deposits do not show evidence of a high-energy environment and exhibit good evidence for a low-energy environment, i.e. finely laminated siltstones and shales. It is therefore likely that the strata was deposited in undisturbed conditions below wave base. There is no indication of abnormal salinity. The abundance of plant fragments may indicate a fairly shallow sea, not too far distant from coastal environments, yet a shell-bearing littoral fauna is rare. Shepard (1956), in a study of the Mississippi delta, remarked on the great abundance of wood fragments in the sediments around the delta. Trümpy, (1960) came to the conclusion after studying the Alpine flysch, that most flysch rocks have been formed at depths exceeding "200 meters", yet not exceeding "a few kilometers". It is evident that the rate of supply and the deposition of clastics was rapid within the Gaspe Basin. It would seem logical to assume that the basin was filled or nearly filled with sediments, until finally the rate of deposition increased to such an extent that the sediments accumulated above base level. Evidence of this non-marine environment is found in the overlying Battery Point and Lake Branch Formations. These rocks contain red-beds, cross-bedding, plant fragments, mud-cracks, ripple marks and rain imprints (Carbonneau, 1959; Stearn, 1959b).

The position of the shoreline has not been recognized. Boucot (1953, p.63) believed that the Globithyris fauna is situated between areas of typically marine and non-marine faunas, floras and sedimentary rock types. If this be the case, it is possible that non-marine deposits were formed to the south of the area mapped, and have since been removed by erosion.

It is somewhat difficult to postulate the rock types of the source area during York River deposition.

It is the belief of the writer that the abundance of detrital potash feldspar and sodic plagioclase within the sediment indicate that acidic and intermediate igneous rocks were once present. The existence of volcanics within the source area is considered likely, as detrital fragments are found within the sediment. Much of the detrital fraction may have been derived from reworked sediments since chert grains, quartzite fragments and several quartz grains with worn overgrowths were observed in thin section.

The question now arises; from where did these great thicknesses of clastics come from? Where was the source area? In the early literature many writers have been intrigued by the problem of the Northern Appalachian sediments and of the "land mass of Appalachia". Walcott (1891, p.365), one of the first writers to propose this Atlantic borderland, suggested;

> "It is not improbable that the area of the great coastal plain of the Atlantic slope was then an elevated portion of the continent, and that much sediment deposited during Cambrian and later Paleozoic was washed from it into the seas immediately to the west."

H.S. Williams (1897, p.395) was the first to name the area "Appalachia", and he implied that it was the source area of the later Devonian clastic detritus. Schuchert (1923, p.162) sub-divided the northeastern half of Appalachia, which he named Greater Acadia, into the Acadian geosyncline, the New Brunswick geanticline, and the borderland Nova Scotica. The New Brunswick geanticline, according to Schuchert, lay to the south and east of the St. Lawrence geosyncline.

Kay (1951, p.31), on the basis of abundant evidence, also believed that Middle and Upper Ordovician Silurian and Middle and Upper Devonian sediments came from the east. He suggested two possible source areas; "great crystalline borderlands formed prior to the beginning of the Cambrian", and "lands raised from earlier Paleozoic geosynclinal belts by intra-Paleozoic mountain building". The second concept suggests that the geosyncline grew by a process of cannibalism.

The writer favors Kay's second suggestion for several reasons. All indications, the valcanism, the rapid facies changes, suggest that the geosyncline was a region of great crustal instability. Stratigraphic information can be matched with times of emplacement of acidic plutonic rocks during Devonian time. The Littleton Formation (Devonian) of New Hampshire contains rhyolite and trachyte flows; the

Oliverian and New Hampshire magma series of the same state are probably Middle Devonian (King, 1959). Potassium-argon dating of granites in southern Quebec and Newfoundland indicates emplacement in the Devonian Period (Lowden, 1961). It would therefore seem likely that within this Devonian geosynclinal complex positive areas of acidic and intermediate igneous rocks and sedimentary strata were shedding the clastics of the York River Formation.

Rising cordilleras would furnish large amounts of detrital material, but it is difficult to explain how the detritus was reduced to the comparitively small grain size which is consistent along the length of the Gaspe Basin (Stearn, 1959b; Carbonneau, 1959; McGerrigle, 1950). There may have been fragmentation around small positive areas within the basin, but evidence for the existence of these is lacking. Djulynski, *et al* (1959) have reasoned that a powerful and prolonged source of sand must be attributed, in most cases, to weathering of a wide area of subdued relief, and that large rivers transport the sand to the sea. The feldspar content of the York River Formation is high, and it has been often suggested in the literature that a high feldspar content is evidence of a nearby source, short transport and rapid burial. Russell (1937), on the other hand, has effectively shown that along the Mississippi River for example, there is little downstream change in feldspar content. Therefore it is possible that the York River sediments may have been derived from a large, distant source area of low relief.

The exact location of the source areas is unknown, but certain inferences may be made from the information gathered. No important conglomerates are present within the York River Formation, so an immediate source area is not indicated. A northern source is probably eliminated if limestone was being deposited on the shelf area. It is unlikely that if the detrital fraction of a graywacke sandstone was derived from the north, that it could bypass the zone of carbonate deposition on its way from the Canadian Shelf to the Gaspe Basin. The marked thickening towards the south may indicate that the source area is in that direction.

