REGIONAL GEOLOGY OF THE TOPSAIL-FOXTRAP AREA

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REGIONAL GEOLOGY OF THE TOPSAIL - FOXTRAP AREA

BY

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A THESIS

Submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

MEMORIAL UNIVERSITY OF NEWFOUNDLAND

1963

TYPOGRAPHICAL ERRORS

Abstract p. X last line, the word "annually" should be added to correspond to production given on p. 120

13 5 ll. from bottom, read monadnocks

33 5 ll. from bottom, insert the page no. after page

38 3 ll. from top, a period, not a comma after the word "group"

80 8 ll. from top, read sphene

94 top line, Page no. is missing

CONTENTS

		Page
ABSTRACT		
Chapter		
I	Introduction	1
	Location, Size, and Accessibility of Area	
	Previous Geological Work	
	Present Investigation	
	General Geology	
	Acknowledgements	
II	Physiography and Glacial Geology	12
	Topography	
	Drainage	
	Glacial Geology	
III	Volcanic Rocks	18
	Introduction	
	Lower Division of Harbour Main group - Rhyolitic Volcanics	
	Distribution and Thickness	
	Description of Main Rock Types	
	Microscopic Petrography	
	Problems of Lithology	
	Upper Division of Harbour Main group - Andesitic Volcanics	
	Distribution and Thickness	
	Description of Main Rock Types	
	Microscopic Petrography	
	Structural Relations	
	Mode of Origin	
	Age	
IV	Sedimentary Rocks	46
	General Statement	
	Conception group	
	Distribution	
	Description of Main Rock Types	
	Microscopic Petrography	
	Structural Relations	
	Mode of Origin	
	Age	

Chapter		Page
	Black Hill Sequence	
	Name	
	Distribution	
	Description of Main Rock Types	
	Microscopic Petrography	
	Structural Relations	
	Mode of Origin	
	Age and Correlation	
V	Intrusive Rocks....................................	66
	General Statement	
	Meta-Diorite	
	Location and Size	
	Petrographic Description	
	Origin and Age	
	Holyrood Batholith	
	Distribution	
	Description of Main Rock Types	
	Microscopic Petrography	
	Age	
	Felsite Intrusions	
	Basic dikes	
VI	Metamorphism and Metasomatism..................	86
	Introduction	
	Description and Discussion	
VII	Structural Geology................................	95
	General Statement	
	Unconformities	
	Folds	
	Faults	
	Cleavage, Schistosity and Jointing	
	Ages of Deformation	
VIII	Geologic History..................................	111
IX	Economic Geology..................................	118
	General Statement	
	Pyrophyllite	
	Minor Epithermal Sulfides	
	Till and Gravel Deposits	
	Bibliography..................................	122

ILLUSTRATIONS

Plates

			Page
Plate	I	Geological Map of Topsail - Foxtrap Area....	(pocket)
Plate	II	Geologic Sections to accompany the above map..	(pocket)
Plate	III	Magnetic Profiles across Topsail Fault zone.	(pocket)

Figures

Figure	1	Sketch Map showing latest glacial movement in Torbay Map area. After Rose (1952)......	16
"	2	Outline of Processes of Alteration in Rhyolite Rock. After Buddington (1916).........	87
"	3	Point Diagram of Joints in the Holyrood Granite......................................	109
"	4	View of valley containing Conway Brook (looking northeast). White Hill is seen in background at right........................	125
"	5	Large hill of Black Hill rocks showing lee and stoss shape, west of Johnny's Pond......	125
"	6	Small flow folds in red, banded rhyolite....	126
"	7	Large remnant of red, unaltered rhyolite in almost pure pyrophyllite, at the main pyrophyllite quarry, Johnny's Pond..............	126
"	8	Pale green, massive pyrophyllite, main pyrophyllite quarry, Johnny's Pond..............	127
"	9	Pyrophyllite showing relict "agglomerate structure" main pyrophyllite quarry, Johnny's Pond....................................	127
"	10	Spherulitic rhyolite showing development of chalcedonic nodules........................	128

			Page
Figure	11	Development of asbestos (anthophyllite) on slip surfaces in massive andesite.......	128
"	12	Highly cleaved band of tuffaceous sediments between two flows (?) of andesite..........	129
"	13	Interbedding of white argillaceous rocks and dark brown graywacke of the Black Hill sequence...................................	129
"	14	Conglomerate bed near the base of the Black Hill sequence.........................	130
"	15	Red argillaceous sediments overlying conglomeratic band in the Black Hill sequence...................................	130
"	16	Fragments of broken beds, due to slumping in the Black Hill sediments................	131
"	17	Granite dike intruding meta-diorite........	131
"	18	Xenolith of meta-diorite in granite........	132
"	19	Close view of quartz-feldspar porphyry.....	132

REGIONAL GEOLOGY OF THE TOPSAIL - FOXTRAP AREA

by

James M. Dawson

Abstract

This thesis is concerned with an area of Precambrian volcanic, sedimentary and intrusive rocks located south of the east side of Conception Bay in the north-central part of the Avalon Peninsula, Newfoundland. Physiographically the region can be divided into a southeastern, gently rolling, plateau-like surface about 600 feet above sea level, and a northwestern sector in which the dominant features are north-northwest-trending ridges and valleys apparently carved by glaciers travelling in this direction.

The oldest major rock group occurring here is the Harbour Main group which is mid-Proterozoic or older in age. The base of this group is not exposed, however, the visible portion comprises a lower, rhyolitic division and an upper andesitic division, both of which consist of lavas and pyroclasics. To the east of the volcanic rocks lie greenish sandstone, siltstones and cherty sediments of the Conception group, part of which is intertongued with the andesitic rocks of the Harbour Main group.

The Harbour Main and Conception rocks are intruded by small podlike bodies of felsite, which are particularly prevalent in the zone where andesitic and sedimentary rocks are intertongued. The two main groups mentioned above are intruded by the Holyrood "granite" batholith which consists mainly of adamellite but contains smaller bodies of quartz-feldspar porphyry and aplite. Within the granite an isolated roof pendant of meta-diorite is found. This may be related to the andesites of the Harbour Main group or may represent an older or younger intrusive mass. A small number of basic dikes invade the granite and the Harbour Main group. However, in the rhyolites several sheared basic dikes are found which are possibly older than the granite.

Lying unconformably upon the granite and volcanic rocks are small, isolated, remnants of interbedded graywacke and slate or shale, herein called the Black Hill sequence.

Shortly before the emplacement of the batholith, the Harbour Main rocks and intertongued sediments were deformed and subjected to low grade regional metamorphism. This resulted in overall schistosity and cleavage, and in chloritization and epidotization of the andesites. Late plutonic hydrothermal solutions altered the sheared fragmental acid volcanics, in the vicinity of the granite-rhyolite contact, to quartz schist, quartz-pyrophyllite-sericite schist and smaller amounts of almost pure pyrophyllite schist.

Such folds as can be discerned in the Conception group seem to trend north-northeast and are quite tight, becoming more open to the east. They have probably formed at the same time as the schistosity prevalent in the Harbour Main group as both have the same trend. Folds formed later within the Black Hill sequence have an approximate east-west trend.

There are many faults in the area, a large proportion of which belong to two sets: (a) north to north-northeast-trending, longitudinal faults and (b) northwest-trending transverse faults. The major longitudinal faults seem to have a diagonal displacement whilst the transverse faults are normal faults. Displacement at most faults is rather small. Most, if not all faults are younger than the Black Hill sequence. The largest of the longitudinal faults, the Topsail Fault, is of post-Ordovician age.

The main deformations can be placed in two orogenic periods of Precambrian age. The older of these began at some time after the Harbour Main volcanics had been formed and ended with the intrusion of the granite. The later one occurred in post-Black Hill time, folding these rocks as well as other late Precambrian sediments to the east of the area. Apart from some faulting, the rocks do not seem to have been deformed during Paleozoic and younger time.

The only mining carried out in the area is concerned with the pyrophyllite deposits occurring at Johnny's Pond, about 2 miles south of Manuels. At present, approximately 20,000 tons of 75 per cent-pure pyrophyllite are exported.

CHAPTER I

INTRODUCTION

Location, Size and Accessibility of Area

The area with which this thesis is concerned is located on the Avalon Peninsula of Newfoundland, approximately 20 miles west of St. John's, just south of the east side of Conception Bay. It lies within north latitudes 47°23' and 47°33'30" and west longitudes 52°53' and 53°00'. Of the land surface included within these boundaries about 35 square miles were mapped geologically.

The area is easily reached by the Conception Bay Highway or the Trans-Canada Highway, the latter going approximately through its centre. Several secondary roads from settlements on the south shore of Conception Bay to the Trans-Canada Highway provide further access to the region. Outlying parts of the area are reached only by travelling through the dense growth of black spruce, which is especially prevalent in the eastern portion.

Previous Geological Work

The area south of Manuels - Foxtrap was mapped during the early days of geological investigation in Newfoundland. However, this early work was of a broad reconnaissance nature in connection with efforts to map the entire Avalon Peninsula. The only detailed work done in this area concerned its pyrophyllite deposits, and their formation from acid volcanics by hydrothermal alteration.

The first geologic study of the Avalon Peninsula was carried out by J.B. Jukes in 1839 and 1840. He subdivided the rocks into two "formations" equivalent to the Precambrian sedimentary rocks and the early Paleozoic sedimentary rocks. The present Conception Group was included in his "Lower Slate Formation".

A geologic map of the Avalon Peninsula showing the distribution of formations was compiled in 1881 by Murray and Howley. This was the result of investigations carried out by these workers during the years 1864 to 1881. They recognized the major lithostratigraphic units of Jukes and subdivided the igneous rocks of the Avalon Peninsula into the "Laurentian gneisses", representing the areas of granitic rocks, and the "metamorphic slates and sandstones", which roughly correspond to the present Harbour Main group.

Walcott (1899) grouped all the Precambrian sedimentary rocks lying above the volcanics as the "Avalonian series". He called the lower two formations the "Conception and Torbay slates".

In 1907 Howley published a geological map of Newfoundland which described the Avalon Peninsula rocks in much the same manner as the previous map of 1881. However, he revised the "metamorphic slates and sandstones" and called them the "Lower Huronian series". This he described as a "series of mixed igneous and aqueous deposits, all highly metamorphosed". This series was placed stratigraphically below the Avalonian series.

Buddington (1916) published a paper on "Pyrophyllitization, Pinitization and Silicification of Rocks around Conception Bay, Newfoundland". It was the first geological work done in the present area and though it was of a specialized nature, the geology of the rocks in the vicinity of the altered rhyolites was also discussed to some extent. In 1919 Buddington published the results of a more regional study on "The Precambrian Rocks of Southeastern Newfoundland". In this report he proposed the name "Avondale Volcanics" for the Lower Huronian series of Howley. This was subsequently changed by Howell (1925) to the "Harbour Main Volcanics".

John S. Vhay, a student of Buddington, again investigated the pyrophyllitized rocks of the Manuels area in 1937. He compiled a very detailed report of the geological features and the economic possibilities of the rhyolitic rocks. He confined himself mostly to detailed descriptions of the major pyrophyllite deposits.

E.R. Rose (1952) mapped a large part of the eastern half of the Avalon Peninsula on a scale of 4 miles to the inch. This was the beginning of the program by the Geological Survey of Canada to systematically map the Island of Newfoundland. The present map area was included in Rose's Report.

W.D. McCartney (1959) mapped an area of approximately 2,700 square miles immediately west and northwest of the present area. In discussing the rhyolitic rocks of the Harbour Main group, with the exception of a small amount of rhyolitic breccias, he describes them all as ignimbrites.

W.D. Brueckner (1962) restudied the mutual relationships of the Precambrian formations in the vicinity of St. John's and north to Cape St. Francis. From his studies, which are being continued, it became apparent that the stratigraphic interpretation of the older Precambrian rocks by previous workers needs to be modified.

Present Investigation

The present study was carried out in order to describe the regional geology of this portion of the Avalon Peninsula in a more detailed manner than had previously been done. One of the more important facets of the work was the ascertaining of the relative age relationships between the different rock types of the area. This is a controversial problem in all parts of the Avalon Peninsula where these rocks occur.

The field work for this thesis was carried out from May to October 1962. Mapping was done with the aid of aerial photographs on scales of 660 and 1320 feet to the inch. The final map was enlarged to a scale of 1000 feet to the inch. An effort was made to map every outcrop in the area; densely wooded areas were covered by means of closely spaced traverses. A small magnetometer survey was carried out to locate exactly the southern extension of the Topsail Fault lying under a cover of glacial drift and alluvium. Laboratory work included the study and description of over 800 hand specimens and 105 thin sections. This was done during the winter of 1962 - 63 in the Geology Department of Memorial University of Newfoundland.

General Geology

The area under consideration forms a part of the north-central Avalon Peninsula. This region was glaciated in Pleistocene time and many of the land forms show a superficial northwest trend, superimposed upon the north to northeast trend of the underlying bedrock structures. The bedrock consists entirely of Precambrian sediments, volcanics and intrusive rocks.

Stated simply, the area is underlain by a band of sedimentary and volcanic rocks which have been intruded by a granitic batholith. The oldest (?) rock type found is a small roof pendant of meta-diorite lying within the Holyrood granite, however, its relationship to the other types is unknown. The Harbour Main group is the oldest major rock unit in the area. It consists almost entirely of volcanic rocks and has a lower rhyolitic division and an upper andesitic division. The Conception group, consisting of greenish sandstones and siltstones is partly contemporaneous with the Harbour Main group as it is intertongued with the andesitic rocks of the latter. Some portions of the Conception group, however, are probably younger than the Harbour Main rocks. The Conception and Harbour Main rocks have been intruded by the Holyrood batholith, which consists mostly of adamellite, but has small bodies of quartz-feldspar porphyry and aplite associated with it. Lying unconformably upon the Harbour Main group and Holyrood batholith are small remnants of the later Precambrian Black Hill sequence, which consists of interbedded coarse graywackes and shales. Minor acid and basic intrusions are also found scattered through the area, intruding rocks of the Harbour Main and Conception groups, and occasionally the Holyrood granite. To the north, near the south shore of Conception Bay, Cambrian sediments unconformably overlie the Precambrian rocks.

The intrusion of the granite, with the attendant contact metamorphism and hydrothermal solutions, brought about considerable alteration to rocks of the Harbour Main group, especially the rhyolites. The latter rocks are locally altered to quartz schists and quartz-pyrophyllite-sericite schists, which at some places are pure enough to be mined as pyrophyllite ore.

Structurally the area is quite complex but little can be said about the folding, especially in the Harbour Main group, where it is impossible to establish any major fold features. Faulting, however, has been observed throughout the area and faults of several types have been distinguished. The majority of the faults can be assigned to two groups: longitudinal (north to north - northeast trending) and transverse (northwest trending). The transverse faults seem to be normal dip-slip faults; the longitudinal faults probably have a diagonal-slip displacement. Cleavage and schistosity are remarkably consistent throughout, generally striking between N 10° E and N 30° E. They are thought to be genetically related to the folding, as their strike coincides with the fold trends observed within, and outside the area. Jointing is fairly common but was noticed particularly within the granite, where at least two major sets were established.

The area is considered to have undergone two major periods of orogenic deformation during Precambrian time. The earlier of these was the orogeny which later brought about the intrusion of the granite, and the other took place in post-Black Hill time. In post-Cambrian times the rocks do not seem to have been appreciably deformed, perhaps because the Holyrood granite and Harbour Main volcanics acted as a resistant block during the Paleozoic folding, which is manifest further west.

The only mineral or material of economic importance found in the area is pyrophyllite, which is presently being mined in small quantities by open pit methods. Considerable quantities of low grade pyrophyllite ore are found within the contact zone, but a major difficulty is encountered in the separation of impurities from pyrophyllite in this material.

Acknowledgements

The writer wishes to express his sincere gratitude to all those who assisted him in any way during the preparation and writing of this thesis. He is especially indebted to the following: The National Research Council of Canada who provided financial assistance, without which the field work could not have been carried out; and to Dr. W.D. Brueckner under whose supervision this thesis was written and whose advice and criticism was always welcomed.

The writer would also like to thank the following members of the Department of Geology of Memorial University, all of whom gave freely of their time and experience on his behalf: Dr. V.S. Papezik, for his advice on the petrographic descriptions; Dr. R.D. Hughes and Professor H.D. Lilly, for their suggestions and encouragement; Mr. J.H. Drover, for drafting the final map and figures; Mr. A.F. King for his help in the magnetometer survey.

The assistance of the following members of the Newfoundland Department of Mines and Resources is also gratefully acknowledged: Mr. George Chafe, Chief Parks Officer for Newfoundland, for his kind permission to camp in the unopened Butter Pot Park; Mr. Derek Johnston, Director of Mineral Resources, for the loan of a Sharps Magnetometer.

Mr. J.H. McKillop, geologist, for his practical assistance in the preparation of base maps.

The writer was ably assisted in the field by Mr. John F. Dawson Jr., an engineering student at St. Mary's University, Halifax.

Thanks are also due to Mr. Foster Thornhill, technician with the Geology Department for making the thin sections, and to Mr. Ray Gillespie, Geologist with Newfoundland Minerals Limited, for his information on the pyrophyllite deposits.

In the northwest sector the ridges are made up of bedrock, but as one approaches the shore of Conception Bay, these ridges are covered by increasing amounts of erratics and glacial till. As a rule the valleys are quite wide and U-shaped, and have considerable amounts of glacial till and alluvium at their lower ends. There are about 6 north-northwest-trending ridges in this area, the most pronounced of which is that lying between Manuels River valley and the valley containing Little Pond and Conway Brook. At Johnny's Pond this ridge splits into two subsidiary ridges, the western one consisting mostly of granite and known as White Hill, and the eastern one made up predominantly of rhyolite. The prominent hill of sediments found near the northern extremity of the east ridge is known as Black Hill.

In the southeast sector the relief is much less pronounced. Although the area is, in general, higher than that to the northwest, there are no deep river valleys. The region is quite flat with occasional monadrocks protruding here and there. The most prominent feature is the wide and flat valley of the Manuels River.

It is obvious that throughout the entire map area, the underlying structure and rock types have controlled the physiographic features to some extent. In reference to this Buddington (1919) wrote:

> "The trend lines of the more impressive and marked physiographic features have been controlled for the greater part by the presence of ancient fault and fracture lines, which have to a large degree determined the distribution of the underlying rocks with their varying degrees of resistance to erosion and weathering and the consequent parallel lineaments of the present topography. Joints too have played a prominent role in localizing the erosive agents".

Drainage

Generally speaking the "plateau" area in the south and east is poorly drained. This is in part due to its lack of appreciable relief and the extensive cover of glacial drift. Considerable areas of bog are found in this sector. The major river in the eastern part is the northward-flowing Manuels River. In its southern reaches it has a very low gradient, and wide meanders and small ox-bow lakes are commonly observed. Its lower course has a somewhat steeper gradient and is more incised into the glacial drift and bedrock.

The northwest "valley and ridge" sector is fairly well drained by a number of small rivers which flow north-northwest into Conception Bay. Because of their relatively high gradient the river valleys are almost devoid of boggy areas.

Glacial Geology

It is apparent that the entire map area was glaciated during Pleistocene time. A mantle of glacial drift covers much of the bedrock in the area. It varies in thickness, being thin on most of the ridges and thicker in the lower lying valleys. In the bog areas to the south occasional circular mounds of glacial material are encountered. These mounds could possibly be drumlins which have been partially buried by the bog.