Rivers can be barred from laterally entering a geosynclinal trough by flanking positive areas. According to Djulynski, *et al.* (1959), Kuenen (1957) has compared this picture to present-day land-locked trenches, and found that the supply from the end is the rule. An important result of the mapping done by Djulynski, *et al.* (1959) in the Polish Carpathians is the strong predominance of longitudinal transport in flysch troughs. It is as yet enigmatic whether longitudinal transport occurred in the Gaspe Basin , as vectorial properties are rare in the sediments. However, Carbonneau (1959) believed that the current direction, as inferred from the orientation of fossils, cross-bedding and ripple marks, was southwesterly. This direction may well have been parallel to the axis of the depositional basin, but there is no evidence to suggest that the measurements were taken at outcrop locations coincident with the trace of the axial plane of the basin.

It is the belief of the writer that the sediments of the York River Formation represent the first major influx of clastics into what had been a predominantly limestone depositing sea. These clastics were deposited in the Gaspe Basin as a result of the first pulse of the Acadian Orogeny, which deformed the geosynclinal belt in the latter part of the Devonian Period.

Tercier (1947) has attached an orogenic significance to the meaning of flysch deposits, and, translating freely, he described flysch as "the deposits which immediately precede the main paroxysmal phase of a mountain chain". The term flysch consequently expresses a close relationship between sedimentation and orogenic processes.

The York River Formation therefore corresponds to the important class of sedimentary rocks known as flysch, both in lithologic aspect and in position within the tectonic and orogenic frameworks.

CHAPTER IV

CONCLUSIONS

The following conclusions can be drawn:

1) The York River Formation comprises a monotonous, thick, marine succession of graywacke sandstones, siltstones and shales.
2) The York River Formation is part of an uninterupted depositional cycle, which continued through most of the Silurian and Devonian Periods.
3) Paleontologic evidence, based primarily on the presence of the brachiopod Amphigenia, indicates that the York River Formation was deposited during the Onesquethaw Age of the Devonian Period (Early Onondagan).
4) The Fortin Group, which crops out on the south side of the Heppel Syncline, is the stratigraphic equivalent of the Grande Greve and Cape Bon Ami Formations.
5) The structural geometry of the area mapped indicates one episode of cylindroidal folding around a horizontal axis which trends at N.50.E. The dominant structure is the Heppel Syncline.

6) Igneous activity within the geosynclinal belt is evidenced by the intrusion of a diorite dike.

7) Interpretations, based on a regional study, are as follows:
    a) The York River Formation is a typical flysch deposit.
    b) Deposition of the York River Formation occurred in a rapidly subsiding, elongate geosynclinal trough, which has been called the Gaspe Basin. The rate of deposition finally exceeded the rate of subsidence, since non-marine deposits unconformably overlie the York River Formation to the east.
    c) Turbidity currents played an important part in fashioning the lithologic character of the York River Formation.
    d) Axial transport was probably an important factor in the distribution of the York River Formation clastics.
    e) Deposition of the York River Formation immediately preceeded the paroxysmal phase of Acadian deformation.

8) Further work should be directed toward extending the mapping of the York River Formation to the west, and investigating the structural geometry in that area. Particular emphasis should be placed on vectorial properties.

References Cited

Alcock, F.J., (1935), Geology of the Chaleur Bay Region: Geol. Surv. Canada, Mem.183, 146p.

Arkin, H. and Colton, R.R., (1939), Statistical Methods, College Outline Series, Barnes and Noble, Inc., N.Y., 4th ed. 226p.

Ayrton, W.G., (1960), The Chandler-Port Daniel Area, Gaspe: Unpublished manuscript, Que. Dept. Mines, 27p.

Beland, J., (1960), Rimouski-Matapedia Area; Que Dept. Mines, Prelim. Rept. 430, 18p.

Billings, M.P., (1954), Structural Geology, Prentice Hall Inc., 2nd ed., 514p.

Boucot, A.J., (1953), The Lower Devonian Rocks of West-Central Maine: Unpublished Ph.D. thesis, Harvard University.

Burk, C.F., (1959), A Regional Study of the Silurian Stratigraphy of Gaspe Peninsula, Quebec: Unpublished Ph.D. thesis Northwestern University, 87p.

Carbonneau, C., (1959), Richard-Gravier Area: Que.Dept. Mines Geol. Rept. 90, 63p.

Chayes, F., (1952), Notes on the Staining of Potash Feldspar with Sodium Cobaltinitrite in thin section: Amer. Mineralogist, vol. 37, March-April, p. 337-340.

Clark, R.H. and McIntyre, D.B., (1951), The Use of the Terms Pitch and Plunge: Amer. Jour. Sci., Vol. 249, p. 591-599.

Clark, T.H., (1952), Montreal Area, Laval and Lachine Map-Areas: Que. Dept. Mines, Geol. Rept. 46, 159p.