Further evidence of glaciation is found in the polished and grooved surfaces of many outcrops, especially those which are partially covered with drift. Erratic boulders are very commonly observed, especially in the area underlain by granite. The lee-and-stoss shape of many of the hills is particularly striking (see Figure 5), and the many examples of glacial striae indicate that the direction of movement was approximately southeast-northwest.

Buddington (1919) in discussing the regional geology of the Avalon Peninsula stated that "The results of glaciation expressed in the present topography point to the presence of local ice caps flowing into the individual bays in a direction perpendicular to the major outlines of the bays

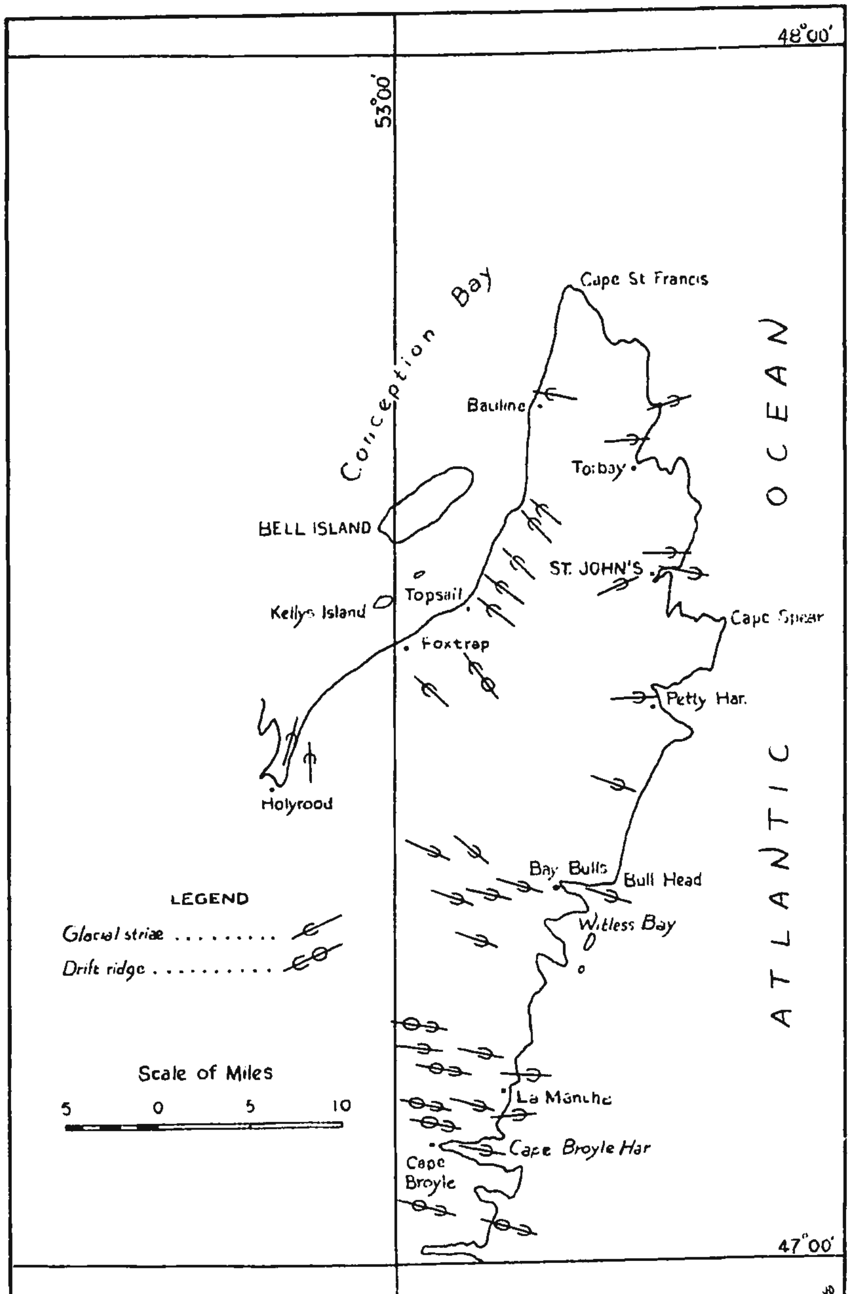


Fig. 1. Sketch map showing directions of latest glacial ice movement in Torbay map area, Newfoundland (After Rose 1952)

at each point". This certainly seems to be the case in the area under discussion, as all the observed features point to the fact that the ice moved northwest towards Conception Bay from the central and southern portions. A sketch map after Rose (1952), shows the directions of the latest ice movement in the northeastern part of the Avalon Peninsula (see Figure 1).

It is probable that an uplift of the land occurred following the period of glaciation. Daly (1921) estimated the amount of this uplift to be in the vicinity of 600 feet around St. John's, because this appears to be the lowest limit of undisturbed glacial erratics. However, Buddington (1919) took exception to this statement: "The presence of perched boulders in precarious positions on the tops of hills at much lesser elevations around Conception Bay renders this estimate of doubtful value".

Definite evidence of some post glacial uplift has been found by W.D. Brueckner (personal communication) in the form of a raised beach, about 20 to 25 feet above present sea level, south of Horse Cove, a few miles north of the writer's area.

CHAPTER III

VOLCANIC ROCKS

Introduction

The volcanic rocks of the Topsail - Foxtrap area which include intermediate and acid types, and flows as well as pyroclastics, are all included in the "Harbour Main group" as defined by previous authors.

The Harbour Main volcanic rocks were originally mapped as the "Huronian" by Howley (1907). He described them "as composed of mixed igneous and aqueous deposits in a highly metamorphosed condition". They were subsequently called the "Avondale Volcanics" by Buddington (1919) because of their "type locality" being at Avondale on the west shore of Conception Bay. He described them as:

> "this series with a small amount of interbedded, more or less waterworn volcanic materials ...... of great but unknown thickness, at least several thousand feet, and forming so far as is known the basal member of the later Precambrian or Proterozoic in Newfoundland".

Because the name Avondale had previously been applied to a formation in the United States, Howell (1925) changed the name to "Harbour Main Volcanics". Rose (1952) finally designated these rocks as a "group". However, McCartney (1959) said that Avondale is still the type locality and that the one proposed by Rose at Harbour Main is not typical in that it displays sedimentary rocks of the Conception group. McCartney (1959) defined the Harbour Main group as comprising "a succession of volcanic and sedimentary rocks more than 6,000 feet thick .... underlying the Conception group in the eastern Avalon Peninsula".

The Harbour Main group outcrops extensively in eastern Newfoundland, forming considerable portions of the Avalon and Burin Peninsulas. Estimations of the thickness of the Harbour Main group, in the regions mentioned, range up to 7,000 feet. However, because of the very nature of these rocks (e.g. lack of marker horizons, and discontinuous and local lenses of volcanics), and the fact that their base is nowhere exposed, the total thickness must remain a doubtful factor. For the same reasons the lower boundary of the group cannot be defined.

In the Topsail - Foxtrap area the Harbour Main volcanic rocks outcrop in two roughly parallel bands, which strike approximately north-south and occupy the central part of the area. The western band is made up of rhyolitic rocks while the eastern one consists predominantly of andesitic rocks.

According to the writer's observations, the andesites of the eastern band seem to overlie the rhyolites to the west. This age relationship is in agreement with the observations of McCartney (1959), in the region immediately west and northwest of this area. In the Pouch Cove - Cape St. Francis area on the east side of Conception Bay, however, rhyolitic volcanics are underlain by andesites (W.D. Brueckner, personal communication). As there are in the writer's area a few outcrops of andesite which could be interpreted as underlying the main rhyolite mass, it is possible, though not definitely ascertainable, that the rhyolites do occupy a position between andesites below and above, as in the region farther north. In the following chapter the rhyolitic rocks are nevertheless considered as the "lower division", since this represents the obvious relationship of the two main types to be described.

The Harbour Main volcanic rocks are generally thought to be overlain unconformably by the Conception group (McCartney (1959), Rose (1952), Buddington (1919)). For some areas this is a definitely established fact. For example, McCartney (1959) has found several unconformable contacts including an angular unconformity near Holyrood Bay. In the eastern portion of the present map area, as well as in the Pouch Cove - Cape St. Francis area, however, volcanic rocks of the Harbour Main group are interfingered with those of the Conception group.

In the central part of the writer's area, the volcanics are overlain unconformably by sedimentary rocks, which because of lithological similarities, have been correlated with the Conception group by previous writers (Vhay 1937, Rose 1952). However, because of the isolated occurrences of these rocks, and some lithological and age differences between them and "Conception" rocks to the east, the author prefers to discuss them separately under the name Black Hill sequence (see Chapter 4).

Lower Division of Harbour Main group - Rhyolitic Volcanics

The rhyolites in this area have received considerable attention by previous workers because of their economic significance. The presence of pyrophyllite or "Agalmatolite" as it was first called, was noted by Howley in the latter half of the nineteenth century. These deposits were investigated more closely by Buddington (1916) and intensively studied by Vhay (1937). For the most part, however, Vhay confined himself to the detailed description of the various pyrophyllite prospects. In this present report the rhyolites are discussed in a less selective manner, giving similar emphasis to all parts of their outcrop area. The major rock types are described briefly; for a detailed description of them the reader is referred to Vhay (1937).

Distribution and Thickness

The main body of the rhyolite outcrops in a fairly narrow band which extends almost due south from Manuels Bridge for a distance of about 9 miles. It has an average width of approximately 1500 feet, being cut in two at one point by a small tongue of granite. A few small outcrop areas are found to the east of this main mass. They are inliers, exposed only because the overlying intermediate volcanics have been eroded at these places.

No accurate estimate of the thickness of this sequence can be given. Much of the area is drift covered and where large outcrop areas are exposed, the relationships are so obscured by faulting or hydrothermal alteration that no continuous section can be established. It can perhaps be assumed that the thickness lies somewhere between 1,000 and 2,000 feet.

Description of Main Rock Types

Although no continuous section can be defined, it was noticed in a number of instances that relatively unaltered, flow banded, or massive, red rhyolite flows were overlain by yellowish-green, and buff coloured, fragmental and spherulitic rhyolites. These latter rocks are hydrothermally altered and contain pyrophyllite and/or sericite in varying amounts. The possible succession of pyroclastics overlying more massive rocks, primarily flows, is only noticed in the vicinity of the granite contact, where the fragmentals have this distinctive pale cream-yellow colour, due to hydrothermal alteration. However, there are quite a few fragmental rocks which have been formed by deformation at the time of the granite intrusion, and not by primary explosive volcanic activity.

Unaltered, or slightly altered, "silicified flows" (see Chapter 6) make up the largest individual type of rhyolite occurring in the area. They may be red, purplish-gray, and occasionally green. They exhibit a great variety of textures and may be fine grained and dense, flow banded, or porphyritic. Some flows have considerable lithic fragments present and could be interpreted as being welded tuff in part. These features usually vary much within short distance.

The aphanitic, unbanded, red rhyolites are quite homogeneous and do not display any structural features. In many instances, they grade into porphyritic varieties, which nearly always display white euhedral to subhedral feldspar phenocrysts. These phenocrysts never exceed 3 to 4 mm. in length. The flow banded types consist of laminations varying from a fraction of a millimeter to over a centimeter in width. The bands themselves have differences in colour ranging through purplish-red to gray. Many spectacular examples of small scale flow folds are present (see Figure 6) as well as "boudinage-like" structures, which probably represent breakage of layers while still in a plastic state. Some laminae show small gash joints perpendicular to the strike of banding, and filled with other rhyolitic material. Where these rocks have been silicified they are chalky white to buff coloured, but the banding is still perfectly preserved. Although there are small stringers of pyrophyllite or sericite along some of the planes between laminae, this type of rhyolite is never altered massively to pyrophyllitized rock, even though it may be quite near the granite contact.

Rhyolites having eutaxitic texture (welded tuffs) are exposed in a large mass in the cliffs about 2,000 feet north of the main pyrophyllite quarry. The rocks here have a mottled and blotchy appearance with irregular and streaky areas of red-purple material in a pink or cream coloured matrix. The whole rock seems to be very homogeneous and dense. Some of the "fragments" are oval or tear drop shaped, whilst others are attenuated and folded into irregular shapes. Some fragments of former consolidated rhyolitic rocks, including breccias, are seen occasionally and these are more clearly defined. They are somewhat embayed and the rims are lighter in colour than the interiors. This is probably due to reaction with the hot lava at the time of their inclusion.

Many types of breccia and agglomerate were observed, but no one type has any appreciable areal extent. Most of these coarse fragmental rocks are now altered, their fragmental nature apparently making them susceptible to shearing and the hydrothermal activity which followed it. They have all been pyrophyllitized and silicified to a greater or lesser extent forming quartz schists, quartz-pyrophyllite schists, and occasionally areas of "pure" pyrophyllite. The most common type is a white, to buff coloured, quartz-pyrophyllite schist. It may be composed almost entirely of lenses of quartz ranging up to 6 inches in length, but usually consists of varying amounts of pyrophyllite and sericite along the shear planes. The quartz fragments have been oriented so that their long axes trend in the direction of foliation, and the masses of pyrophyllite are wrapped around these inclusions.

Another type of breccia which is not uncommon in the area is perfectly exposed in a deep rock cut about 1,000 feet east of Little Pond on the Trans-Canada Highway. It consists of angular fragments of red rhyolite in a matrix of greenish yellow material, which is obviously pyrophyllitized to some extent. This breccia does not seem to have been affected greatly by shearing and is quite hard and massive. Many of the unaltered red fragments are flow banded.

Very coarse breccias, the so-called "ellipsoidal schists" of Vhay, may be either silicified or pyrophyllitized. This "ellipsoidal schist" is apparently formed where the blocks of a flow breccia were silicified and the matrix sheared. The blocks range up to 2 feet in diameter and usually consist of flow banded rhyolite, where the former nature of the rock can be determined. However, where the blocks were subjected to strong shearing and drawn out into roughly elliptical shapes, their original character is obliterated. From the relict structures which can be seen in the main pyrophyllite quarry at Johnny's Pond, it seems probable that this area of pyrophyllite was derived from coarse breccia like that forming the "ellipsoidal schists".

Small bodies of water-laid tuffs, and occasionally boulder conglomerates are found interbedded with the flows and other fragmentals. They are no doubt the result of very local erosion during quiescent intervals in the period of volcanic activity.

The spherulitic rhyolites constitute a very distinctive rock type. These rocks are almost invariably altered, and are now represented by a quartz-pyrophyllite rock which is filled with quartz nodules of various sizes (see Figure 10). These nodules range in size from those seen only with the microscope to spherical masses 10 inches in diameter. They are composed of massive, white, chalcedonic quartz sometime having fragments of unaltered red rhyolite at their centers. It is not uncommon to see the central portions as vugs filled with drusy quartz crystals. These rocks are always sheared, the planes of schistosity passing around the hard nodules of quartz. At a very large outcrop just north of the Trans-

Canada Highway at Little Pond, these yellow-green altered rocks overlie reddish, flow banded, unaltered rhyolites. The outcrop exposes a section containing a small anticline and syncline (about 1,000 feet across), and here the two rock types are perfectly conformable.

Relatively "pure" pyrophyllite rock is exposed in a few small lenses in outcrops which would normally be described as quartz-pyrophyllite schist. The only large masses of this material outcrop at Johnny's Pond. The high grade pyrophyllite usually has a good cleavage parallel to the schistosity, but in the main quarry at Johnny's Pond, much of it is fairly massive (see Figure 8). The pyrophyllite is soft, having a cryptocrystalline texture and a waxy luster. It is most commonly pale green-yellow in colour, but where the tenor of iron and other accessories in the original rock was appreciable, it is now light brown, reddish or purple.

Microscopic Petrography

In thin section the dense, fine grained, and sometimes porphyritic rhyolites consist essentially of a mixture of fine grained (average size 0.07 mm. in diameter) anhedral quartz and potash feldspar with subordinate plagioclase. The proportions of these minerals vary and K-feldspar makes up as much as 80 per cent of some rocks.[1] No ferromagnesian minerals are present, but magnetite usually makes up about one or two per cent of the rock. Accessory zircon, leucoxene, and sericite are commonly present, as well as finely divided red iron oxide, which gives the rock its overall red colour. In some specimens the quartz is obviously secondary, forming nests of tiny irregular grains with radial extinction. The denser rhyolites occasionally exhibit perlitic structure. Much of the glass has devitrified, and the discontinuous, convolute and spherical cracks are now present in a mass of tiny grains of quartz and potash feldspar showing an aggregate polarization. The cracks are quite prominent although having hazy outlines. A few cavities, which may have been formed after the breakdown of ferromagnesian minerals, are now filled with secondary chlorite and chalcedony.

The rocks with eutaxitic structure are full of irregular blebs, most of which seem to be somewhat elongated in one direction. This is probably due to flattening while the mass was still plastic. There are very few phenocrysts,

1 In these extremely fine grained rocks the percentage of potash feldspar was estimated after staining a rock slice with Sodium Cobaltinitrate.

and the irregular fragments consist of essentially the same material as the groundmass, that is, a fine grained quartzo-feldspathic mixture with aggregate polarization. It seems likely that these blebs were originally glass shards which underwent devitrification. They are clearly outlined by rims of dust-like opaque minerals along their margins. In their central portions, the crystals are commonly slightly coarser. The deformation of these blebs is particularly pronounced where they have been folded around, or pinched between, phenocrysts or accidental lithic fragments.

The quartz-pyrophyllite schists consist of mats of dense pyrophyllite-sericite wrapped around angular quartz fragments and pieces of former rhyolite, now altered to clusters of small quartz grains. The large lumps or lenses of quartz seen in hand specimens contain numerous fine flakes of pyrophyllite-sericite. The more siliceous varieties have much fine grained quartz disseminated through the masses of "micaceous minerals". The pyrophyllite-sericite always occurs in small flakes and seems to have a random orientation. In a number of instances it has been seen to replace quartz.

The majority of the spherulitic lavas have had the original spherulites replaced by chalcedonic quartz, however, some of the smaller ones still display the typical radiating structure. These unsilicified spherulites consist of the usual quartzo-feldspathic mixture with much fine grained pyrophyllite-sericite present. The groundmass consists of a fairly constant mixture of these micaceous minerals and tiny quartz grains.

It seems likely that the original rock was a glassy rhyolite with scattered spherulites, since the groundmass has many relict perlitic cracks which stand out because they contain stringers of relatively "pure" pyrophyllite.

Problems of Lithology

Two points of difference between the writer's observations and those of previous workers are to be mentioned here briefly. The first concerns the use of the term "ignimbrite" by McCartney, and the second, the distinction made by Vhay between pyrophyllitized and pinitized rhyolites in the area.

McCartney (1959), in mapping the Harbour Main Volcanics immediately west of this region described nearly all the rhyolitic rocks as ignimbrites. It is evident that he uses this term to denote a rock unit and not a rock type, for he includes flow banded, spherulitic, and porphyritic varieties within it. Of the latter type he says "Recrystallization is well advanced ...... quartz phenocrysts retain their embayed shapes, and the feldspars remain broken and angular to embayed..... but no shards are recognizable".