Clarke, J.M., (1908), Early Devonic History of New York and Eastern North America: New York State Mus. Mem. 9, pt.1, 336p.

Cooper, C.A., <u>et al</u>., (1942), Correlation of the Devonian Sedimentary Formations of North America: Geol. Soc. Amer. Bull., Vol. 53, p. 1729 - 1794.

Crickmay, G.W., (1932), Evidence of Taconic Orogeny in the Matapedia Valley, Quebec: Amer. Journ. Sci., 5th Ser., Vol. 24 p. 368 - 386.

Cumming, L.M., (1959), Silurian and Lower Devonian Formations in the Eastern Part of Gaspe Peninsula: Geol. Surv. Canada, Mem. 304, 45p.

Dawson, W., (1871), Fossil Plants of the Devonian and the Upper Silurian Formations of Canada: Geol. Surv.Canada, pt.1, p.1 - 42.

Dresser, J.A., and Dennis, T.C., (1944), Geology of Quebec: Que, Dept. Mines, Geol. Rept. 20, p. 292-332.

Dzulynski, S., Ksiazkiewicz, M. and Kuenen, Ph. H., (1959), Turbidites in Flysch of the Polish Carpathian Mountains: Bull. Geol. Soc. Amer., Vol. 70, p. 1089 - 1118.

Ells, R.W., (1883), Report on the Geological Formations in the Gaspe Peninsula: Geol. Surv. Canada, Rept. of Progress for 1880 - 81 - 82, pt. DD, p. 1-32.

----------- (1884), Report on Explorations and Surveys in the Interior of the Gaspe Peninsula 1883: Geol. Surv. Canada, Rept. of Progress for 1882-83-84, pt. E, p. 1-34.

Fairbairn, H.W., (1949), Structural Petrology of Deformed Rocks, Addison-Wesley Press, Inc., 344p.

Geological Society of America, (1951), Rock Color Chart: New York.

Jones, I.W., (1936), Upper York River Map-Area, Gaspe Peninsula: Que. Bureau of Mines, Annual Rept. for the year 1935, pt. D, p. 3-31.

Kay, M., (1951), North American Geosynclines: Geol. Soc. Amer., Memoir 48, 143p.

Kindle, C.H., (1936), A Geological Map of South-Eastern Gaspe: The Eastern Geologist, April, No. 1.

Kindle, E.M., (1938), The Correlation of Certain Devonian Faunas of Eastern and Estern Gaspe: Bull. Amer. Paleontology, Vol. 24, No. 82, p. 1-52.

King, P.B., (1959), The Evolution of North America: Princeton University Press, New Jersey, 189 p.

Krumbein, W.C., and Sloss, L.L., (1951), Stratigraphy and Sedimentation: W.H. Freeman and Co., San Francisco, 497p.

Kuenen, Ph. H., (1957), Longitudinal Filling of Oblong Sedimentary Basins: K. Nederl. Geol. Mijnb. Gen. Verh., Geol. Ser. Vol. 18, p. 189-195.

Logan, W.E., (1845), Geological Survey of Canada Report of Progress 1843: p. 23-159.

------------ (1846), On the Geology of the Chat and Cascapedia Rivers, Gaspe, and Part of Chaleur Bay: Geol. Surv. Canada, Rept. of Progress for 1844.

Logan, W.E., (1863), Geology of Canada, Report of Progress of the Geological Survey From its Commencement to 1863: Geol. Surv. Canada, p. 390-453.

Lowdon, J.A., (1961) (Compiled by), Age Determinations by the Geological Survey of Canada: Geol. Surv. Can., Paper 61-17.

McGerrigle, H.W., (1946), A Revision of the Gaspe Devonian: Trans. Roy. Soc. Canada, Sect. iv, Vol. XL, p. 41-54.

---------------- (1950), The Geology of Eastern Gaspe: Que. Dept. Mines, Geol. Rept. 35, 168p.

---------------- (1953), Geological Map, Gaspe Peninsula: 1" to 4 miles, Que. Dept. Mines, Map 1000.

---------------- (1954), The Tourelle and Courcellette Areas, Gaspe Peninsula: Que. Dept. Mines, Geol. Rept. 62, 63p.

---------------- (1959), Madelaine River Area, Electoral District of Gaspe North: Que. Dept. Mines, Geol. Rept. 77, 50p.

Natland, M.L., and Kuenen, Ph. H., (1951), Sedimentary History of the Ventura Basin, California, and the Action of Turbidity Currents: Soc. of Econ. Paleontologists and Mineralogists, Spec. Pub. No. 2, p. 76-107.

Parks, W.A., (1931), Geology of the Gaspe Peninsula: Bull. Geol. Soc. Amer., Vol. 42, p. 785-800.

Pettijohn, F.J., (1957), Sedimentary Rocks: 2nd Ed., Harper Bros., New York, 718p.

Roliff, W.A., (1952), Oil Occurrences in East-Central Gaspe: Trans. Roy. Soc. Canada, Vol. 46, Ser. 3, Sec. 4, p. 53-67.

Russell, R.D., (1937), Mineral Composition of Mississippi River Sands: Bull Geol. Soc. Amer., Vol. 48, p. 1307-1348.