Since the two areas are adjacent and the rhyolites are all classified as belonging to the Harbour Main group, it would be natural to assume that the rhyolites of the Topsail - Foxtrap area are similar to the rocks of McCartney's area. However, from a survey of the literature there seem to be conflicting opinions as to the specific properties which constitute an ignimbrite.

The term ignimbrite as used by Cook (1959) means:

> "a nonsorted pyroclastic deposit of probable Pelean or nuée ardente origin .... used as a rock unit and not as a rock type. An ignimbrite may be composed of tuff or tuff breccia, and it may be welded, partially welded, or entirely non-welded".

Smith (1960) defined welded tuff as:

> "..... a rock or rock body in which vitric particles have some degree of cohesion by reason of having been hot and viscous at the time of their emplacement. The term welded tuff does not carry a stratigraphic connotation".

Cook (1955) outlined some of the criteria of ignimbrites:

> "Ignimbrites may be distinguished from lava flows by great extent, horizontal depositional surface, lack of vesicles, presence of compaction, but not

flow structures (foliation without lineation for example), generally low specific gravity decreasing upwards, abundance of glass shards, as well as the possible presence of incoherent basal ash, lithic fragments throughout the mass, and an upward decrease in hardness. Ignimbrites may be distinguished from air fall and waterlaid tuffs by absence of bedding, lack of sorting, presence of rude prismatic jointing, compaction structures and welding".

H.E. Enlows (1955) says,

"Because deposits of nuées ardentes are gradational with those of ash showers and lava flows, exceptions will be found to all typical characteristics".

In the area under discussion it is obvious that many of the rhyolitic rocks do not conform to even the broadest definition of "ignimbrite", but all gradations exist there between true "airfall" tuffs and agglomerates, and the typical welded tuffs showing eutaxitic structure. The great age of the rhyolites and their highly disrupted nature make it difficult to say whether some of the observed features are primary or secondary. The rocks have been subjected to at least two periods of silicification (see Chapter 6, page), which could possibly have indurated "airfall" tuffs to hard "welded-looking" varieties.

Because of the many varieties of flows and fragmentals present, and the fact that much of the outcrop area is intensely altered, the writer has refrained from calling these rocks ignimbrites.

Vhay (1937) mapped the altered rhyolitic rocks of Manuels in great detail and outlined areas of silicified-pyrophyllitized rocks and areas of silicified-pinitized rocks. Pinite is a green impure variety of sericite having less potash and more water than ordinary muscovite. Winchell (1959) merely refers to it as an alteration product of cordierite. In the field, no distinction could be found between quartz-pyrophyllite rocks and others which are supposedly rich in pinite. Similar difficulty was encountered when a microscopic examination of the rocks was carried out. Mr. R. Gillespie, geologist with Newfoundland Minerals Ltd., (personal communication) has found that it is impossible to make a clear distinction between the two. From the many assays that the Company has made, there appears to be a varying mixture of pinite (sericite) and pyrophyllite, as well as minor amounts of other minerals (e.g. Alunite) throughout the area.

Upper Division of Harbour Main group - Andesitic Volcanics

Distribution and Thickness

The bulk of the andesitic volcanics in the writers area lie to the east of the rhyolites. They outcrop in a strip which parallels the rhyolite outcrop area and continues north to Cape St. Francis. There are a few outliers to the west, the largest of which is an area of pillowed flows on the west side of Black Hill. It is separated from the main mass of andesite by rhyolite and sediments of the Black Hill sequence.

The main outcrop area includes lenses of sediments which are thought to be tongues of the Conception group. Because of this intertonguing the thickness of the volcanics is nowhere constant, but they attain their maximum thickness in the north with approximately 2,000 feet.

Description of Main Rock Types

The andesitic rocks are composed dominantly of flows with lesser amounts of tuff, agglomerate, breccia, and volcanic conglomerate. Pillow flows occur in the northern part of the area whereas those of the south and east are massive. The agglomerates, tuffs and conglomerates outcrop in small discontinuous lenses. Shearing is very common but has affected the pyroclastics more than the flows.

The massive flows vary from light green, medium to coarse grained varieties to greenish - black, fine grained rocks. Weathering has produced variations in colour from light brown to purple. On the weathered surface of the coarser varieties, abundant plagioclase crystals showing pilotaxitic texture can be seen. Occasionally these flows contain large blocks of red unaltered rhyolite as much as 2 feet in diameter. Amygdaloidal and porphyritic flows are occasionally observed. The amygdules are filled with either epidote or calcite and are generally stretched into elliptical shapes due to secondary deformation. The pillowed flows are generally green-black in colour. The pillows are usually deformed so that the attitude of the flows cannot be determined. In size, the pillows range from 1 to 4 feet in diameter. The interstices between the pillows are often filled with clots and stringers of epidote, as are the numerous gas cavities usually present.

The tuffs are fairly coarse grained and consist of crystals of plagioclase, some fragments of rhyolite and andesite, and occasionally fragments of a granitic-looking rock. All this material lies in a greenish matrix which is quite sheared and chloritic.

The agglomerates and breccias are intensely sheared. They consist of elliptical fragments of andesite in a matrix which looks almost entirely chloritic. In the Manuels River bed near the railway trestle, a large outcrop of these fragmental rocks is exposed. The fragments have been stretched into long thin plates and lie in a chloritic matrix. Several thin compact beds of volcanic ash are present in the mainly coarser fragmental rock. A large portion of the fragmental rocks here have been soaked with hematite and the colour of the groundmass is deep red instead of the usual green.

The coarser grained flows do not exhibit the shearing as markedly as the finer varieties or the coarse pyroclastics. However, the coarser flows near Manuels River bridge on the Trans-Canada Highway have veinlets (½ inch thick) of asbestos developed on some of the slip planes (see Figure 11). The asbestos mineral was identified as anthophyllite, and in several places its fibre is quite flexible and silky. Epidotization has occurred in the andesites on a large scale. Veins and clots are ubiquitous, and small disseminated sunbursts of this mineral are observed in many flows. The veins sometimes reach a width of 2 inches. Pyrite is another mineral which seems to have been introduced along the shear zones. Rusty patches of limonite usually betray its presence. In local areas of intense deformation (e.g. Topsail Fault zone), the rocks have been converted to pure chlorite schist.

The interbedded lenses of sediments were at first thought to be an intrinsic part of the Harbour Main group, Microscopic study shows that they are Conception-type sediments, somewhat more tuffaceous because of their intimate association with the Volcanics. In the southern part of the area, near Manuels River, the scarcity of outcrops makes it impossible to determine the extent of the interbedding. However, northwards at the railway line in eastern Topsail, a number of sections are exposed which show an intimate interbedding of sediments and andesitic flows and tuffs. This interbedding of volcanic and sedimentary rock is interpreted merely as being the result of periodic volcanism in a near-shore marine environment.

Microscopic Petrography

On the whole the rocks can be described as moderately to intensely sheared andesitic volcanics, because of the composition of the plagioclase feldspars, and the almost complete transformation of ferromagnesian minerals to chlorite.

Under the microscope, the medium to coarse grained andesites consist mainly of moderately to highly saussuritized plagioclase laths averaging An35-38 in composition. Extremes of An30 and An44 have been found. These laths are commonly broken, exhibiting tiny faults or bending of the twin lamellae. They have a pilotaxitic texture and show faint suggestions of flowage. The only other major constituent is chlorite, which usually makes up 15 to 25 per cent of the rock. Much of it occurs as pseudomorphs after former pyroxenes. It is present in sheaflike aggregates and commonly shows an anomalous blue interference colour under crossed nicols, which is characteristic of the chloritic mineral penninite (Winchell, 1959). In one slide, some of the pyroxenes are preserved and were determined to be diopside. Various amounts of epidote are always present as tiny veinlets or as disseminated crystals. Accessory minerals include sphene, sericite, magnetite, leucoxene, and pyrite.

In the coarser grained lavas, the plagioclase laths average .5 mm. in length, whereas in the finer types the laths average .07 mm.. In the finer grained rocks, chlorite and sericite are drawn out into stringers, and occasionally secondary quartz is present as veins, or nests of grains with radial extinction. The porphyritic flows have phenocrysts of plagioclase in a groundmass of plagioclase microlites. The groundmass feldspars seem to be slightly more sodic than the phenocrysts. The rocks show an indistinct flow structure, which is only well marked around phenocrysts.

The pillowed flows consist mostly of plagioclase (An30-34) and chlorite. The chlorite fills spaces formerly occupied by the pyroxene crystals. A few pyroxenes are still present but are quite altered. Black opaque minerals constitute a larger portion (6 per cent) of this type of rock. About one half of this material is finely disseminated magnetite and limonite. The rest of the opaque material is white under reflected light, and is possibly leucoxene. Epidote and chlorite fill the amygdules. Several larger saussuritized feldspar crystals present probably represent the remnants of former phenocrysts.

In thin section the tuffs are seen to consist of andesitic and rhyolitic fragments. The rhyolitic fragments are either porphyritic or fine grained, dense and perlitic. No pieces of pyrophyllitized rhyolite were seen. Lesser amounts of broken plagioclase and orthoclase crystals, and occasional rounded quartz grains are also present. These fragments lie in a groundmass which is essentially chloritic.

Structural Relations

The Harbour Main group in this area is bounded on its west side by the intrusive Holyrood granite. Along the south shore of Conception Bay it is unconformably over-lapped by gently dipping Cambrian sediments. On its eastern margin it is intertongued with sedimentary rocks conventionally considered as part of the Conception group. To the south the outcrop area narrows until, according to Rose (1952), the Conception group sediments come into contact with the Holyrood granite, beyond the southern limit of the area investigated.

Rose (1952) and earlier workers did not attempt to subdivide the rock types within the Harbour Main group itself as regards age relationships. McCartney (1959) described the Harbour Main group on the west side of Conception Bay, and stated that here the andesite rocks were underlain by rhyolite. In the present area the abundance of rhyolite debris in the andesitic tuffs and the occasional inclusion of large rhyolite boulders in the andesitic flows, seems to indicate that the rhyolitic rocks are the older of the two. The actual contact between the two rock types was only seen at one locality in the extreme south of the map area, near the granite. This contact dips steeply to the east and the position of the rhyolite suggests that it underlies the andesite.

In the Pouch Cove - Cape St. Francis area rhyolitic rocks definitely overlie, and are perhaps intercalated with, andesitic rocks (W.D. Brueckner, personal communication).

In view of this fact, an attempt was made to discover if this relationship was also present in the writer's area. Only two outcrops were found which could possibly be interpreted to underlie the rhyolite. Two thousand feet east of Little Pond, on the Trans-Canada Highway, an outcrop of andesite is exposed by a rock cut. It lies in the midst of a rhyolite outcrop area, though none of its contacts with that rock type are exposed. Its position suggests that it dips under the rhyolite but it could just as easily be an erosional remnant of the overlying andesitic rocks, outcropping further east. The second locality is found at the south end of Mine Hill near the main pyrophyllite quarry. Here too, the andesite appears to underlie rhyolitic rocks but the limited exposure and the high degree of faulting in this region prevent proving this.

Mode of Origin

From the definite evidence observed in the writer's area it was concluded that there was initially a period of volcanic activity which saw the extrusion of the rhyolitic rocks. If the observed succession of pyroclastic rocks above various types of flows is correct, it would indicate that an interval of dominantly explosive volcanic activity followed the relatively quiet extrusion of the fine grained flows and tuffs.

During the period of eruption of the rhyolitic rocks there was minor sedimentation. However, the nature of these deposits (local areas of conglomerate and sedimentary breccia) indicates that they are mainly the deposits of ephemeral streams. Buddington (1919) believed the entire Harbour Main group to be subaerial in origin and although this cannot now be maintained in full, his deductions seem to apply to the rhyolites:

> "The constant association of volcanic conglomerates or sandstones with the breccias, tuffs, and flows indicates the work of either river erosion or waves or both. The first seems most probable. Such conglomerates are commonly found associated with subaerial volcanics of all ages. Those of Newfoundland are such as might be expected to form along river valleys draining a region of great active volcanic cones such as this probably was. Although some of the conglomerates may have been deposited in standing water, the indications are that for the most part they were deposited on a land surface during quiescent periods between successive volcanic outbursts which repeatedly buried them with the products resulting from extravasation and explosion".

The eruption of the rhyolitic rocks was followed at some later time by the extrusion of intermediate volcanic rocks. Although previous workers have not recognized the presence of other than subaerial flows, pillowed andesites do occur in the northern part of the thesis area. Some of the andesitic tuffs and flows interbedded with the fine grained Conception group sediments were also probably erupted into the sea, though the flows do not show pillowed structure. The absence of conglomerates and other features characteristic of shore lines precludes the possibility that transgressions of the Conception sea were responsible for the formation of the intertonguing lenses of sedimentary rocks.

All the observed features point to a stable marine environment surrounding a region of active volcanic cones. The volcanic material extruded at any one time was probably deposited both on land and in the sea. Periodic eruptions of volcanic material into the basin of sedimentation resulted in the conformable interbedded volcanic-sedimentary sequence now observed.

Age

Buddington (1919) described the Harbour Main group as the lowest member of the later Precambrian (Proterozoic) in Newfoundland. Rose (1952) assigned it to the Proterozoic or possibly the Archean. In 1957 a K/Ar age determination on feldspars from the Holyrood granite gave an absolute age of 910 million years $\pm$ 10 per cent. In all probability the Harbour Main rocks are mid-Proterozoic or older in age since they are intruded by the Holyrood granite. However, if this age determination for the granite is not correct, a somewhat younger age would be more likely (see Chapter 5).

CHAPTER IV

SEDIMENTARY ROCKS

General Statement

The sedimentary rocks occurring in the Topsail-Foxtrap area were all previously assigned to the Conception group. Under this name Rose (1952) combined the "Conception slates" and the "Torbay slates" of Walcott (1899). Rose considered these to represent the lower and upper divisions of the Conception group but was unable to define a boundary between them. Walcott estimated that each of these subdivisions was about 3,000 feet thick. The Conception slates consist mainly of green-gray sandstones and argillaceous siltstones, and the Torbay slates, although in part very similar, are characterized by more varied colours especially red and brown.

In recent years, investigations of Rose's Conception group east of Conception Bay have been started by members of the Geology Department of Memorial University. These studies have so far confirmed that no definite boundary exists within the group, while strata containing detritus from two differing source areas seem to be more or less irregularly mixed and/or interfingered. Definite lateral intertonguing of the Conception group rocks with the Harbour Main volcanic rocks has also been observed at a number of places, so that the concept of general unconformable overlap of the Conception group on the Harbour Main group can no longer be maintained for the easternmost part of the Avalon Peninsula.

It may be that a new nomenclature will eventually be introduced for the Conception group rocks of this belt. At present, however, an interim decision had to be made for this thesis as follows:

The Conception-type rocks lying to the east of the Harbour Main volcanics, and being in part intertongued with them, are described under the name "Conception group" as they clearly belong to the belt so designated by Rose (1952) on the Torbay Map Sheet.

The sedimentary rocks overlying the Harbour Main volcanics of the writer's area unconformably, and preserved only in isolated occurrences, are however described under the provisional name of "Black Hill sequence".

Conception Group

Distribution

The Conception group rocks outcrop on the eastern fringe of this map area, and are only revealed in very scattered outcrops within extensive areas covered by glacial drift and bogs. The largest continuous section is exposed in the canal which has been blasted from Thomas Pond to Western Pond. Although the rocks have been buckled into rather tight folds, they appear to have been considerably faulted and this undoubtedly accounts for some of the rapid changes in strike occasionally observed. The thickness of the Conception group strata outcropping in this area is perhaps 1,500 to 2,000 feet.

Description of Main Rock Types

In the small number of outcrops observed to the east of the andesitic volcanics, and especially in the large canal exposure, the rocks seem to be merely a series of irregularly interbedded medium to fine grained sandstones, siltstones, and dense cherty rocks. On the weathered surface these rocks vary from light to dark brown in colour. They commonly occur in beds 2 to 3 feet thick, and many of the sandstones show laminae varying from several millimeters to 2 centimeters in thickness. Graded bedding or cross bedding was not observed in any of these strata, although such features are probably present. The massive sandstone beds appear to be fairly well sorted, but some of those exhibiting alternating finer and coarser laminae occasionally contain large fragments of rhyolite or feldspar, with the bands bending around them. Some of these laminae contain crystals and thin lenses of pyrite. Where the fine grained argillaceous siltstones are laminated, they show a slight change in colour, but no change in grain size that could be ascertained in the field. The cherty beds are generally dark blue-gray in colour and are very tough, breaking with a conchoidal fracture. Although some show thin laminations, the majority are quite homogeneous.

Where these sediments are near, or interbedded with, the andesites they have a tuffaceous aspect, are softer, and for the most part finer grained. None of the cherty rocks were observed to be interbedded with the volcanic rocks. These tuffaceous sediments generally exhibit shearing features and some of the thinly bedded types in the transition zone, near the railway line in Topsail, have been metamorphosed to phyllites. The rocks here exhibit crenulations and the characteristic micaceous minerals on the cleavage planes, which nearly always coincide with the bedding planes. Near the Topsail fault zone these "tuffaceous" sedimentary rocks are quite sheared and altered, with streaks of chlorite along the shear (bedding) planes and thin bands of rusty material, which is undoubtedly the residue of weathered pyrite. Primary slump structures were found in some of these rocks, although none could be found east of the "transitional" zone.

Microscopic Petrography

The massive unlaminated sandstones are seen to be fairly well sorted rocks with a small amount of groundmass (up to 15 per cent). The grains are subangular to subrounded and average 0.2 mm. in diameter. According to the Wentworth scale, they are, therefore, fine to medium grained sand. The more prevalent thinly laminated rocks are, in general, finer grained and would have to be classified as medium grained siltstones. These rocks vary from those in which the laminae consist of alternating coarser and finer bands of clastic grains, to finer grained varieties where thin bands of clastic grains lie between thicker bands composed almost entirely of clay particles. A few ragged crystals of quartz and feldspar are dispersed through these laminae of clay material. These clay rich rocks are referred to as shaly siltstones.

Within the coarser sandstones and the clay-free siltstones the chief detrital mineral is quartz, which usually makes up from 40 to 60 per cent of the rock. Orthoclase and plagioclase occur in roughly equal amounts and comprise 20 to 25 per cent of the rock. These feldspar grains look fairly fresh and are only altered in rocks which have been silicified. Small amounts of rhyolite fragments are sometimes present and the groundmass, which makes up the bulk of the remainder, contains abundant chlorite (as much as 10 per cent in some specimens). Accessory minerals include muscovite, sphene, calcite, pyrite, magnetite, and leucoxene.

When these rocks are found near the andesites the amount of groundmass becomes proportionally larger, reaching as much as 50 per cent of the rock. The laminated character is not too often displayed. In short, the strata change from well bedded and well sorted rocks to graywacke-type sediments. Quartz and feldspar are present in roughly the same proportions as in the "cleaner" sediments, but there are more rhyolite fragments. Chlorite makes up a considerable amount of the groundmass and epidote becomes an important accessory. The matrix is usually a mixture of very fine grained quartzo-feldspathic material with varying amounts of chlorite and subordinate sericite.

The dense cherty rocks are observed to be poorly sorted siltstones, which have been thoroughly silicified. They are composed of small amounts of ragged quartz and feldspar grains lying in a mass of fine grained and obviously secondary silica. Some of the feldspars are seen to be partially replaced by silica. A few of these rocks exhibit the thin laminations previously described. The laminae are not easily distinguished under the microscope as they are now largely composed of silica. However, many of the bands are outlined by thin stringers of spherical pyrite nodules. Accessory carbonate and chlorite are also present as well as occasional rhyolite fragments. The rock seems to have been an originally fine grained clastic sediment into which silica was introduced during diagenesis. These highly siliceous beds are interlayered with the normal massive or laminated sediments, and it seems that during the deposition of the sediments as a whole, there were frequent influxes of water highly charged with silica, which transformed some of the beds into the chert-like rocks now observed.

The rocks interbedded with the andesites are chiefly fine grained, but there are occasional fine to medium grained impure sandstones which display most of the characteristics of graywackes: high feldspar content, high rock fragment content, little or no sorting, and a large proportion of groundmass. The fine grained varieties are also poorly sorted, although this is not very obvious due to their small grain size(fine to medium grade silt). These particular rocks are characterized by a large proportion of clay minerals, rhyolite fragments, and chlorite.

A typical coarser rock from this interbedded sequence is composed of 15 per cent feldspar, 25 per cent quartz, 10 per cent rock fragments, both andesite and rhyolite, and 45 per cent matrix. The matrix is a fine grained mixture of quartzo-feldspathic material and sericite-chlorite. In many rocks the sericite or pyrophyllite flakes have been drawn out into stringers which are wrapped around the larger grains. This amalgamation of sericite has resulted in uniform extinction of large sections of the clay stringers. The most common accessories are epidote, pyrite and limonite, magnetite, sphene and leucoxene. Apatite and rutile were observed occasionally, as were leucoxene pseudomorphs of bladed intergrowths of magnetite and ilmenite.

One specimen taken from the "tuffaceous" rocks which is quite argillaceous, displays small scale slumping structures. Usually, however, the rocks seem to be affected most by later shearing. In several thinly bedded specimens, shearing has almost completely destroyed the bedding. The slightly coarser bands of quartzitic material are now represented by elongate segregations of small grains lying in a mass which consists predominantly of clay minerals. In a specimen of phyllitic rock, tiny faults were observed under the microscope. They make an angle of approximately 30 degrees with the bedding planes. This and other thin sections show stretching of some larger grains into elliptical shapes, whose long axes parallel the direction of shearing.

Structural Relations

The Conception group rocks occurring in this area are partly intertongued with the volcanic rocks of the Harbour Main group to the west. As said above, this intimate association has also been observed farther north in the Pouch Cove - Cape St. Francis area. To the east of this map area, in the vicinity of St. John's, the Conception rocks are overlain by slates of the St. John's formation. Southwards, presumably the Holyrood granite intrudes directly into Conception group rocks.

Mode of Origin

From the mixture of materials present within the Conception group here described, it can be concluded that these rocks were derived from two different source areas. In the east, the somewhat arkosic nature of the sediments suggests that they might have been derived in part from a pre-Conception granitic or gneissic terrain now nowhere exposed. The change in facies to the west suggests that the weathering and transport of volcanic material from the Harbour Main group was an important factor in the formation of these rocks. The predominant green colour appears to be chiefly a function of the amount of chlorite present. The thinly laminated and relatively well sorted nature of the rocks is typical of sediments deposited under rather quiescent conditions. The laminations suggest the periodic introduction of material, probably by rivers, into a shallow, slowly subsiding marine environment. Intermittent volcanic eruptions account for the intertonguing of Conception and Harbour Main rocks in the Topsail - Foxtrap region.

Age

This group of rocks is definitely Precambrian in age and hence no fossils are found with which to attempt a correlation. In this area it would seem that the Conception group rocks are more or less equivalent in age to the upper division (andesites) of the Harbour Main group and consequently are mid-Proterozoic in age.

Black Hill Sequence

Name

The name Black Hill sequence is used here in reference to those rocks which were considered by Rose (1952) to be a part of the Conception group but which, in contrast to the Conception-type rocks in the eastern part of the area, are unconformable upon the Harbour Main group and the Holyrood granite batholith. These rocks form a remarkably consistent sequence of interbedded coarse lithic graywackes or micro-breccias, and fine grained tuffaceous siltstones or shales. They are the youngest consolidated sediments in the area studied.

Distribution

The rocks of this sequence are exposed in a number of small isolated occurences which are confined to a narrow zone stretching from north of Black Hill to Dog Pond in the south. The discontinuous nature of these rocks is probably due to erosion of the greater part of the sequence. Most of the rocks remaining are either down-faulted blocks or synclinal pockets which escaped the erosion because of their relatively low lying or sheltered position. The largest outcrop areas are located at Black Hill, Dog Pond, and south of White Hill.

The thickness of this sequence cannot be determined accurately because of the patchy nature of the outcrop areas and the intricate folding and faulting. Vhay (1937) estimated that there is a thickness of 1,500 feet present at Black Hill alone. Buddington (1916) gave a thickness of at least several thousand feet for the entire sequence. The writer estimates that there are about 2000 feet of this sequence now remaining in the Topsail - Foxtrap area.

Description of Main Rock Types

The base of this sequence is best exposed in the main pyrophyllite quarry at Johnny's Pond. Here, the north limb of a small tightly folded syncline is observed to unconformably overlie pyrophyllitized rhyolite. At the base there is a coarse pebble conglomerate consisting of rubble from the weathering of highly pyrophyllitized rhyolite. This is overlain by about 30 feet of red sediments which consist of conglomerates and thin argillaceous bands (see Figure 15). The fragments in the conglomerate beds are mostly silicified, flow banded rhyolite, red unaltered rhyolite, and pale greenish pyrophyllitized rocks. The fragments are as large as 3 inches in diameter and are quite well rounded. Above these red beds are greenish sediments which make up the bulk of the sequence.

At only one other location was the base of this sequence exposed. At the south end of Black Hill the red sediments overlie a conglomerate or agglomerate made up of andesitic fragments. Conglomerates and argillaceous or sandy bands are interbedded at this locality as at the pyrophyllite quarry.

The thin sequence of red sediments is characteristic of the lowest part of the Black Hill sequence wherever it is exposed, however, it never comprises more than 50 feet of the section. Where there are coarse fragments and conglomeratic bands, graded bedding can usually be seen.

The red sediments are exposed near the Trans-Canada Highway east of Little Pond and here they are found to be mainly fine grained, paper-thin slates. In contrast with the large proportion of conglomeratic bands in the exposures near Johnny's Pond and Black Hill, here there are only a couple of thin bands of conglomerates full of somewhat angular pieces of pyrophyllitized rhyolite.

The red basal rocks are overlain by a thick, monotonously regular sequence of interbedded coarse detrital rocks and fine grained tuffaceous shales. This interbedding can even be distinguished at a distance because of the dark brown weathering of the coarse grained beds and the whitish weathering colour of the fine grained shales or slates (see Figure 13).

The thickness of individual beds of these two types varies from 3 feet to ¼ inch and the proportion of coarse to fine rocks varies from outcrop to outcrop. However, the interbedding of the two is always displayed.

The coarse detrital rocks could be described as microbreccias because semi-angular fragments as large as 1/3 inch are not uncommon. Beds of this type of sediment are always quite massive and unsorted. The rock consists of fragments of various kinds of rhyolite, andesite, white feldspar, and some quartz in a greenish chloritic matrix.

The fine grained shales or slates interbedded with the coarser rocks are well sorted, and many of them have an average grain size of from 5 to 8 microns which is just above the clay range. They exhibit laminations varying from 3 to 10 mm. in thickness, and where thin laminae of the coarser (graywacke) material are present, excellent examples of channelling are often seen. The well laminated character is not always preserved, however, and in the syncline at Johnny's Pond these rocks show many slump structures and fragments of broken beds (see Figure 16). Most of the fine grained rocks display the thin parting, parallel to the bedding, which is characteristic of slates. However, in places they remain quite massive;

such rocks have been referred to by Buddington (1916) as "Halleflinta slates".

Microscopic Petrography

The red beds are seen to owe their colour to large amounts of finely disseminated red iron oxide. The matrix of the conglomeratic bands consists of mixed detrital material, coloured deep red by the hematite present. Most of the fragments in these bands are rhyolite, which is usually in an advanced stage of alteration, either through weathering or earlier hydrothermal alteration. Flakes of sericite and pyrophyllite are always present in these fragments. The finer grained conglomeratic horizons contain an appreciable amount of feldspar and quartz grains, as well as andesite fragments, but rhyolite still makes up the bulk of the material. The feldspars are usually highly sericitized and some are partly or wholly altered to carbonate.

The red slate is a homogeneous mass of very fine grained detrital material and clay minerals. It is difficult to discern much of the original constituents other than a small amount of quartz and feldspar. The feldspar is quite altered and shows ghost-like outlines against the background of clay material and hematitic dust. The bedding is sometimes outlined by slight changes in grain size and tiny stringers of magnetite grains.

The coarse grained greenish rocks of the interbedded sequence have most of the characteristics of a lithic or volcanic graywacke. The individual grains are unsorted, subangular to subrounded, and vary from 0.1 to 2.0 mm. in diameter, however, particles as large aa 1 cm. are not uncommon. Both rhyolitic and andesitic debris account for the majority of material, but rhyolite is always the more abundant of the two, varying from 35 to 55 per cent in different localities. Perlitic and porphyritic rhyolite fragments are quite common as well as sericitized and pyrophyllitized varieties. Andesitic fragments constitute between 10 and 30 per cent of the rocks. Free quartz is never very abundant, and in most of the specimens examined, only 3 or 4 per cent of the rock is quartz. In contrast to this, feldspar,both orthoclase and plagioclase, is always an important constituent. Variations in the proportion of plagioclase and orthoclase probably reflect differences in the rock types of the source area. Usually orthoclase is the more abundant of the two, but occasionally plagioclase is the more frequent. Nearly all these feldspars are considerably altered, showing a fair degree of rounding, and being replaced in large measure by sericite and other secondary minerals. On the average, feldspar makes up 20 per cent of the rocks, but occasionally it may reach 30 per cent. The groundmass which is finely ground volcanic material and chlorite rarely exceeds 20 to 25 per cent of the rock. Sericite sometimes becomes an important constituent of the groundmass. Magnetite is always the predominant accessory mineral, usually making up about 1 per cent of the total material.

The fine grained tuffaceous or argillaceous slates are well sorted and thin bedded. In some of the beds the average grain size is as large as 60 microns, but usually the particles vary from 5 to 20 microns in diameter. This relegates them to the category of fine to very fine silt. In the very fine layers only a small proportion of the individual particles can be identified, and entire bands seem to consist of clay minerals with scattered grains of quartz and feldspar. The slightly coarser layers also consist largely of clay minerals, but the amount of quartzo-feldspathic material is greater. Epidote and chlorite are usually present in appreciable amounts - 5 to 10 per cent. In one instance, 30 per cent epidote was found but this is obviously a local anomaly.

Structural Relations

In its outcrop areas the Black Hill sequence represents the remnants of a more widespread sedimentary unit which was deposited unconformably upon the Harbour Main group and the Holyrood granite during later Precambrian times.

In the quarry at Johnny's Pond the sequence is seen to be unconformable upon pyrophyllitized rhyolite. Near the south end of Black Hill it unconformably overlies intermediate volcanic rocks. Its contact with the granite has never been observed, however, fairly cogent proof of the Black Hill sequence being deposited after the orogeny which brought about the intrusion of the granite is provided by the following facts:

i) the sedimentation succeeded the pyrophyllitization of the rhyolite.

ii) the sediments do not have a baked or hornfelsic appearance even in outcrops as close as 10 feet from the granite (as was observed in several instances).

iii) no xenoliths of these sediments were found in the granite although rhyolite and andesite xenoliths and roof pendants are common.

Mode of Origin

The constituents of the coarse "graywacke-type" rocks of the Black Hill sequence indicate that it was essentially derived from the acid and intermediate volcanic rocks of the Harbour Main group. The large proportion of feldspar is indicative of sediments that were quickly eroded, transported only a short distance, and then rapidly buried. All observed outcrops of the sequence occur in a narrow area which lies almost entirely within the outcrop area of the Harbour Main rocks. It is therefore postulated that in later Precambrian times a long narrow basin or inlet of the sea was formed, and into this depression sediments were rapidly deposited. A complete inundation of the area can be ruled out as this would have elininated the source of the clastic debris. The interbedded nature of the rocks suggests that there was periodic supply of coarse sedimentary material probably by floods. Between these times of rapid accumulation, only finer grained material was deposited indicating relatively quiescent intervals. The small thickness of red beds at the base seems to indicate that there was a time during the early stages of deposition when oxidizing conditions prevailed in the basin of sedimentation; or climatic conditions were such as allowed the accumulation of iron oxides in the weathering product of the source areas.

Age and Correlation

The only definite statement that can be made regarding the age of the Black Hill sequence is that it is younger than the intrusion of the Holyrood batholith - 910 million years ± 10% (see page 81). The red sediments at the base of this sequence could possibly be of the same age as the fine grained red beds of the Hibbs Hole formation of Hutchinson (1952), which lies near the top of the Conception group on the west shore of Conception Bay. Red sedimentary rocks are also found in the upper part of the Conception group occurring at Middle Cove and Torbay, northeast of the present map area. If this correlation is correct, the Black Hill sequence would be younger Proterozoic in age.

CHAPTER V

INTRUSIVE ROCKS

General Statement

A variety of intrusive rocks are found within this thesis area. They range in size from a batholith, only part of which is included within the map area, to dikes and irregular intrusions measurable in feet and inches. The batholith consists of "granite" (actually an adamellite). Among the smaller intrusives meta-diorite, quartz-feldspar porphyry, aplite, felsite, and basic dike rocks have been distinguished.

The meta-diorite is the oldest of the intrusive rocks. It is intruded by the granite for which potassium-argon age determinations have given an absolute age of 910 million years $\pm$ 10%. The minor felsite bodies were observed to intrude all rocks in the area except the meta-diorite and granite. The basic dikes are found cutting the Harbour Main volcanics and the Holyrood granite.

META-DIORITE

Location and Size

The rock to be discussed here makes up a body of moderate size on the ridge immediately west of the valley containing

Hennesey's Pond and Little Pond. It is elongated in a north-south direction and has a length of approximately 6,500 feet and an average width of 600 feet. It is surrounded by the Holyrood granite and its rather sinuous contact with the latter is somewhat gradational in many places. The body of meta-diorite obviously represents a roof pendant in the Holyrood batholith.

Petrographic Description

Megascopically the meta-diorite is a gray to pale brown weathering, medium grained, somewhat "porphyritic-looking" rock. It is called "meta"-diorite because of the semi-alignment of the hornblende needles and the presence of large anhedral plagioclase crystals (0.6 to 1.0 cm.) which resemble porphyroblasts. Both the overall grain size and the frequency of the "porphyroblastic" plagioclase crystals vary irregularly throughout the observed outcrops. The large anhedral crystals of plagioclase could possibly have been formed by secretion of feldspathic material from the granite. Staining of polished specimens shows that the only potash feldspar present is in tiny granite veins which everywhere penetrate the intruded rock. One of the most striking features observed in the field is the vast amount of epidote present in the meta-diorite.

Veins and stringers of epidote are ubiquitous and it is probable that they are genetically related to the granite intrusion.

In thin section the rock consists almost entirely of hornblende and plagioclase. Many of the prismatic hornblende crystals are broken and partially altered. They average 0.7 mm. in length. Some are as long as 2.0 mm. and ophitically envelop smaller crystals of plagioclase. These crystals also enclose magnetite, zoisite and other alteration products. They are pleochroic from pale yellow-green to dark green. Much of the plagioclase is so highly saussuritized that it appears only as an undifferentiated mass of altered feldspathic material. The larger "porphyroblasts" averaging 5 to 7 mm. in length are not quite as altered as the smaller plagioclase crystals, although they are saussuritized, and they exhibit zoning. The average composition of the feldspars is An43-46. Hornblende usually makes up 30 to 35 per cent of the rock while feldspar accounts for 55 to 60 per cent. Chlorite pseudomorphs after biotite usually constitute 3 to 4 per cent of the average specimen. Some of the biotite crystals have not been completely altered to chlorite and thin sheets of the original material are left in the centers of these pseudomorphs. Accessory minerals include magnetite, pyrite, leucoxene, spene and epidote.

Origin and Age

The rock described above was called meta-gabbro by Buddington (1919) and Rose (1952) and was described by the latter as being "intrusive into volcanic rocks of the Harbour Main group". It is, however, nowhere found in contact with Harbour Main rocks and seems to lie wholly within the Holyrood "granite". It is more correctly described as meta-diorite since the plagioclase is less basic than An50 and the chief mafic mineral is hornblende.

Concerning the genesis Buddington (1919) said,"whether this rock is the result of recrystallization during the intrusion of the granite or whether it is primary is difficult to say". From the writer's observations there is no doubt as to the meta-diorite being a remnant of an igneous body older than the Holyrood "granite". Although the contact is quite gradational in some localities, veins and stringers of granite, varying from 1 inch to 4 feet in thickness, are found cutting across the intruded rock (see Figure 17). Xenoliths of the meta-diorite are found not only in its immediate vicinity, but as much as 2 miles to the west (see

Figure 18). The meta-diorite roof pendant seems to have been "soaked" in granite as there is a zone of contaminated granite around its borders. Near its extreme northern end there is a transition from meta-diorite through gneissic hornblende granite to normal quartz monzonite or adamellite.

The dioritic nature of the rock seems to indicate a genetic relationship with the andesitic volcanic rocks of the Harbour Main group. It may be a plug remnant of one of the andesitic volcanoes; or perhaps only a thick lava flow more metamorphosed than others observed in the area; or an entirely independent intrusive body. The writer favours the last possibility. The meta-diorite is, in any case, older than the Holyrood batholith.

HOLYROOD BATHOLITH
("granite", aplite, quartz-feldspar porphyry)

Distribution

The Holyrood granite was named by Buddington (1919) and includes most of the rocks formerly called Laurentian by Howley (1907). Its main outcrop area extends south from the southern shore of Conception Bay for a distance of about 20 miles and is approximately 5 to 6 miles in width. However, there are a number of small intrusive bodies farther west which are considered by McCartney (1954 b) to be genetically related to the Holyrood batholith.

The northeastern portion of the main mass occupies a strip about 2 miles wide along the western border of the Topsail - Foxtrap map area. The contact with the intruded Harbour Main group to the east is remarkably straight though showing small irregular intrusive fingers. At Manuels Bridge on the Conception Bay Highway a small "outlier" of granite, surrounded by Harbour Main rocks, is exposed in the river bed. Along the south shore of Conception Bay the granite is overlain unconformably by fossiliferous Cambrian beds.

Description of Main Rock Types

The main mass of the Holyrood batholith consists of "granite". Quartz-feldspar porphyry which has been found at a few localities and aplite dikes and larger intrusions, which cut the granite in large number, appear to be genetically related to the granite and their description is therefore included in the following paragraphs.

In its typical outcrops the granite is a medium to coarse grained pinkish white rock consisting dominantly of quartz with plagioclase and orthoclase in varying amounts. Dark minerals, chiefly chlorite and biotite, are always subordinate and rarely constitute more than 10 per cent of the rock. The texture can be described as hypidiomorphic-granular. The anhedral quartz crystals are always larger than the feldspar crystals, averaging 7 to 8 mm. in diameter. They stand out as irregular knobs on the gray weathered surface.