Schuchert, C., (1923), Sites and Natures of the North American Geosynclines: Bull. Geol. Soc. Amer., Vol. 34, p. 151-229.

Shepard, F.P., (1956), Marginal Sediments of the Mississippi Delta: Amer. Assoc. Petrol. Geol. Bull., Vol. 40, No. 11, p. 2537-2623.

Stearn, C.W., (1959a), Causapscal Area, East Half: Que. Dept. Mines, Prelim. Rept. 382, 10p.

Stearn, C.W., (1959b), The Geology of the Causapscal-East Area, Gaspe: Unpublished manuscript in the files of the Que. Dept. Mines, Quebec, 70p.

Sujkowski, Zb. L., (1957), Flysch Sedimentation: Bull. Geol. Soc. Amer., Vol. 68, p. 543-554.

Tercier, J., (1947), Le Flysch dans la Sedimentation Alpine: Ecl. Geol. Helv., 40, No. 2, p. 164-198.

Trumpy, R., (1960), Paleotectonic Evolution of the Central and Western Alps: Bull. Geol. Soc. Amer., Vol. 71, p. 843-908.

Walcott, C.D., (1891), Correlation Papers; Cambrian: U.S. Geol. Surv. Bull. 81.

Weiss, L.E., (1958), Structural Analysis of the Basement System at Turoka, Kenya: Overseas Geol. Min. Resources Bull., Vol. 7., 65p.

Wheeler, H.E., (1958), Time-stratigraphy: Amer. Assoc. Pet. Geol. Bull., Vol. 42, p. 1047-1063.

Williams, H., et al., (1958), Petrography - an Introduction to the Study of Rocks in Thin Section: W.H. Freeman and Co., San Francisco, 406p.

Williams, H.S., (1897), On the Southern Devonian Formations: Amer. Jour. Sci., Vol. 3.

--------------- (1910), Age of the Gaspe Sandstone: Geol. Soc. Amer., Vol. 20, p. 688-698.

APPENDIX

PILOT STUDY

The object of this study was to determine the number of counts that must be made in thin section in order that an accurate and representative mineral composition of the rock can be obtained. This condition was satisfied, for the purpose of this study, when the arithmetic mean ($\bar{X}$) was stabilized and the standard deviation (s) for each component (quartz, feldspar and matrix) fell below 5%.

Six thin-sections, chosen at random from the York River Formation, were investigated on a statistical basis. For each thin-section, a total of 600 counts were made, and these results are shown on Table 5. The following components were recorded: quartz, chert, feldspar, matrix, rock fragments and unstable minerals. No division as to the type of feldspar counted was made. The main difficulty lay in determining what size quartz grain should be counted as 'quartz', and what should be included along with the agillaceous matrix. Gilbert, (Williams, <u>et al</u>, 1958, p. 297) has mentioned this complication and has suggested that any fragment less than 20 microns should be included in the matrix; this suggestion was followed. The counts were made under medium power. Traverses were made across the slide by moving a mechanical stage one division at a time, the grain directly under the crosshairs being counted each time.

These data were treated in the following manner. The variance (s^2), for the components quartz, feldspar and matrix for each mode (25,50,75,100 . . . . .600), was calculated using the following formula:

$$S^2 = \frac{\leq(x^2) - \frac{(\leq x)^2}{N}}{N-1}$$

Where N is the total number of slides examined in the pilot study, and x is the number of counts of each individual component, $\leq(x^2)$ therefore is the sum of squares and $(\leq x)^2$ is the square of the sum of six counts. The standard deviation (s), which is simply the square root of the variance (s^2), was calculated, as well as the arithmetic mean ($\overline{X}$). The latter, in this study, is the sum of six counts divided by six (Table 6).

To illustrate the results graphically (Fig. 13), the arithmetic mean ($\overline{X}$) has been plotted against the number of points counted. The arithmetic mean ($\overline{X}$) becomes stable after approximately 300 points have been counted. The confidence band outlined by one standard deviation (s) on either side of the mean has also been constructed. At 300 points both quartz and feldspar have a standard deviation of less than 5%. The matrix, however, has a standard deviation of 5.25%, but it was decided that the necessity of counting 100 more grains in order to lower the standard deviation by 0.35% was unnecessary for the purpose of this study.

Arkin and Colton (1939, p.38) point out that if an amount equal to one standard deviation is calculated on either side of the arithmetic mean, 68.27% of the values will be included within the limits indicated.

This means that in 68.27% of the cases, for a sample chosen at random, the mineral composition will be:'

Quartz	37.7% ± 2.7%
Feldspar	13.2% ± 3.7%
Matrix	35.0% ± 5.25%

TABLE 5.

Modes Determined At Intervals From 25 To 600.

THIN-SECTION X-50-4

TOTAL	QUARTZ	CHERT	FELDSPAR	MATRIX	RK. FRAGS.
25	11	3	5	5	1
50	19	5	11	11	4
75	29	10	14	16	6
100	40	12	19	21	8
150	60	14	26	39	11
200	79	17	32	59	13
300	116	24	48	93	19
400	147	30	62	134	27
500	184	33	75	172	36
600	224	41	96	200	39

THIN-SECTION X-50-5

TOTAL	QUARTZ	CHERT	FELDSPAR	MATRIX	RK. FRAGS.
25	13	0	2	10	0
50	20	2	4	23	1
75	31	5	6	30	3
100	40	7	9	39	5
150	56	10	15	63	6
200	77	14	18	83	8
300	115	27	23	123	12
400	153	38	27	166	16
500	195	44	40	203	18
600	247	47	51	237	18

THIN-SECTION X-50-6

TOTAL	QUARTZ	CHERT	FELDSPAR	MATRIX	RK. FRAGS.
25	7	1	5	11	1
50	16	4	8	17	5
75	24	7	13	24	7
100	35	10	16	33	8
150	49	14	24	51	12
200	68	17	30	71	14
300	103	27	46	105	19
400	134	34	63	142	27
500	164	39	80	185	32
600	198	46	97	219	43

TABLE 5. (cont.)

THIN-SECTION X-50-7

TOTAL	QUARTZ	CHERT	FELDSPAR	MATRIX	RK. FRAGS
25	11	0	3	9	2
50	21	1	4	21	3
75	31	5	7	29	3
100	40	9	9	39	3
150	52	12	15	64	5
200	66	15	21	88	7
300	111	20	33	123	10
400	149	31	47	160	13
500	192	37	53	199	19
600	237	44	66	231	22

THIN-SECTION X-50-8

TOTAL	QUARTZ	CHERT	FELDSPAR	MATRIX	RK. FRAGS
25	7	6	4	7	1
50	16	8	7	18	1
75	28	12	8	25	2
100	34	16	11	37	2
150	60	20	20	48	2
200	78	23	27	66	6
300	110	40	42	99	9
400	148	50	56	136	10
500	172	65	69	182	12
600	213	73	82	219	13

THIN-SECTION X-50-9

TOTAL	QUARTZ	CHERT	FELDSPAR	MATRIX	RK. FRAGS
25	16	0	4	5	0
50	32	0	6	12	0
75	41	2	11	18	3
100	49	8	15	23	5
150	72	9	24	39	6
200	91	12	36	53	8
300	128	22	53	85	12
400	171	32	71	111	15
500	214	38	91	138	19
600	255	47	107	172	19

TABLE 6.

PILOT STUDY DATA SHEET.

QUARTZ.

	Σx	Σx^2	$(\Sigma x)^2/6$	S^2	S	S (in%)	$\bar{X}$	$\bar{X}$ (in%)
25	65	765	704	12·2	3·5	14·0	10·8	46·5
50	124	2,738	2563	35·0	5·9	11·8	20·7	41·6
75	184	5,804	5,643	32·2	5·7	7·6	30·7	42·5
100	236	9,446	9,283	32·6	5·7	5·7	39·3	39·4
150	349	20,625	20,300	65·0	8·1	5·4	58·2	39·0
200	459	35,515	35,114	80·2	9·0	4·5	76·5	38·3
300	683	78,095	77,748	69·4	8·3	2·7	113·8	37·7
400	902	136,320	135,601	143·8	11·9	2·96	150·3	37·5
500	1121	211,021	209,440	316·2	17·8	3·55	186·8	37·2
600	1371	315,773	313,274	499·9	22·4	3·72	228·5	38·0