The bulk of the granite is remarkably similar throughout its extent in the writer's area. Variations are found at fault and shear zones, near roof pendants and xenoliths, in the vicinity of the meta-diorite outcrop area (see above), and at the contact with rocks of the Harbour Main group.

Before proceeding to describe the variations found in crushed zones, it should be noted that there are two types of mylonitized granite: crushed zones formed quite early in the granite's history when perhaps the outer solidified layer was cracked and then healed by granitic material that was still liquid, and larger crushed zones which have resulted from later faulting with the crushed material being welded together by heat and pressure, but not cemented by introduced granitic material.

In later fault and shear zones the granite is usually crushed and rewelded. Broken pieces of granite as large as 6 inches across are found in some of the mylonitized zones.

On a fresh surface the rock has a greenish cast which is due to the finely comminuted material present as well as to the biotite and chlorite. Sometimes clumps of quartz and feldspar crystals are surrounded by stringers of chlorite and biotite. Small slickensided surfaces are not uncommon.

A unique rock type is exposed in a deep rock cut of granite approximately 1½ miles west of Little Pond on the Trans-Canada Highway. On the south side of the road, a portion of the outcrop is extensively sheared. The former granite now consists of mostly green micaceous minerals and quartz eyes. The green micaceous mineral may be pinite (sericite) although some of it is definitely chlorite. A microscopic examination of a specimen showed that it consists of 60 per cent quartz, 10 per cent plagioclase, and 25 per cent highly birefringent "sericitic-looking" material. This material, if it is indeed sericite, was probably formed by the alteration of potash feldspar as this mineral is not present now.

Roof pendants as large as 200 feet across are occasionally found in the granite. Many of them appear to be the loci of shear zones. In the western part of the granite only basic or intermediate rocks of Harbour Main affinity are found as roof pendants and xenoliths. They are usually quite altered and baked, and the granite in the immediate vicinity is somewhat contaminated. Near the contact of the granite with the Harbour Main group on its east side, roof pendants and xenoliths of rhyolite and andesite are quite common. The large exposure of granite at White Hill is particularly noticeable in this respect. Both red, unaltered rhyolite and greenish, pyrophyllitized rhyolite are found. Roof pendants of quartz feldspar porphyry are also displayed at this locality.

Near the large meta-diorite roof pendant described above, the content of ferromagnesian minerals (hornblende) in the granite increases. Tongues of dark almost gneissic granite penetrate the meta-diorite, and away from its margins parts of the granite show faint alignment of minerals, reminiscent of flow banding, which trends in a northwest-southeast direction.

The rocks in the immediate vicinity of the contact between the granite and the Harbour Main group are quite distinctive. They invariably show evidence of crushing and appear to be quartz deficient. These rocks always display red and brown staining due to the limonite and pyrite present.

Aplite dikes varying in thickness from a fraction of an inch to several feet are fairly evenly distributed throughout the granite. However, about one mile north of Gull Pond a small stock of aplite intrudes the granite. Much of this area is drift-covered and outcrops are scarce, but the stock is estimated to be about 3,000 feet long, from north to south, and about 1,000 feet wide. Other small irregular intrusions of aplite were observed, notably in the area north of Soldiers Pond.

Where the aplite occurs as dikes it is pink in colour and quite fine grained, having only scattered dark minerals. At one locality these dark minerals were observed to be aligned parallel to the strike, giving the rock a somewhat gneissic appearance. In the larger intrusions, the aplite is slightly coarser grained, has a saccharoidal texture and the ferromagnesian minerals, principally biotite, are more abundant.

A small area of quartz-feldspar porphyry is located on the road from Manuels to the pyrophyllite quarry. At first it was thought to be merely a local contemporaneous phase of the granite, however, smaller occurrences of this rock are also found near Big Pond and west of Little Pond, as well as in the large outcrop of granite at White Hill. It is possible that the quartz-feldspar porphyry is a remnant of a conduit through which rhyolitic rocks were extruded. It is more likely, however, that it is genetically related to the granite, having been intruded a short time before the emplacement of the granite batholith proper. In either case its occurrences would represent roof pendants in the granite.

The quartz-feldspar porphyry weathers to a chalky white colour with occasional protruding quartz crystals. It consists typically of rounded quartz, orthoclase and plagioclase crystals in a dense, chocolate brown or greenish gray matrix (see Figure 19). Subordinate amounts of small biotite crystals are always present. Small xenoliths of the typical green, coarse grained andesite of the Harbour Main group were also found in it.

Microscopic Petrography

In thin section the granite is composed of large, irregular, sutured quartz crystals and varying amounts of slightly smaller plagioclase and orthoclase crystals. Dark minerals are always subordinate. Although the proportions of the two types of feldspar vary, the amount of plagioclase is rarely less than that of orthoclase. Most commonly, either the amounts of the two feldspars are approximately equal, or plagioclase is more abundant than potash feldspar (sometimes making up as much as 2½ times the amount of potash feldspar present). Because of these varying feldspar ratios, the rock grades from leuco-adamellite to leuco-granodiorite.

Some specimens contain as much as 70 per cent quartz. This mineral invariably displays cracks and undulatory extinction. The cracks are sometimes filled with small stringers of sericite and chlorite. Broken fragments of feldspar are also found included within the quartz crystals. Inclusions of fine dusty material are always present.

Potash feldspar is found in subhedral to anhedral crystals. Usually, varying amounts of scaly aggregates of sericite and other alteration products are found within this mineral. String perthite is quite common and occasionally a type of microcline perthite is observed. This latter variety contains thin veins of albite showing chessboard structure.

The plagioclase crystals have an average composition of An26-28. Many of the crystals display zoning. The centers are almost always highly altered to secondary minerals whilst the rims are comparatively fresh. Some of the borders in the zoned crystals have a composition as sodic as An22.

The only dark minerals present are chlorite and biotite. Most of the biotite has been altered to chlorite and this mineral has a distinctive lavender interference colour under crossed nicols. Within the pseudomorphs of chlorite after biotite, exsolved blebs of magnetite lie along cleavage planes as trains of inclusions. Epidote is also found as an alteration product of biotite. Other accessories include zircon, apatite, sericite, rutile, and sphene.

The dark greenish granitic rocks found in fault and shear zones do not vary greatly in composition from the "normal" granite but show evidence of extreme crushing. Small brecciated zones contain broken quartz and feldspar grains with many finely disseminated flakes of chlorite. The scattered chlorite, together with finely ground quartzo-feldspathic material, is responsible for the greenish cast of the rock. Plagioclase laths are nearly always distorted and faulted, the small fissures being filled with sericite. The crushing of the granite near its contact with the Harbour Main group is quite similar to the crushed rocks previously described. However, limonite and pyrite are quite abundant, filling many of the cracks and coating some of the crystal fragments. There seems to be less quartz than in the "normal granite" and that which is present encloses broken fragments of feldspar and chlorite. Occasionally wormlike intergrowths of quartz and feldspar are observed, as well as small fragments of rhyolite.

The aplitic rocks display the characteristic interlocking texture. They consist mostly of orthoclase and quartz with subordinate plagioclase. A typical specimen contains 55 to 60 per cent quartz and 30 to 35 per cent orthoclase. Plagioclase (An29-31) usually makes up 5 per cent of the rock. Chlorite with the characteristic lavender interference colour is present only in very minor amounts. The aplitic dike rocks sometimes display a crude banding with alternating layers richer and poorer in orthoclase. Accessory grains of sphene, magnetite, actinolite, and apatite also appear to be aligned. This alignment is probably due to flowage parallel to the dike walls.

The quartz-feldspar porphyry consists of very rounded and corroded quartz crystals and subhedral plagioclase and orthoclase crystals in a groundmass of potash feldspar microlites. This groundmass usually constitutes about 65 per cent of the rock. The phenocrysts average 4 mm. in diameter. Sometimes the feldspar phenocrysts occur as clumps of 2 or more crystals welded tightly together. The presence of small amounts of chlorite crystals with the unique lavender interference colour seems to indicate a genetic relationship with the granite batholith proper. However, as chlorite seems to be an alteration product after biotite, it could be that all the rocks containing it ("granite", aplite, and porphyry) suffered the same metamorphism and/or metasomatism. If this is true then the chlorite would not indicate a primary genetic relationship. Considerable epidote is associated with the chlorite and commonly occurs as sunbursts within the chlorite. Magnetite, too, is an important accessory and minor amounts of spene, calcite, and sericite are also present.

Age

In the writer's area, the Holyrood granite was observed to intrude the meta-diorite and both acid and intermediate rocks of the Harbour Main group. Rose (1952) reports that "lower beds" of the Conception group are intruded by this batholith as well. However, McCartney (1959) postulates a pre-Conception age for the "Holyrood plutonic rocks". As the contact between the Holyrood granite and the Conception group was not observed anywhere within the Topsail - Foxtrap area, the writer can make no definite statement on the age relationship between these two rock types. However, since some of the sedimentary rocks of the Conception group are contemporaneous with rocks of the Harbour Main group, it is most probable that they are older than the Holyrood granite.

Within the batholith itself, it seems that the quartz-feldspar porphyry is slightly older than the "granite" whilst the aplite dikes and stocks are somewhat younger.

An age determination was carried out by H.W. Fairbairn on a sample of granite collected by W.D. McCartney in 1957. This sample was taken from a locality near Duffs, Conception Bay, approximately 5 miles west of the writer's area. The determination which was based on the K/Ar ratio in feldspar yielded an absolute age of "910 $\pm$ 10% million years" for the granite. However, the validity of this result has been questioned and at the time of writing representative samples from the granite have been collected for another age determination. The Geological Survey of Canada intends to use the Rb/Sr ratio in feldspars in this case.

Felsite Intrusions

Small irregular bodies of felsite are found intruding Conception group rocks as well as rocks of the Harbour Main group. At one locality felsite was also found in a granite outcrop, however, this is thought to be a xenolith. The felsite intrusions rarely have a dike-like shape and are usually found as small irregular pods. Such bodies were observed to vary from several feet to over 50 feet across, however, they may be even larger than this. The contacts with the intruded rocks are extremely irregular. These small hypabyssal intrusions seem to be particularly abundant in the zone of interbedded andesitic volcanics and Conception sediments.

The felsite weathers to an almost pure white colour. It has a porphyritic texture and is composed of white euhedral to anhedral feldspar crystals in a gray-green matrix. These phenocrysts average 1 mm. in length. Staining indicates that the groundmass is composed dominantly of potash feldspar.

A microscopic study reveals that the rock consists mainly of plagioclase phenocrysts in a matrix of potash feldspar microlites. The microlites average 50 microns in length. In some specimens the microlites are quite irregular in outline and appear to be fused together in a compact feldspathic aggregate. The groundmass usually makes up 80 per cent of the rock. Plagioclase phenocrysts average An28-30 in composition and usually contain small amounts of sericite flakes. Diamond-shaped and prismatic pseudomorphs which are always present to a minor extent, contain an aggregate of chlorite, epidote, and sphene. Small irregular particles of chlorite are also distributed homogeneously throughout the groundmass and this mineral commonly makes up 5 per cent of the total material. Magnetite is an important accessory mineral occurring both as stringers of tiny grains and as small well formed cubic crystals. Secondary quartz sometimes occurs as tiny veinlets or as cavity fillings.

Basic Dikes

Basic dikes are only occasionally encountered in the area. They were observed to intrude the Harbour Main volcanics and the Holyrood granite. Vhay (1937) described basic dikes in the vicinity of Johnny's Pond and stated that they were older than the granite. However, Rose (1952) noted that basic dikes were found intruding the granite. It is possible that there are two unrelated suites of basic dikes present within the map area because some of the specimens examined microscopically show differing mineral compositions. Because of the poor exposures in the central part of the area, it is possible that some bodies mapped as basic dikes are actually roof pendants of more or less metamorphosed extrusive rocks included in the Holyrood granite.

Most of the dikes range in thickness from 6 inches to 20 feet, but are seldom traceable for any great distance because of the mantle of glacial till covering much of the bedrock. The rocks are generally fine grained and greenish black and weather to a gray-brown colour. Some dikes appear to be highly altered and fracture quite readily, whilst the majority of those found within the granite are fairly massive. The largest occurrence mapped as a basic dike is located about ½ mile east of Big Pond near the contact between the granite and the rhyolite. Its contact with the granite is visible at many places and appears to be intrusive; however, in its southernmost part the rock resembles the intermediate (andesitic) volcanics, which suggests that it is more probably a roof pendant than a dike.

Thin sections of this large "dike" show that the rock is fairly well altered consisting mainly of a felted mass of plagioclase crystals (An30-33), chlorite, and opaque minerals. Plagioclase makes up about 65 per cent of the rock, chlorite about 20 per cent, and opaque minerals about 15 per cent. Magnetite makes up about 5 per cent of the opaque material; the remainder is cream-white in reflected light and is probably leucoxene. A few extremely altered phenocrysts of plagioclase are present, as well as several larger chlorite-filled spaces which were probably occupied originally by large ferromagnesian crystals.

Two thin sections were cut from specimens of basic dikes found in the granite near the western border of the area. These rocks have a diabasic texture; one consists primarily of plagioclase and a clinopyroxene (probably augite), the other of plagioclase, hornblende and chlorite. This latter specimen is quite altered and the amphibole may have been formed by alteration of original pyroxene. The plagioclase laths have a composition in the andesine-labradorite range (An47-50). Lesser amounts of biotite, pyrite, magnetite and sphene are also present.

The basic dikes cutting the Holyrood granite are definitely younger than this intrusion. The presence of pre-granite basic dikes intruded into the Harbour Main rocks is possible. Such older dikes, which have suffered the same pre-granite deformation as the Harbour Main group, occur in large number along the east side of Conception Bay, to the north of the writer's area (W.D. Brueckner, personal communication).

CHAPTER VI

METAMORPHISM AND METASOMATISM

Introduction

The intrusion of the granite with its attendant hydrothermal solutions produced various physical and chemical alterations within the Harbour Main volcanic rocks, especially the rhyolites. The most prominent of these alterations is the silicification, pyrophyllitization, and sericitization (pinitization) of areas of rhyolitic rocks. It is difficult to assess the effect of the granitic intrusion upon the andesitic rocks. However, the conversion of the ferromagnesian minerals to chlorite was probably partly due to the intrusion of the granite and the shearing stresses which preceded it. Epidote which is ubiquitous in these volcanics as stringers and disseminated grains is also probably due to the low grade regional metamorphism to which the andesites were subjected.

The reports of Buddington (1916) and (1919) and Vhay (1937) have been drawn on extensively in the writing of this chapter.

Description and Discussion

Buddington (1916) stated that regional silicification

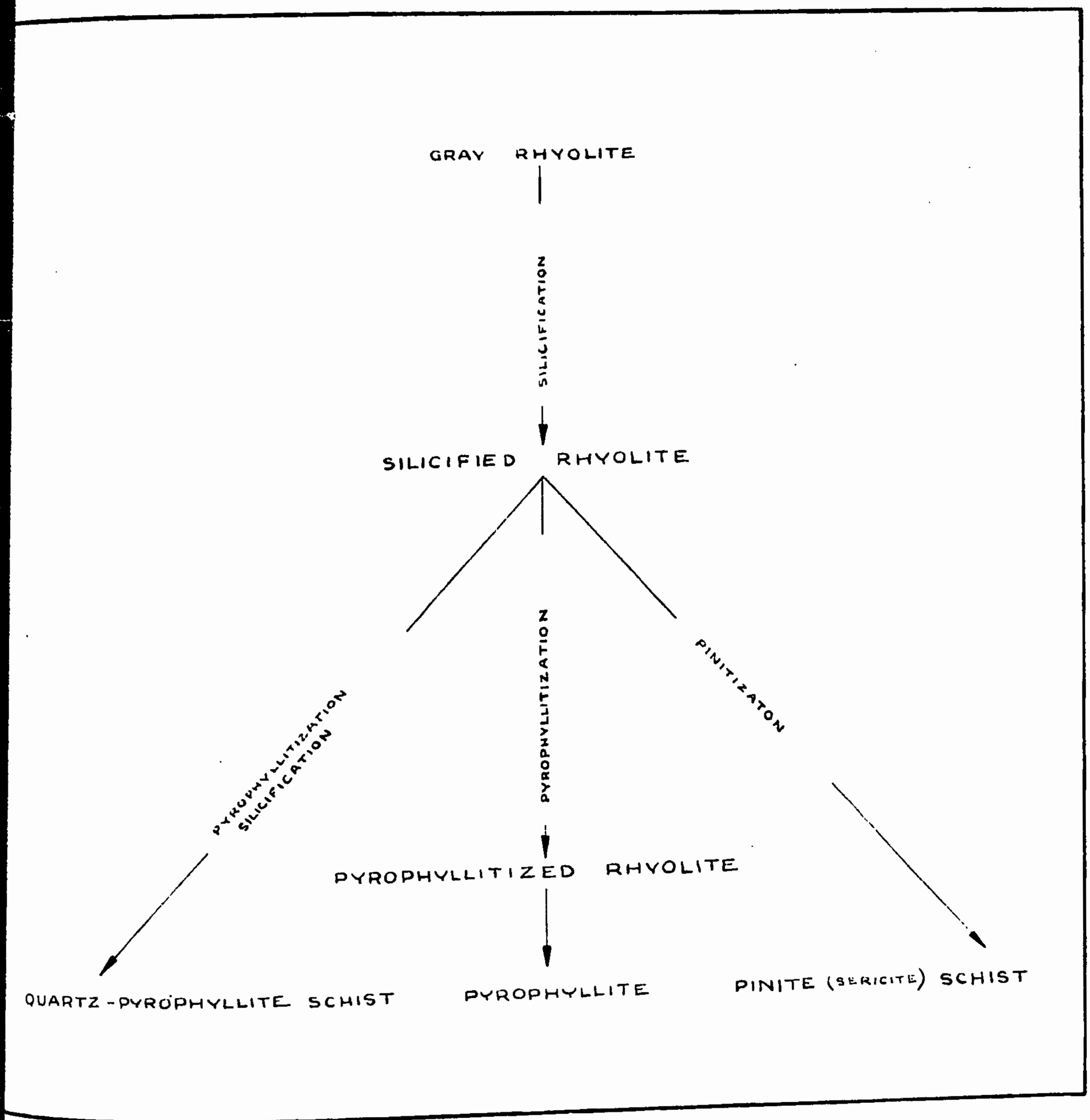


Fig. 2. Outline of processes of alteration in Rhyolite rock. (After A.F. Buddington, 1916.)

was the first process of alteration to which the rhyolites were subjected. The more pronounced but local alterations - pyrophyllitization, pinitization, and local silicification - were later superimposed upon these somewhat silicified rocks. He lists several criteria in attempting to prove that there was, first, a period of regional silicification:

> " i) few later quartz veins are found traversing the pinite, quartz schists, or pyrophyllite;
>
> ii) fragments of breccia in the volcanic breccias often exhibit quartz veins which stop abruptly at the contact with the matrix;
>
> iii) under the microscope aggregates of sericite scales are found replacing granular quartz which had previously been the heart of a spherulite, and the sericite scales finger into and enclose unreplaced fragments of quartz, proving definitely their later origin".

However, Vhay (1937) suggested that all the silicification, as well as the pyrophyllitization and pinitization (seritization) is related in origin to the granite intrusion. From the writer's observations, much of the rhyolite does appear to be slightly silicified, apart from the local,intense silicification near the granite contact. This regional silicification is not manifested in the intermediate volcanic rocks, which overlie the rhyolite and are older than the granite intrusions.