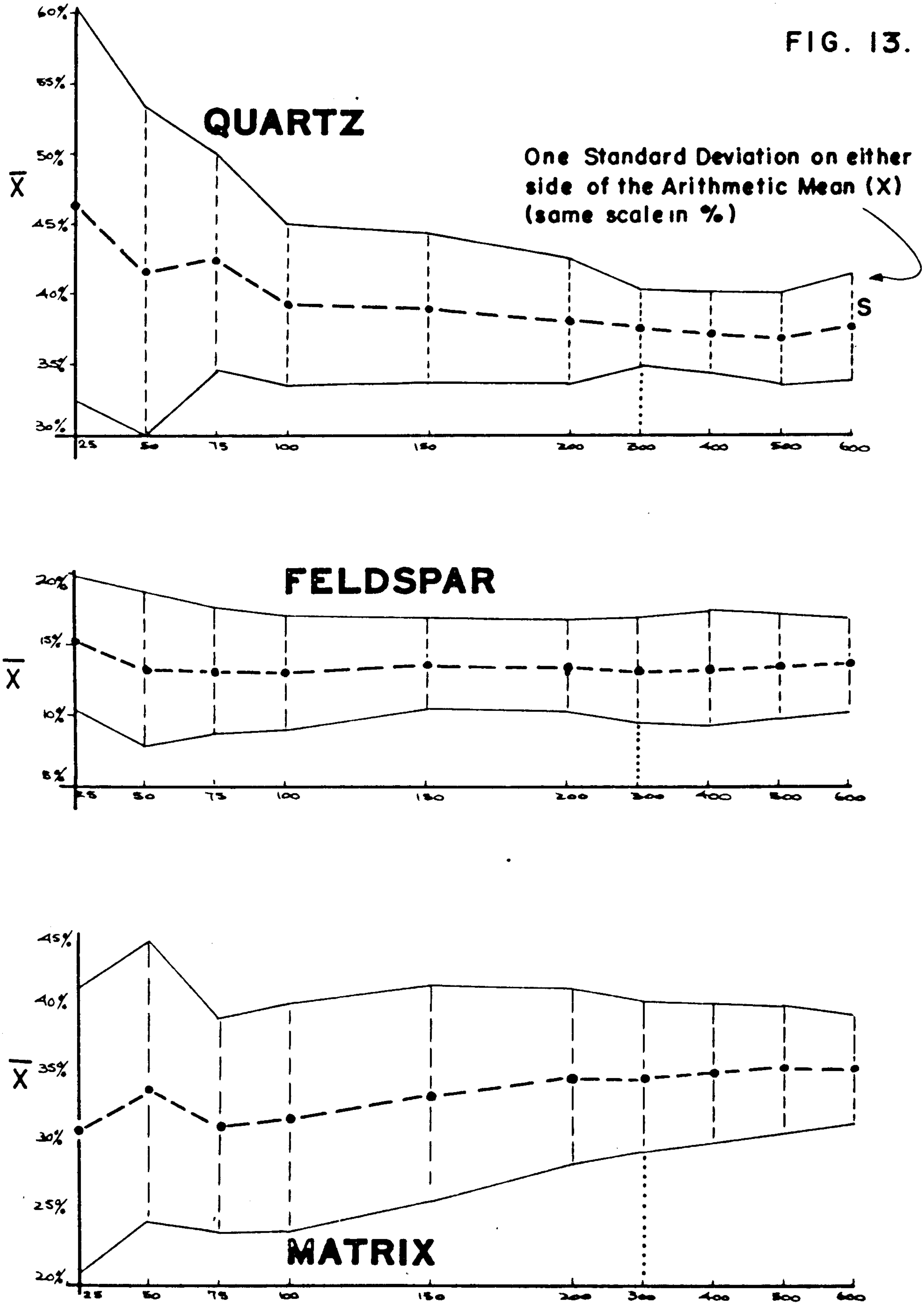
MATRIX

	Σx	Σx^2	$(\Sigma x)^2/6$	S^2	S	S (in%)	$\bar{X}$	$\bar{X}$ (in%)
25	47	401	368	6·8	2·6	10·4	7·8	31·0
50	102	1848	1,734	22·8	4·8	9·55	17·0	34·0
75	142	3522	3,361	32·3	5·7	7·6	23·7	31·5
100	192	6470	6,144	65·4	8·1	8·1	32·0	32·0
150	304	16,012	15,302	142·1	11·8	7·8	50·7	33·8
200	420	30,320	29,400	184·0	13·6	6·3	70·0	35·0
300	628	66,958	65,731	245·5	15·7	5·25	104·6	35·0
400	849	122,093	120,134	391·9	19·8	4·9	141·5	35·4
500	1079	196,787	194,040	549·4	23·4	4·6	179·8	35·8
600	1278	275,036	272,214	564·4	23·8	3·9	218·0	35·5

FELDSPAR.

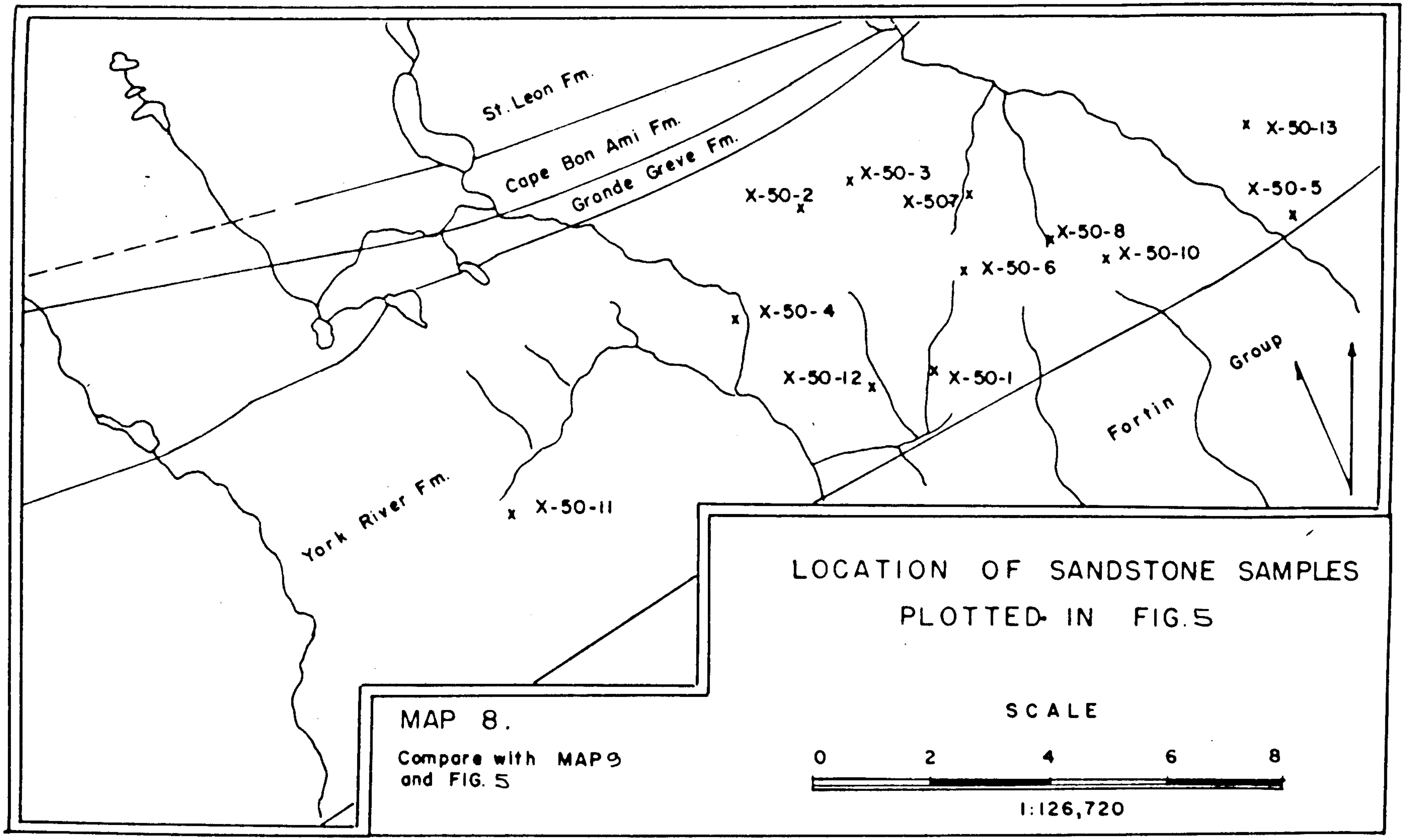
	Σx	Σx^2	$(\Sigma x)^2/6$	S^2	S	S (in%)	$\bar{X}$	$\bar{X}$ (in%)
25	23	95	88	1·4	1·2	4·8	3·8	15·2
50	40	302	267	7·1	2·7	5·4	6·7	13·4
75	59	635	580	11·0	3·3	4·4	10·0	13·4
100	79	1125	1,040	17·0	4·1	4·1	13·2	13·2
150	124	2,678	2,563	23·1	4·8	3·2	20·7	13·8
200	164	4,714	4,483	46·3	6·8	3·4	27·3	13·6
300	245	10,611	10,004	121·4	11·0	3·7	40·8	13·2
400	326	18,928	17,713	243·1	15·6	3·9	54·3	13·6
500	408	29,476	27,744	346·4	18·6	3·7	68·0	13·6
600	499	43,755	41,500	451·0	21·2	3·5	83·2	13·9

FIG. 13.



One Standard Deviation on either side of the Arithmetic Mean (X) (same scale in %)

(N.B. abscissa scale compressed from 200-600.)



LOCATION OF SANDSTONE SAMPLES PLOTTED IN FIG.5

MAP 8.

Compare with MAP 9 and FIG. 5

TABLE 7.

Mineral Composition of Samples

Sample Number	Quartz	Chert	Feldspar	Matrix	Rock Fragments
X-50-1	40.3	7.3	11.0	33.3	8.0
X-50-2	38.3	5.3	9.3	41.3	4.0
X-50-3	41.7	4.0	11.3	37.7	5.3
X-50-4	32.7	5.7	16.0	35.7	6.7
X-50-5	44.0	6.7	9.3	38.0	2.0
X-50-6	30.6	6.3	17.0	38.0	8.0
X-50-7	42.0	8.0	11.0	36.0	3.0
X-50-8	34.3	11.0	13.3	40.0	1.3
X-50-10	30.6	6.0	11.0	42.0	4.7
X-50-11	43.0	5.7	7.3	39.0	5.0
X-50-12	39.0	3.7	7.3	44.3	5.7
X-50-13	44.3	4.7	7.0	38.3	5.7

All values in percent; determined by 300 point counts.