Therefore the writer concurs with Buddington (1916) when he writes:

> "The first stage then in the alteration of these volcanics has consisted in the silicification under relatively static conditions by hot siliceous waters of rhyolite flows ..... The solutions which effected this alteration doubtless belonged to the same general period of volcanic activity as the extrusion of the lavas themselves".

Locally these slightly silicified rhyolites were later altered to varying degrees by the intrusive Holyrood granite. Prior to the introduction of the hydrothermal solutions, the volcanic rocks were sheared, probably during the main stage of the orogeny which was accompanied by the intrusion of the granite. Buddington postulated that when faulting took place between the volcanics and the intrusive granite, the still hot magmatic waters were released and found their way upward along these fault zones. These thermal waters were responsible for the "metasomatic replacement and alteration of previously silicified rhyolitic volcanics".

Proof that these altered rocks have originated through replacement was given by Buddington (1916):

> " i) the presence of unattached and unsupported portions of the country rock within the replacement products (excellent examples of this phenomenon are now visible in the main pyrophyllite quarry at Johnny's Pond, see Figure 7);

ii) the introduction of large quantities of some elements and the solution of others without any notable change in volume or porosity;

iii) gradational contacts;

iv) the preservation of primary features (e.g. perlitic structures, schistosity, spherulites and breccia structure) in the secondary rock" (see Figure 9).

According to Vhay (1937) three major factors seem to have influenced and localized the formation of pyrophyllitized rock. These features are:-

" i) Proximity to fissures near the granite boundary which served as channelways for the hydrothermal solutions. This factor is the hardest to prove, but the distribution of the pyrophyllite suggests a genetic relation to the granite intrusion. A fissure zone on the granite contact may have served as a channelway for the solution derived from the cooling granite at depth, or, more likely from the same source as the granite magma. Further evidence of some such relation is the fact that the only places where strong pyrophyllitization was observed in relatively unsheared rock was very near the granite contact.

ii) Acidic composition of the rock. Pyrophyllite has replaced acidic rocks, for the most part rhyolitic flows, flow breccias and spherulitic flows, and to a lesser extent rhyolitic breccias and conglomerates.

iii) Sheared condition of the rock. Most of the pyrophyllitization has taken place in more or less sheared rock. The few exceptions are in places close to the granite contact where the solutions were especially active. In other places where it appears that a massive rock has been replaced, it is usually found either

> that the rock is a massive block around which shearing passes close by, or that the shearing is not pronounced and shows up only when the rock is examined in thin section. Insomuch as schistosity is commonly not well developed in the massive flows, these rocks are not pyrophyllitized to any extent.

Although pyrophyllite can form under varying conditions, the usual product of hydrothermal alteration of the rhyolitic rocks is sericite (or in this case pinite). It has been established that almost all of the altered rocks contain a mixture of pyrophyllite and sericite. Two equations were used by Buddington (1916) to explain why one or the other, or both of these minerals should form.

$$\text{I} \quad 6KAlSi_3O_8 + 2H_2O = \underset{\text{(Sericite)}}{2KH_2Al_3Si_3O_{12}} + 2K_2SiO_3 + 10SiO_2$$

$$\text{II} \quad 6KAlSi_3O_8 + 3H_2O = \underset{\text{(Pyrophyllite)}}{6HAlSi_2O_6} + 3K_2SiO_3 + 3SiO_2$$

> "From the equations 3 factors are suggested as the possible elements influencing the alternative development of sericite and pyrophyllite:
>
> i) the effectiveness of hydrolysis.
>
> ii) the mass action effect of the excess silica in solution.
>
> iii) the mass action effect of the excess potash in solution.
>
> The dominance of the first two factors would be conducive to the formation of pyrophyllite and the dominance of the third would be favourable to the

production of sericite.

From a comparison of the analyses of the silicified rhyolite with that of pyrophyllite it can be seen that the change in composition is such as might have been brought about essentially through three processes:

i) introduction of Alumina,

ii) replacement of alkalies by hydroxyl,

iii) solution and removal of silica.

From a further look at the analyses it is noticed that although silicified rhyolite, pyrophyllitized rhyolite, and pyrophyllite have all decreased in their content of iron, magnesium, potash, and soda, the pinite (sericite) analyses show an increase in the first three of these elements. During the formation of the pyrophyllite, vast quantities of potash must have been liberated and carried in solution by circulating waters. It is possible that away from the main channels these waters may have deposited their load as pinitic (sericitic) replacements of the rhyolite under the control of lower temperatures and pressures and the mass action effects of the excess potash in solution. It seems reasonable to suppose that the pinite here was an essentially contemporaneous formation with the quartz-pyrophyllite schists and the pyrophyllite, receiving some of the magnesium, potash, and iron released by the formation of the pyrophyllite, as well as the quartz schists have received some of the silica originating at the same time".

With regard to the fractures used as channelways by the hydrothermal solutions, the author concurs with Vhay (1937) that their location is difficult to determine. All the obvious small faults exhibiting slickensides have to be ruled out as these also cut the rocks of the Black Hill sequence, which were deposited long after the hydrothermal alteration of the rhyolites. It is possible, however, that the intricate network of well-healed mylonite zones in the granite and the contact zone provided the channelways postulated.

Besides the replacement of the rhyolitic rocks by pyrophyllite, sericite, and silica, other contact metamorphic effects include the bleaching of rhyolitic flows in the immediate vicinity of the contact, mylonitization of the rocks in the contact zone, and the introduction of small amounts of pyrite.

Along localized zones, such as the Topsail Fault zone, andesitic flows and pyroclastic rocks have been changed to almost pure chlorite schists. However, generally the andesitic rocks are not nearly as altered as the rhyolites, doubtlessly because they were shielded from the bulk of the intrusive granite by the underlying rhyolitic rocks. The chief alteration visible is the almost complete conversion of ferromagnesian minerals to chlorite. Epidotization is an important alteration process in the andesites. This is to be expected as epidotization is usually associated with chloritization. "In low grade metamorphism of basic igneous rocks, removal of CaO and

Al_2O_3 in aqueous solution with complementary introduction of epidote or prehnite into adjacent rocks, is a common phenomenon" (Turner and Verhoogen, 1951).

Most of the massive andesitic flows display only a faint schistosity in a direction varying from N10°E to N30°E. However, the andesitic pyroclastic rocks and the fragmental rhyolites as well, exhibit a strong alignment in this direction. The only observed contact between the granite and the andesitic volcanics is at Manuels River bridge on the Conception Bay Highway. Here, the intermediate volcanics have been baked to a black, tough, hornfels-looking rock.

CHAPTER VII

STRUCTURAL GEOLOGY

General Statement

In the Topsail - Foxtrap area three main unconformities are found. There is evidence for two main periods of folding during Precambrian time. Faulting is quite common in the area, and the Harbour Main rocks display a prominent schistosity.

These features will be discussed in greater detail below.

Unconformities

Three unconformities are known to exist within the Topsail - Foxtrap area:

a) between the "upper" and "lower" divisions of the Harbour Main group;

b) between the Black Hill sequence, and the Harbour Main volcanic rocks and Holyrood intrusive rocks;

c) between the Cambrian fossiliferous strata and the Precambrian Harbour Main and Holyrood rocks.

The last mentioned unconformity is not strictly included within this report as only the boundary of the overlapping Cambrian rocks was mapped.

The magnitude of the break between the "upper" and "lower" divisions of the Harbour Main group is difficult to ascertain. A sharp contact is suggested by the distribution of outcrops but it has actually been observed at only 1 point (see Page). Since much reworked rhyolitic debris is included in the andesitic rocks, and as it seems improbable that intermediate volcanics would be erupted directly after the extrusion of the rhyolitic rocks, the time interval between the formation of the two types of volcanic rock may have been of appreciable duration.

At two localities, the Black Hill sequence was observed to overlie rocks of the Harbour Main group unconformably. Although the basal contact of this sequence is elsewhere obscured by faults and Pleistocene drift, there are several factors indicating that it also unconformably overlies the Holyrood granite (see Page 61).

The contact between the Cambrian sedimentary rocks and the Holyrood granite is beautifully exposed at Manuels Bridge on the Conception Bay Highway. A Cambrian cobble conglomerate, which is the base of the gently northward dipping sequence, unconformably overlaps the granitic rocks along an irregular surface.

Folds

The Harbour Main rocks were undoubtedly folded during the earlier Precambrian orogeny, but later faulting and metamorphism, as well as a heavy cover of glacial drift, make it impossible to establish any continuity of fold structures in this group. Although the andesitic rocks are, in general, less altered than the rhyolites, outcrops of the former are quite scattered and the majority of the rocks seem to dip to the east or southeast. Isoclinal folding was considered as a possible explanation for the lenses of sedimentary rocks included within the andesites, however, no evidence was found to support this idea.

Most of the Conception group rocks immediately east of the Topsail Fault are found in close, tight folds with steeply dipping beds. However, near Paddy's Pond and Octagon Pond, and east of the writer's area the dips become more shallow and the folds are quite open. Outcrops are very scarce in the area east of the Topsail Fault zone, and synclinal and anticlinal axes are at best approximated on the map. They seem, however, to be consistent in trend, always striking slightly east of north. The trend of the fold axes parallels some of the large faults and most of the schistosity within the Harbour Main group. The plunges of folds (if any) within these rocks could not be determined.

Folds observed in the rocks of the Black Hill sequence differ in their trends from those in the Conception Group. With the exception of the outcrops in the vicinity of Dog Pond and Little Pond, the strike is in general eastwest and the dip south. The axial planes of two folds observed in the Johnny's Pond - Black Hill Pond area also strike approximately eastwest. The larger of the two is an east-plunging syncline at the south end of the main pyrophyllite quarry.

In the fairly large outcrop area around Little Pond and Dog Pond, most of the Black Hill rocks strike northeast and dip gently southeast, however, no definite folding could be discerned.

Faults

Buddington (1919) in writing of the regional geology of the Avalon Peninsula stated that "....faulting on a tremendous scale and often of remarkable intensity has been the predominating feature of the diastrophic processes". Faulting has so disrupted the Harbour Main group, especially the rhyolites, that it is impossible to establish the presence of large scale structural features such as folds. This faulting varies in intensity from microscopic disruption of flow bands to large scale displacements like the Topsail Fault, estimated by Hayes (1931) to have a displacement of approximately 8,000 feet.

Rose (1952) observed that many of the faults trend in two main directions. He called the north-northeast-trending faults longitudinal or strike faults, and the northwest-trending fractures transverse or dip faults. The writer has been able to confirm that these two classes of faults can be discerned. However, there are a number of faults which do not conform to this pattern. In particular, there are a few small scale thrust or reverse faults near Johnny's Pond and Dog Pond. At Johnny's Pond, for instance, rhyolitic agglomerate of the Harbour Main group has been thrust up over sedimentary rocks of the Black Hill sequence.

Movement along the large north-northeast-trending faults seems to have a diagonal slip component. Large longitudinal faults are located in the valleys of Conway Brook and Steady Water Brook and on the west side of the valley containing Cross Brook. The Topsail Fault may also be placed in this category, however, it will be discussed separately. In the case of the first three faults or fault zones, and many smaller ones not placed on the map, the actual surfaces of movement are only rarely observed. But the presence of very pronounced scarps and other lineaments, zones of extreme mylonitization with the introduction of pyrite and later formation of limonite, confirm the presence of faults, although the amount of displacement cannot be ascertained.

One of the more important of these is the fault in the Dog Pond area which brings pyrophyllitized rhyolite up against sedimentary rocks of the Black Hill sequence. From an examination of the attitudes of the sediments and some imperfectly slickensided surfaces, the movement appears to have been vertical rather than horizontal. Another north-trending fault with an essentially vertical movement is located at the southeast side of Black Hill. Here it seems as if the whole mass of sediments at Black Hill on the western side of the fault has been downthrown. The red basal sediments occurring on the east side of the fault are far above their continuation on the west side.

In the granite, small faults and shear zones trending north to north-northwest are quite often associated with basic or intermediate volcanic roof pendants. In the western part of the area a number of the "longitudinal" faults have a northerly to northwesterly strike which coincides with one of the main jointing directions within the granite (see below).

Buddington (1916) considered that "there is a strong possibility that the line of contact between the granite and the volcanics at Manuels marks the approximate locus of a fault zone". This statement appears to be true, as the line of contact between the granite and rhyolite is remarkably straight, and is marked by a steep scarp with the lower lying granite on the west side. The contact between these two rocks types was observed at a number of localities including two small adits east of Trout Pond. In all these instances, the contact was observed to be a fault.

Faults striking northwest to west, or the transverse faults of Rose (1952), do not seem to have much continuity along their length. In the vicinity of such faults little crushing is visible and they seem to be chiefly normal faults. Several of these cross faults occur in the large ridge of granite known as White Hill, and the displacement does not appear to exceed 50 feet.

The <u>Topsail Fault</u> is the largest structural feature observed in the Topsail - Foxtrap area. It extends from north to south through the entire map area and separates much of the Conception group from Harbour Main rocks. Hayes (1931) considered Topsail Head to be the southern limit of the eastern block. However, Rose (1952) extended the fault much farther south. The writer agrees that this structure continues farther south, but believes it to be some distance east of the location proposed by Rose.

There is spectacular evidence of faulting at Topsail beach. Topsail Head itself forms a very impressive escarpment 650 feet above the beach. Along the actual fault plane quartz occurs in the form of stringers and occasionally very thick veins. At some places 2 to 3 feet of fault breccia can be observed. Cambrian beds, which abut the fault plane from the west, have been curved upward and actually overturned in a few places, indicating that this side has moved down relative to the eastern block. At several localities the Cambrian shales have been converted to black manganiferous clay by the dynamometamorphism accompanying the fault movement.

The fault plane strikes 11° east of north and dips 80° to the east. Slickensides and larger fault grooves plunge 45° to the north. However, other workers have found slickensides which are practically vertical. Slickensides plunging gently southward have also been observed (W.D. Brueckner, personal communication).

As one attempts to follow the fault southward, phenomena associated with faulting are only occasionally encountered as the area is heavily drift covered. An outcrop of deformed rocks was found on Fowler's Road due west of Three Island Pond. This outcrop seems to consist of a number of blocks of volcanic and sedimentary rock. The fault zone is beautifully exposed on the Trans-Canada Highway in a new channel which was cut to change the course of the Manuels River. It is a zone of extreme local metamorphism. Some of the andesitic volcanics have been altered to pure chlorite schist. Abundant quartz, calcite, pyrite and epidote have been introduced. Bands of extremely contorted, brecciated, and silicified sediments are also present. The schistosity strikes N 10° E. A slickensided surface which strikes N 10° E and dips 45° W has vertically plunging striae on it.

The writer placed the fault trace about 3,000 feet east of the line designated by Rose (1952) because of the highly disturbed exposures found there, the extensive linear depression formed by the Manuels River, and the lack of fault phenomena along Rose's line to the west.

In July 1953, an aeromagnetic survey of Conception Bay was carried out by the Geological Survey of Canada. A geological interpretation of this survey was made by McCartney (1954). The aeromagnetic map shows a number of "highs" in the area around Topsail Head and north to St. Philips along the east side of Conception Bay. These "highs" are interpreted by

McCartney as being produced by the Topsail Fault zone. During October of 1962, a magnetometer was borrowed from the Newfoundland Department of Mines and Resources, and a few experimental traverses were run across what was considered by the writer to be the southern extension of the Topsail Fault. These traverses gave a number of high readings along the proposed fault trace (see profiles on plate 3). It must be stressed, however, that the magnetometer readings were only taken across a narrow area and the survey was more a cursory experiment than a detailed study.

As has been mentioned above, the eastern side of the Topsail Fault has moved up relative to the west side, however, the amount of displacement is difficult to estimate. Regarding the movement Hayes (1931) states:

> "The total throw at Topsail Head is not measurable, for it is greater than the 600 feet above sea level elevation of the basement Precambrian rocks in the headland, plus the thickness of some hundreds of feet of Cambrian sediments. An upthrust of the east block with a throw of several thousand feet appears probable. The amount of throw at Bauline" - about 10 miles north of the present map area - " is deduced from the fact that 7,000 feet of Cambrian and Ordovician strata appear also to terminate under the sea against the Precambrian fault wall ..... the underlying Precambrian rocks are 880 feet above sea level at Bauline".

Therefore, the total amount of uplift of the eastern block envisioned by Hayes approaches 8,000 feet. Rose (1952) agrees that approximately 6,000 feet of Paleozoic strata have been truncated near Bauline but "the northward curving of the beds and the steepening of their dips observed near Topsail Beach, probably necessitates a considerable decrease in this estimate".

McCartney (1959) states that:

> "post-Ordovician movement of possibly 6,000 feet was preceded in Precambrian time, by considerably greater movements in a normal sense .... and that the east block was down-faulted several thousand feet in post Conception time".

One of his arguments for this Precambrian movement is:

> "the apparent stratigraphic throw which brings Conception beds east of the fault in contact with the older Harbour Main volcanics, west of the fault".

The writer has, however, shown earlier in this report that the Conception and Harbour Main groups are not in unconformable relationship in the Topsail - Foxtrap area, as had been assumed earlier. A large Precambrian movement along the Topsail Fault is, therefore, rather unlikely.

In the writer's estimation, the movement at Topsail Head and northward may possibly have been in the order of several thousand feet, however, south of this locality the movement appears to have been much less. The fault cuts across a transition zone of Harbour Main and Conception rocks with no apparent large displacement or discontinuity.

From the evidence observed, the Topsail Fault appears to be a longitudinal fault with an overall diagonal slip, having a total displacement greater in the north than in the south. There is not sufficient evidence to determine whether all the movement was accomplished at the same time (post-Lower Ordovician), or whether the fault is a re-activated Precambrian structure.

Cleavage, Schistosity and Jointing

The area has undergone low grade regional metamorphism and this is indicated by cleavage and quite prominent schistosity, apart from mineralogical changes. Almost all the volcanic rocks display a schistosity whilst cleavage is mainly displayed by the Conception group sediments interbedded with the andesitic volcanics. The main bulk of Conception rocks east of the Topsail Fault zone display little or no cleavage.

Cleavage and schistosity are remarkably consistent throughout the area striking between N 10° E and N 30° E, and examples of schistosity striking north-northwest were observed.

Schistosity is best developed in the fragmental rocks of both rhyolitic and andesitic composition, although fine grained andesite flows display this phenomenon to some extent.

The coarser grained andesites, as a rule, do not display schistosity to any great degree. The fragmental rhyolites, especially those which have been hydrothermally altered, display a very prominent schistosity with elongate lenses of quartz oriented slightly east of north. The fine grained, unaltered rhyolite flows locally display a cleavage rather than a schistosity, undoubtedly because they are quite brittle and tend to break rather than flow.

The schistosity appears to have formed prior to the intrusion of the granite as the pyrophyllite and sericite were formed in already sheared rocks. As well, such little alignment of minerals as is present in the granite trends north-northwest, but no north-northeast trends are represented.

The meta-diorite shows a slight gneissosity with a crude alignment of the hornblende needles in a north-northwesterly direction. The entire roof pendant is also oriented in this direction.

Jointing is only occasionally displayed in the sedimentary and volcanic rocks, but is quite common in the granite. Approximately 125 joints were measured within the granite and plotted on a Schmidt equal area net (see Figure 3). Two prominent sets of joints were observed: one set strikes between

N 50° E and N 80° E and dips 60° SE, and the other strikes between N 10° W and N 30° W and dips 60° NE. A smaller number of joints were observed to strike between N 60° W and N 30° W and dip 50° SE.

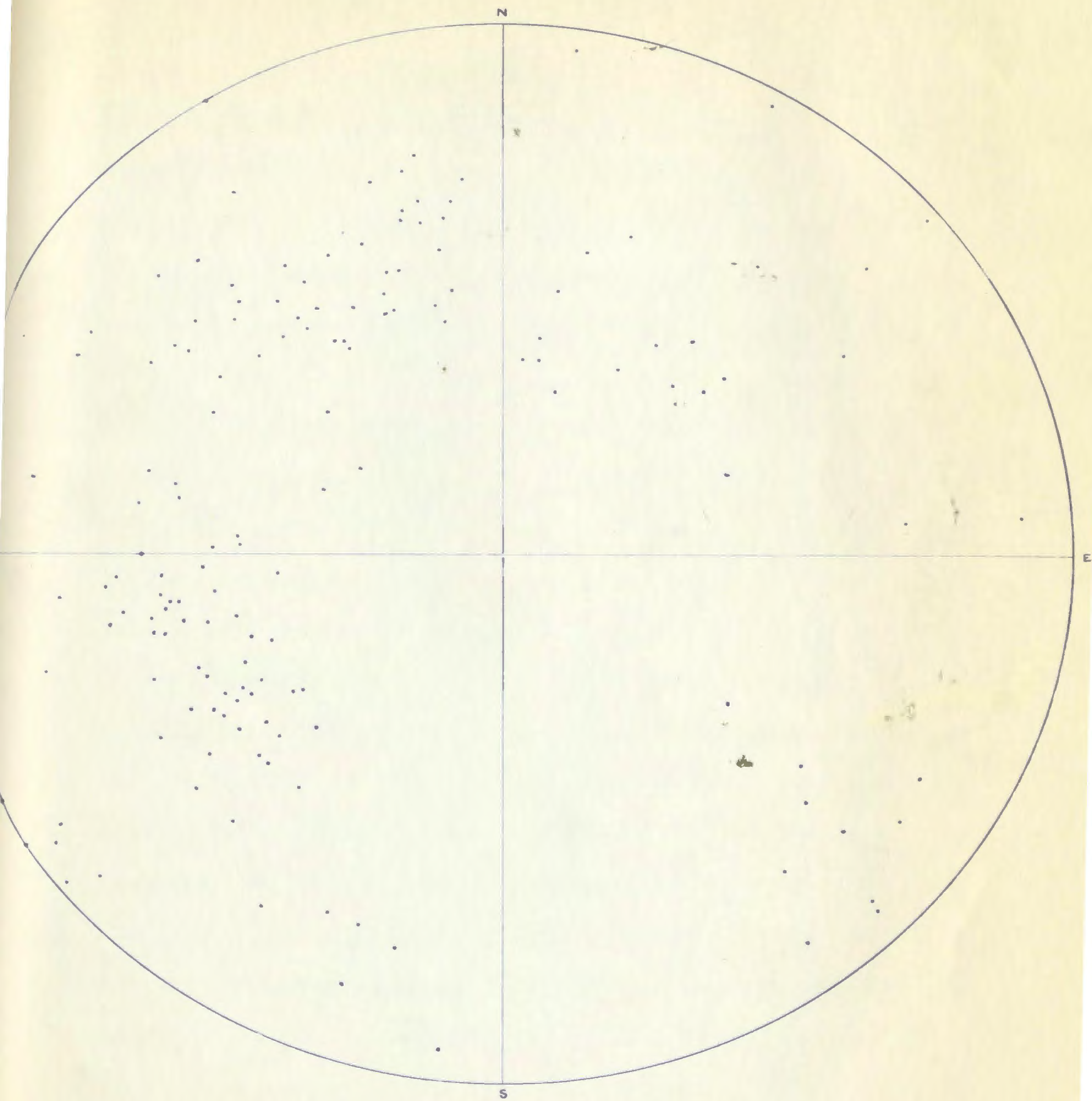
It is possible that the north-northwest-trending joints represent primary longitudinal joints and the joints striking north of east represent primary cross joints, as defined by Balk (1937).

It is interesting to note that many of the small aplite dikes also strike in the directions of the two main joint sets. This would relegate the age of the jointing to shortly after or during the emplacement of the batholith.

Ages of Deformation

Evidence from the various structural features indicates that there were two major periods of orogenic deformation during Precambrian time in the Topsail - Foxtrap area. The first of these is expressed in the prominent north-northeast-trending deformation which preceded the intrusion of the granite, and was probably terminated by this plutonism. If the age determination for the granite is correct, then the age of this older orogenic period is approximately mid-Proterozoic.

In this thesis area the other Precambrian deformational



3 Point diagram of joints in the Holyrood Granite of the Topsail - Foxtrap area plotted on the lower hemisphere.

period can only be dated insofar as it brought about the folding of the Black Hill rocks. It is, however, well represented by folds in the young Precambrian sediments on the eastern side of the Avalon Peninsula. Some of the faulting in the area may have been due to this deformation. This orogenic phase has therefore been relegated to late Precambrian time.

The Topsail - Foxtrap area does not seem to be included in the northern Appalachian folded belt. Cambrian and Ordovician beds lying immediately north of the area are remarkably undisturbed and dip gently to the northwest. Neale et al (1961) state that the Harbour Main group and the Holyrood batholith "have acted as a resistant block throughout Paleozoic folding". These authors claim that the only appreciable deformation of these rocks in post Cambro-Ordovician time was during the Acadian orogeny (Devonian).

Some of the large scale faulting on this part of the Avalon Peninsula is definitely post-Lower Ordovician, but whether it occurred during the Acadian Orogeny or during some later period of deformation, is difficult to determine.

CHAPTER VIII

GEOLOGIC HISTORY

In this chapter, the writer is attempting to give an approximate chronological account of the geologic events within the Topsail - Foxtrap area and environs. This will, it is hoped, give the reader a more concise picture of the geology than can be acquired from the various conclusions reached in the preceding chapters.

The original substratum of the Harbour Main group is now nowhere visible in the Topsail - Foxtrap area. In the region north of the writer's area, rhyolitic volcanics of the Harbour Main group overlie basic to intermediate volcanic rocks and sedimentary rocks (called Conception group). The composition of these sediments suggests that they were, in part, derived from a granitic or gneissic source area, probably situated to the east. In the Topsail - Foxtrap area the lower rhyolitic division of the Harbour Main group, which is the oldest major rock unit outcropping, may overlie basic to intermediate volcanics and sediments as in the Cape St. Francis area, or it may rest directly on older Precambrian gneisses.

Evidence found by the writer and by previous workers indicates that the rhyolitic rocks of the Harbour Main group were extruded in a subaerial environment. After a period of erosion and relative quiescence the upper andesitic volcanics of the Harbour Main group were erupted. Many features in these rocks point to the fact that they were formed in a partly marine and partly subaerial environment. It is likely that there was a ridge of volcanic cones near the sea, or a series of volcanic islands, from which andesitic flows and pyroclastics were erupted with some portions of this volcanic material being laid down under the nearby sea.

During this later volcanism, sedimentation was going on in the Conception sea to the east. Sediments were laid down on the marine volcanics only to be covered by later flows and tuffs. In this way, the transition zone or facies change which is now visible between pure volcanics and pure sediments came into being. To the east of transition zone, "cleaner" Conception sediments were laid down in a large slowly subsiding basin. The nature of most of the Conception rocks is such as to suggest that they were derived from essentially two source areas - the intermediate and acidic Harbour Main rocks to the west and a granitic or gneissic terrain to the east.

The formation of the volcanic and sedimentary rocks just described was followed by an orogenic phase which deformed most of the rocks in this area and subjected them to low grade regional metamorphism expressed in a prominent schistosity in the Harbour Main rocks and some cleavage in the Conception rocks. The folding of the Conception group rocks in the eastern part of the area was probably also accomplished at this time, as the fold axes are oriented in the direction of cleavage and schistosity farther west. The intensity of folding seems to have waned eastwards, and around Paddy's Pond and Octagon Pond, the folds become more open and dips are shallower.

The small hypabyssal felsite intrusives appear to have been intruded at some time after the formation of the Harbour Main and Conception groups, but prior to the intrusion of the Holyrood granite. Some basic dikes may also have been intruded into the volcanic and sedimentary rocks during this interval. To the north of the writer's area, some such small basic and acid intrusives have suffered the same deformation as the volcanics, while others have not. This indicates that such intrusive activity occurred before and after the orogenic deformation.

At a later stage in this orogenic cycle the Holyrood batholith was emplaced. The quartz-feldspar porphyry seems to have been a precursor to the main granite intrusion. However, these smaller bodies were later engulfed by the rising granitic magma and are now roof pendants, comparable to those composed of partly assimilated and metamorphosed Harbour Main rocks. Following the emplacement of the granite primary jointing occurred and quite a few fractures were filled by aplite dikes. Somewhat larger intrusions of aplite also took place at this time.

It is difficult to determine the relative age of the meta-diorite roof pendant lying west of Little Pond. It lies wholly within the granite and does not come into contact with Harbour Main or Conception rocks. Its somewhat gneissic texture leads one to believe that it may belong to some terrane older than any of the rocks in the area. However, it is possible that it is a part of one of the conduits through which the andesitic rocks were extruded, or even a still younger pre-granite intrusion.

After the granite was emplaced hydrothermal solutions found their way upwards through fissures near the rhyolite-granite contact (possibly the zones now represented by rehealed mylonite). The hydrothermal solutions accomplished the metasomatism of sheared rhyolitic volcanics to quartz-pyrophyllite-sericite schist and small areas of high grade pyrophyllite.

A small number of basic dikes were intruded into the granite and the Harbour Main and Conception rocks at some later time.

Then followed a period of uplift and erosion; possibly some faulting occurred during this interval. When denudation had lowered the area so much that the granite was exposed over considerable areas, sedimentation of the Black Hill sequence began in the lowest portions of a still irregular relief. There probably was a long narrow basin or inlet of the sea to which sedimentation was confined. A complete inundation of the area did not take place as this would have covered the source area for the Black Hill sediments. The rhythmic interbedding of this sequence and the coarse clastic nature of the graywackes suggest periodic rapid influxes of material derived mainly from the surrounding Harbour Main rocks. If the correlation of the basal red beds of the Black Hill sequence with the Hibbs Hole formation of Hutchinson (1953) is correct, then these rocks can be placed stratigraphically near the top of the Conception group, as defined by Hutchinson (1953) and McCartney (1959) on the west side of Conception Bay.

At some time after their deposition, the Black Hill rocks were folded. This may have been contemporaneous with the orogenic phase during which the late Precambrian rocks near St. John's, and those lying between Conception and Trinity Bays, were folded. The odd east-west strike of the Black Hill rocks, which contrasts sharply with the main, north-northeast-striking folds around St. John's, might find its explanation in the pronounced irregularities of their basal surface.

It is probable that much of the small scale faulting in the Topsail - Foxtrap area originated during the same late Precambrian orogenic phase. It is thought that the rather rigid Holyrood granite and Harbour Main volcanics may have reacted by rupturing, whereas the more plastic sedimentary strata in this area, and to the east and west, were folded by the orogenic compression.

After this late Precambrian orogenic phase a period of erosion followed until early Paleozoic time, when Cambrian and Ordovician sediments were deposited to the north of the map area, unconformably upon the Precambrian rocks. The area was not affected by Appalachian folding; however, some post-

Ordovician faulting occurred (Topsail Fault), the age of which cannot be determined more precisely.

The post-Ordovician history of the area probably consists of a period of continued erosion lasting until Pleistocene time, when ice sheets, moving northwestward from the central part of the Avalon Peninsula modified the relief of the Topsail - Foxtrap area and spread till and outwash deposits over the region. Later modification included the formation of alluvial deposits in the northern part of the area and bogs in the poorly drained southern and eastern portions.

CHAPTER IX

ECONOMIC GEOLOGY

General Statement

Materials of potential economic value found in the Topsail - Foxtrap area include pyrophyllite, galena and chalcopyrite, and sand and gravel. However, the only mining carried on at present is concerned with the Pyrophyllite deposits near Johnny's Pond.

Pyrophyllite

Large areas of fragmental rhyolitic rocks in the immediate vicinity of the granite have been altered to Quartz-pyrophyllite-sericite schist. Occasionally lenses and irregular areas of relatively "pure" pyrophyllite are found within the schistose rocks. A large concentration of pyrophyllite of various grades is found in the area around Johnny's Pond, about 2 miles south of Manuels.

Deposits of pyrophyllite were first noted by Howley in the latter half of the nineteenth century. In 1902, a company was formed to work the deposits, however, operations ceased in 1905, after approximately 8,000 tons had been shipped to the United States.

Buddington (1916) and Vhay (1937) described the deposits, and the latter mapped the prospects in detail for the Newfoundland Government. He outlined areas of quartz-pyrophyllite schist, quartz-pinite schist and pure pyrophyllite. However, some of the deposits designated as high-grade or pure pyrophyllite by Vhay have since been found to contain appreciable amounts of sericite.

Following Vhay's investigation, the Industrial Minerals Company of Newfoundland began production in 1938. This company operated until 1947 and during this period 10,000 tons of pyrophyllite were exported.

In 1956, Newfoundland Minerals Limited, a subsidiary of American Encaustic Tiling Company, acquired control of the deposits. Since this date, considerable development, including new roads, a new mill and a loading pier, has taken place. During the period from 1956 to 1958, a diamond drilling program was carried out by the Newfoundland Department of Mines and Resources. Subsequently the existence of 1.5 million tons of mineable pyrophyllite was proven at one location - the present main pyrophyllite quarry. In addition to this ore body, additional areas of potential value are found in the general vicinity of Johnny's Pond.

At the present time the pyrophyllite is mined from a large quarry located about ¼ of a mile north of Johnny's Pond. This quarry has been referred to in this report as the main pyrophyllite quarry to distinguish it from smaller quarries in the hill west of Johnny's Pond and farther south. These quarries were cut by the previous companies.

Mining consists merely of blasting the pyrophyllite from 10 to 15 foot benches and transporting it by truck to the nearby primary crusher. The material is crushed to "4 inch" size and then transported by truck a distance of 2½ miles to the Company's stockpile near the loading pier at Long Pond.

Since 1959, the output of pyrophyllite ore has varied from 18,000 to 24,000 tons annually. This material is approximately 75 per cent pure. Most of it is shipped to the Company's main plant at Lansdale, Pennsylvania.

The Company uses pyrophyllite in the manufacture of ceramics. For this purpose it is necessary that the content of alkalies (e.g. Na, K) mixed with the pyrophyllite be as low as possible. Because of this requirement much of the seemingly high grade pyrophyllite cannot be used as it contains sericite (pinite) to varying degrees. Besides this, areas of pyrophyllite with small amounts of elements such as Cu or

Fe must be avoided as these traces cause staining in the finished product.

Minor Epithermal Sulfides

Quartz veins fill some of the rock fractures and in two of these veins, found about ½ mile north of Trout Pond, small amounts of galena and chalcopyrite occur. However, nothing more than traces of these minerals were found. Disseminated pyrite is quite common in both rhyolitic and granitic rocks of the contact zone.

Till and Gravel Deposits

Deposits of glacial till are widespread in the Topsail - Foxtrap area and although most of it is unsorted, there are some areas of sand and gravel. Some of this material was screened and used in surfacing the Trans-Canada Highway during its construction. In the area of gently rolling topography around the south shore of Conception Bay, considerable thicknesses of clay and gravel are found. These deposits are probably partly alluvium and partly glacial debris washed down from the higher regions to the south.

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Fig.4:View of valley containing Conway Brook(looking northeast). White Hill is seen in background at right.

Fig.5:Large hill of Black Hill rocks showing lee and stoss shape, west of Johnny's Pond.

Fig.6:Small flow folds in red, banded rhyolite.

Fig.7:Large remnant of red,unaltered rhyolite in almost pure pyrophyllite, at the main pyrophyllite quarry, Johnny's Pond.

Fig.8:Pale green,massive pyrophyllite,
main pyrophyllite quarry,Johnny's
Pond.

Fig.9:Pyrophyllite showing relict
"agglomerate structure",main
pyrophyllite quarry,Johnny's Pond.

Fig.IO:Spherulitic rhyolite showing development of chalcedonic nodules.

Fig.II:Development of asbestos (anthophyllite) on slip surfaces in massive andesite.

Fig.I2:Highly cleaved band of tuffaceous sediments between two flows(?) of andesite.

Fig.I3:Interbedding of white argillaceous rocks and dark brown graywacke of the Black Hill sequence.

Fig.I4:Conglomerate bed near the base of the Black Hill sequence.

Fig.I5:Red argillaceous sediments overlying conglomeratic band in the Black Hill sequence.

Fig.I6:Fragments of broken beds, due to slumping in the Black Hill sediments.

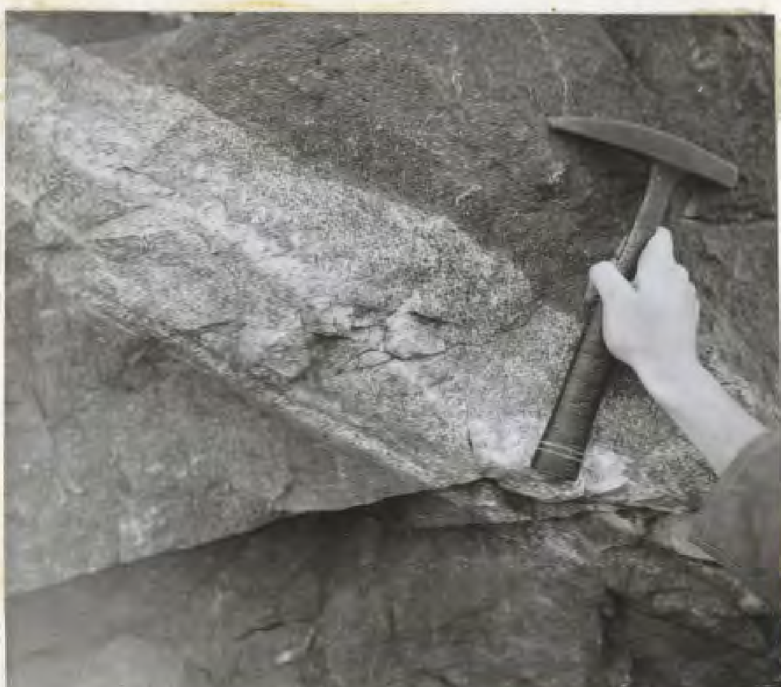


Fig.I7:Granite dike intruding meta-diorite.

Fig.I8:Xenolith of meta-diorite in granite.

Fig.I9:Close view of quartz-feldspar porphyry.