TABLE 8

STRUCTURAL DATA

YORK RIVER FORMATION

BEDDING

50/50	NW.#
50/90	
50/90	
80/80	S.
30/90	
60/90	
65/80	SE.
50/90	
55/90	
65/70	SE.
75/90	
60/80	SE.
75/90	
55/60	SE.
40/15	SE
30/60	NW.
160/10	E.
55/80	SE.
50/80	SE.
50/80	SE.
50/80	SE.
62/80	SE.
55/90	
Horizontal	
60/80	SE.
50/20	SE.
45/65	SE.
35/62	SE.
35/69	SE.
35/70	SE.
60/85	NW.
50/70	NW.
50/70	NW.
60/90	
60/90	
50/45	SE.
50/90	
45/70	SE.
35/70	SE.
45/70	SE.
55/80	SE.
55/90	
55/80	SE.
Horizontal	
35/90	
50/70	NW.
40/80	SE.
60/70	SE.
Horizontal	
75/90	
70/90	
65/90	
40/25	SE.
75/40	NW.
35/35	SE.
40/65	SE.
40/75	SE.
60/90	
55/75	SE.
55/90	
50/45	SE.
Horizontal	
35/25	SE.
Horizontal	
50/35	NW.
50/35	SE.
55/90	
55/90	
45/80	SE.
Horizontal	
45/80	SE.
45/80	SE.
45/45	SE.
45/80	SE.
45/80	SE.
100/15	N.
60/80	SE.
50/90	
50/90	
50/90	
50/80	NW.
130/18	NE.
50/90	
75/80	NW.
55/80	NW.
50/90	
40/90	
35/90	
45/80	NW.
70/40	SE.
80/15	S.
65/32	SE.
Horizontal	
70/40	SE.
60/80	NW.
40/80	NW.
40/45	SE.
30/45	SE.
30/90	
50/90	
55/90	
55/72	NW.
75/75	NW.
60/55	SE.
75/90	
40/90	
60/90	
60/90	
120/40	NE.
135/15	NE.
50/90	
60/80	NW.
40/50	NW.
60/90	
45/90	
Horizontal	
50/30	SE.
50/45	SE.
55/90	
60/80	SE.
60/90	
65/90	
60/90	
70/85	SE.
70/90	
50/5	SE.
65/40	SE.
70/60	SE.
70/60	SE.
60/30	SE.
60/30	SE.

FOLIATION

60/90	
60/90	
60/80	NW.
65/90	
60/90	
65/90	
25/90	
45/90	
70/90	
55/90	
40/90	
40/90	
30/90	
35/90	
60/90	
55/90	
50/90	
50/90	
35/90	
50/90	
40/90	
55/90	
55/90	
45/80SE.	
50/90	
50/80	NW.
40/80	SE.
50/90	
55/90	
35/90	
55/90	
40/75	SE.
50/90	
60/80	NW.
60/80	NW.
90/90	
80/90	
75/90	
55/90	
55/90	
50/80	NW.
40/50	SE.
50/80	SE.
60/90	
65/70	NW.
70/90	

TABLE 8 (continued)

YORK RIVER FM. (cont.)

FOLIATION	
60/90	
60/90	
60/90	
55/80	SE.
55/90	
60/80	SE.
60/90	
60/90	
55/90	
50/90	
45/90	
45/90	
50/45	NW.
85/90	
55/70	NW.
55/90	
80/90	
45/90	
60/90	
50/90	
45/80	NW.
45/80	NW.
45/80	NW.
30/90	
45/90	
45/90	
50/90	
45/80	SE.
45/90	
40/75SE.	
45/90	
35/90	
40/90	
30/90	
30/90	
50/90	

GRANDE GREVE FORMATION

BEDDING	
65/90	
50/80	SE.
75/70	SE.
60/45	SE.
120/15	SW.
45/40	NW.
30/35	NW.
45/50	SE.
55/60	SE.
55/70	SE.
55/55	SE.
50/40	SE.
45/25	SE.
45/15	NW.
140/10	SW.
50/20	SE.
60/35	SE.
50/50	SE.
50/50	SE.
50/40	SE.
45/15	SE.
60/80	SE.
45/60	SE.
50/90	
55/75	NW.
50/90	
75/55	SE.
Horizontal	
135/15	SW.
30/60	NW.
160/5	W.
Horizontal	
80/30	S.
90/50	S.
30/20	SE.
60/30	SE.
75/40	S.
70/50	SE.
90/45	S.
70/30	SE.
65/40	SE.

FOLIATION	
50/80	SE.
50/90	
50/90	
45/90	
45/90	
45/90	
50/90	
50/90	
45/90	
40/90	
40/90	
50/80	SE.
40/90	
40/90	
45/90	
40/90	
60/90	
40/90	
40/90	
30/90	
60/90	
60/90	
60/90	
55/80	NW.
45/90	
50/90	
45/90	

TABLE 8 (continued)

CAPE BON AMI FORMATION

BEDDING	FOLIATION
55/70 SE.	50/90
55/35 SE.	55/90
70/70 SE.	55/90
60/90	60/90
40/45 SE.	40/80 NW.
45/45 SE.	45/90
45/20 SE.	55/90
40/32 SE.	55/90
	55/90
	45/90
	40/90

ST. LEON FORMATION

BEDDING	FOLIATION
20/10 W.	45/90
110/8 SW.	50/90
45/15 SE.	55/90
50/15 SE.	60/90
45/15 SE.	25/90
50/50 SE.	45/90
55/70 SE.	50/90
65/65 SE.	35/90
Horizontal	40/90
70/65 SE.	50/90
50/70 SE.	30/90
50/10 SE.	
Horizontal	
55/20 SE.	
140/10 NE.	
160/10 NE.	
Horizontal	

FORTIN GROUP

BEDDING	FOLIATION
40/90	40/90
50/25 SE.	50/90
0/0	50/90
Horizontal	60/90
55/80 NW.	45/90
40/90	65/90
	35/85 SE.
	40/90
	40/90
	35/90
	70/90
	40/90
	30/90
	50/90
	50/90

#First number refers to strike, second number to dip, followed by direction of dip.