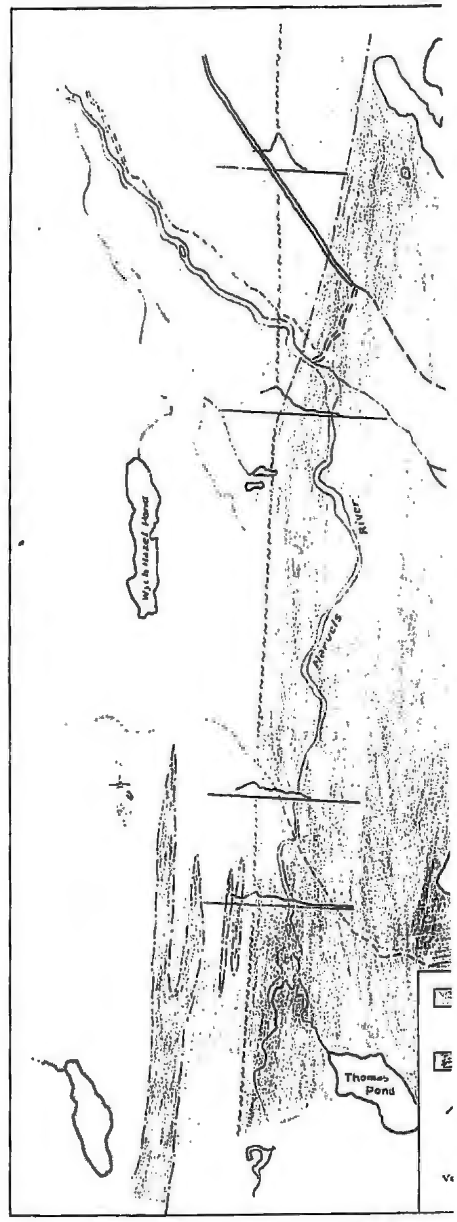
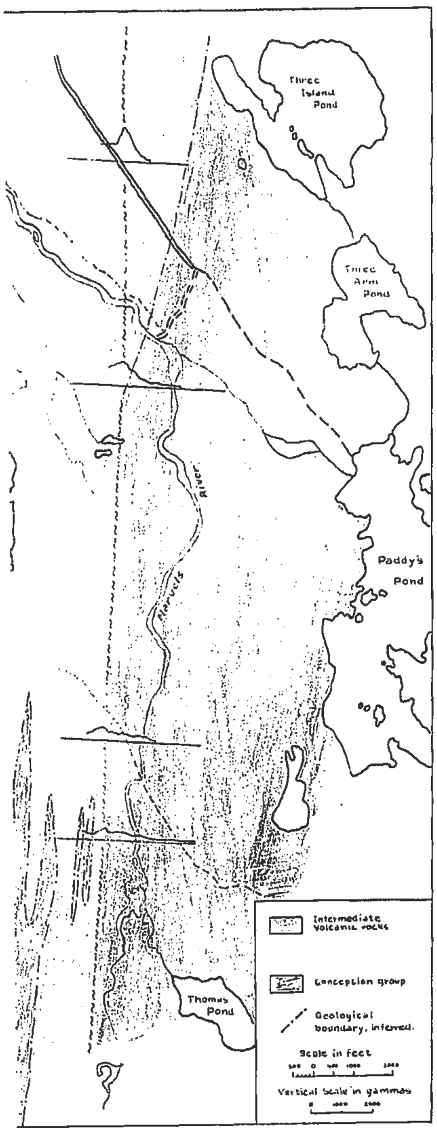
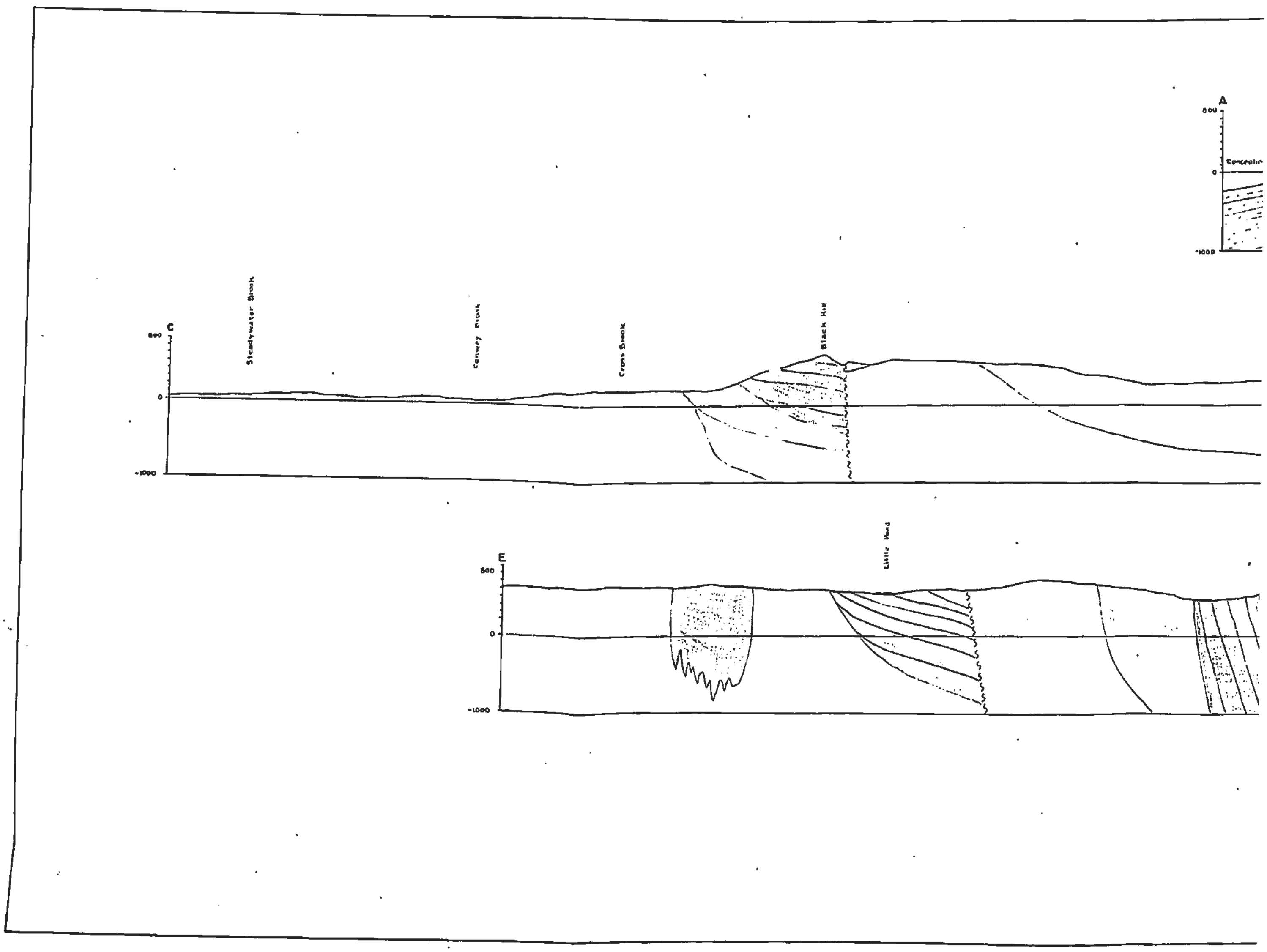


Plate 3. Magnetic profile across presumed location of Topsail Faul



e across presumed location of Topsail Fault.


A
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-1000
C
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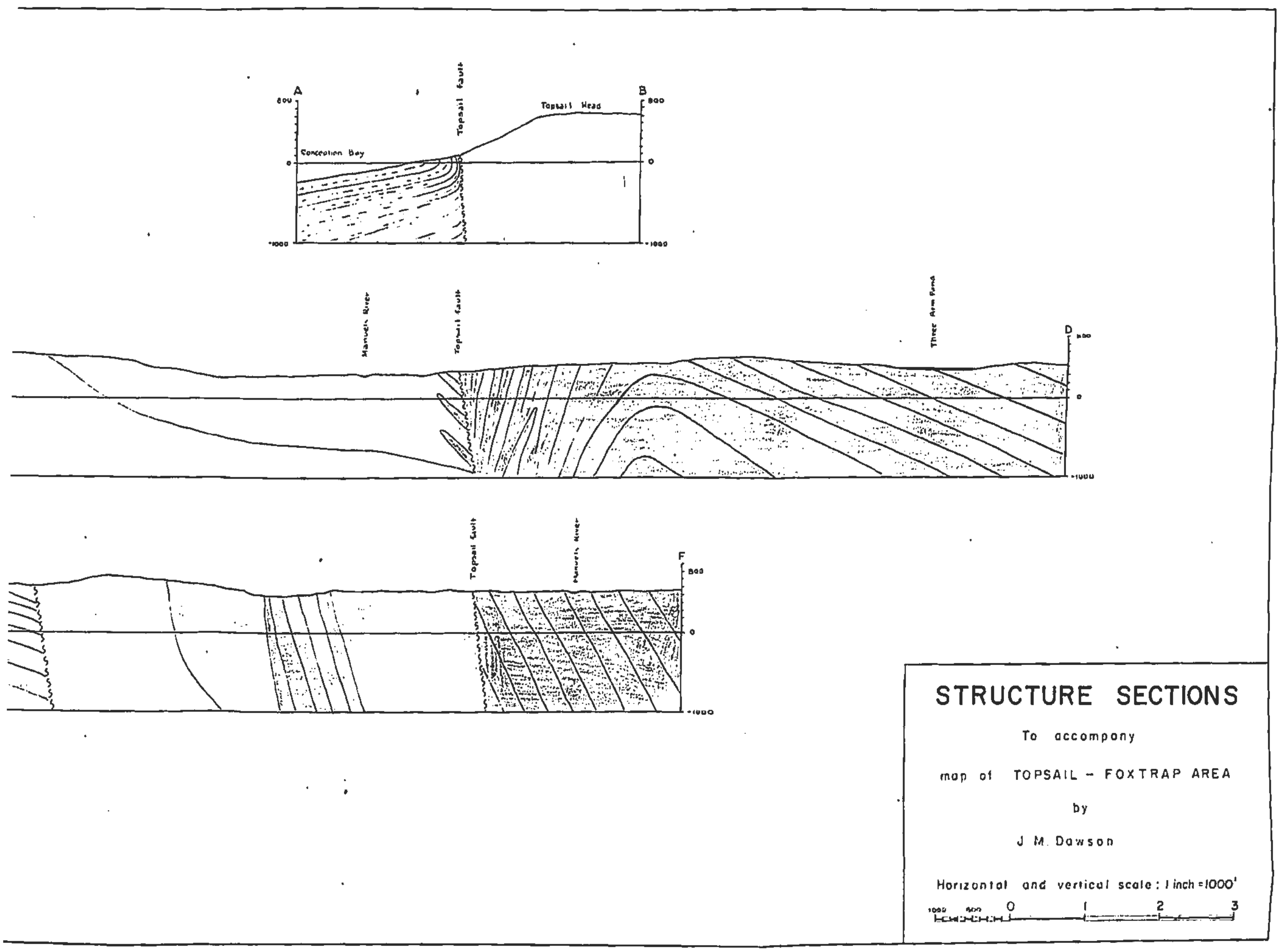
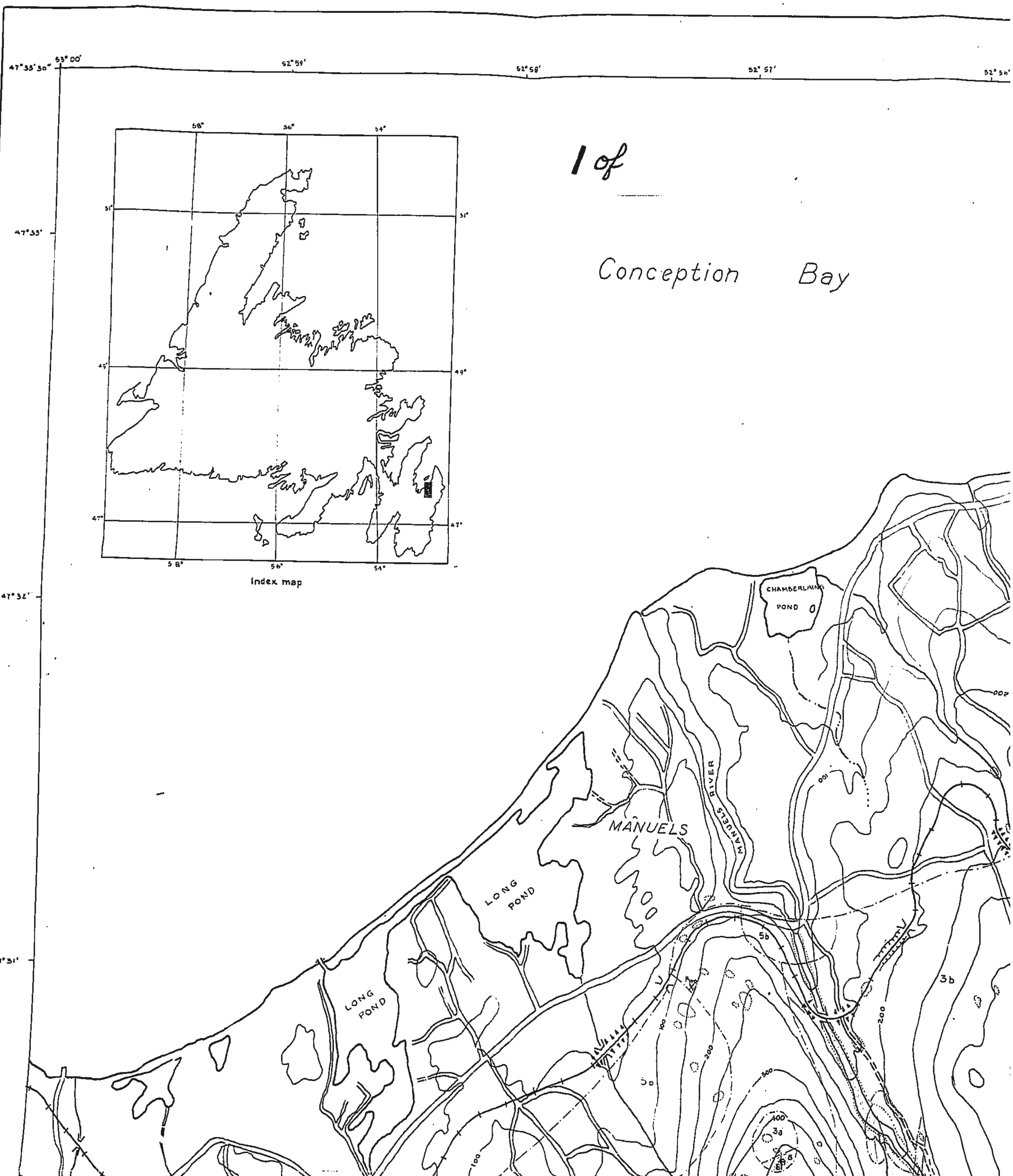
-1000
Steadywater Brook
Cross Brook
Black Hill
E
500
0
-1000
Little Pond


A
B
Topsail Fault
Topsail Head
Conception Bay
Manuels River
Three Arm Pond
D
F
STRUCTURE SECTIONS
To accompany
map of TOPSAIL - FOXTRAP AREA
by
J. M. Dawson
Horizontal and vertical scale: 1 inch = 1000'
0
1
2
3



1 of
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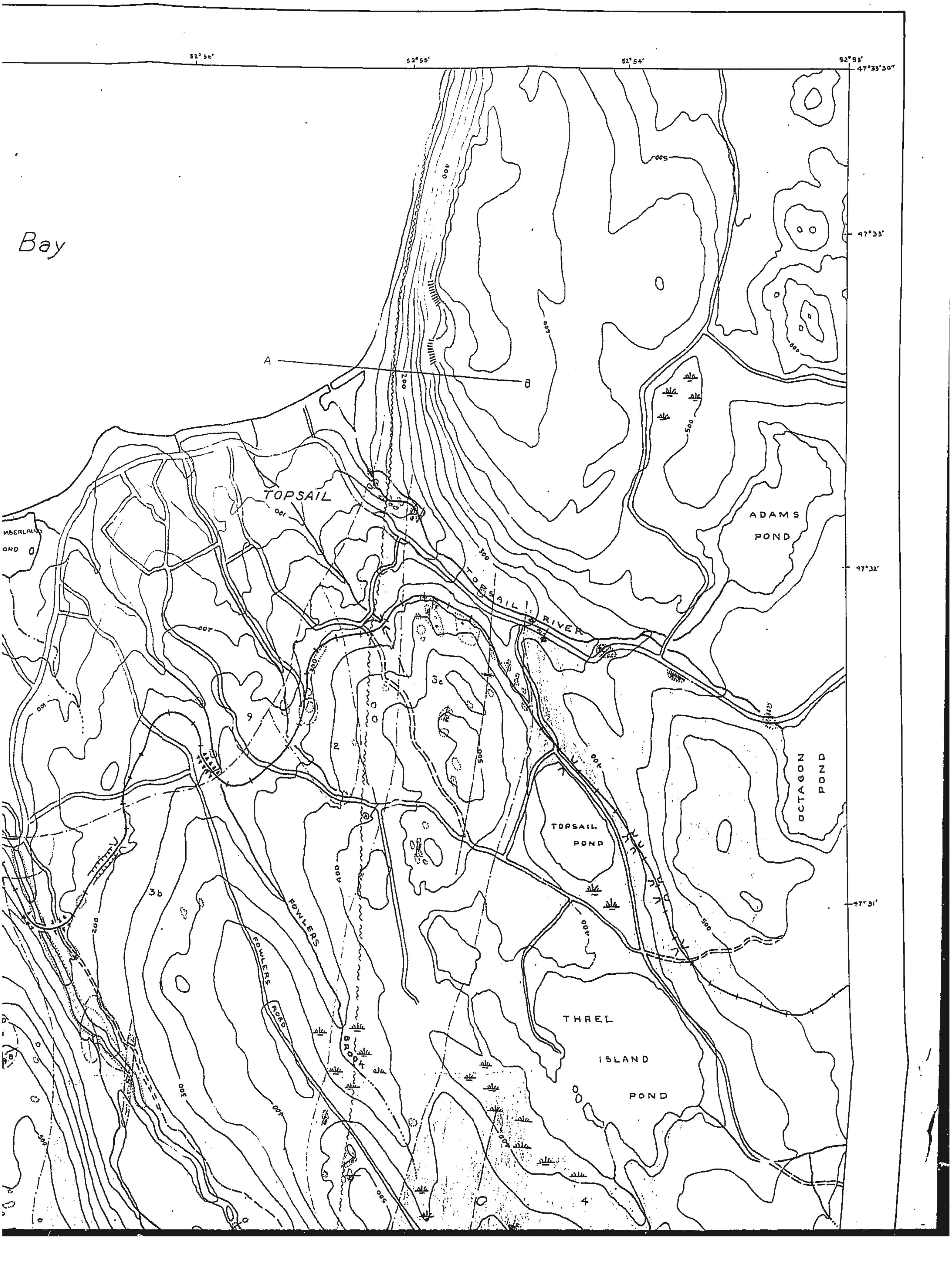
52°58'
52°57'
47°33'
47°32'
47°31'
47°30'
58°
56°
54°
51°
49°
47°
Index map
Conception Bay
CHAMBERLAINS POND
MANUELS
MANUELS RIVER
LONG POND
LONG POND
FOXTRAP



52° 56'
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52° 53'
47° 33' 30"
47° 33'
47° 32'
47° 31'
Bay
A
B
TOPSAIL
TOPSAIL RIVER
ADAMS POND
OCTAGON POND
TOPSAIL POND
THREE ISLAND POND
FOWLERS
FOWLERS ROAD
BROOK
3b
3c
2
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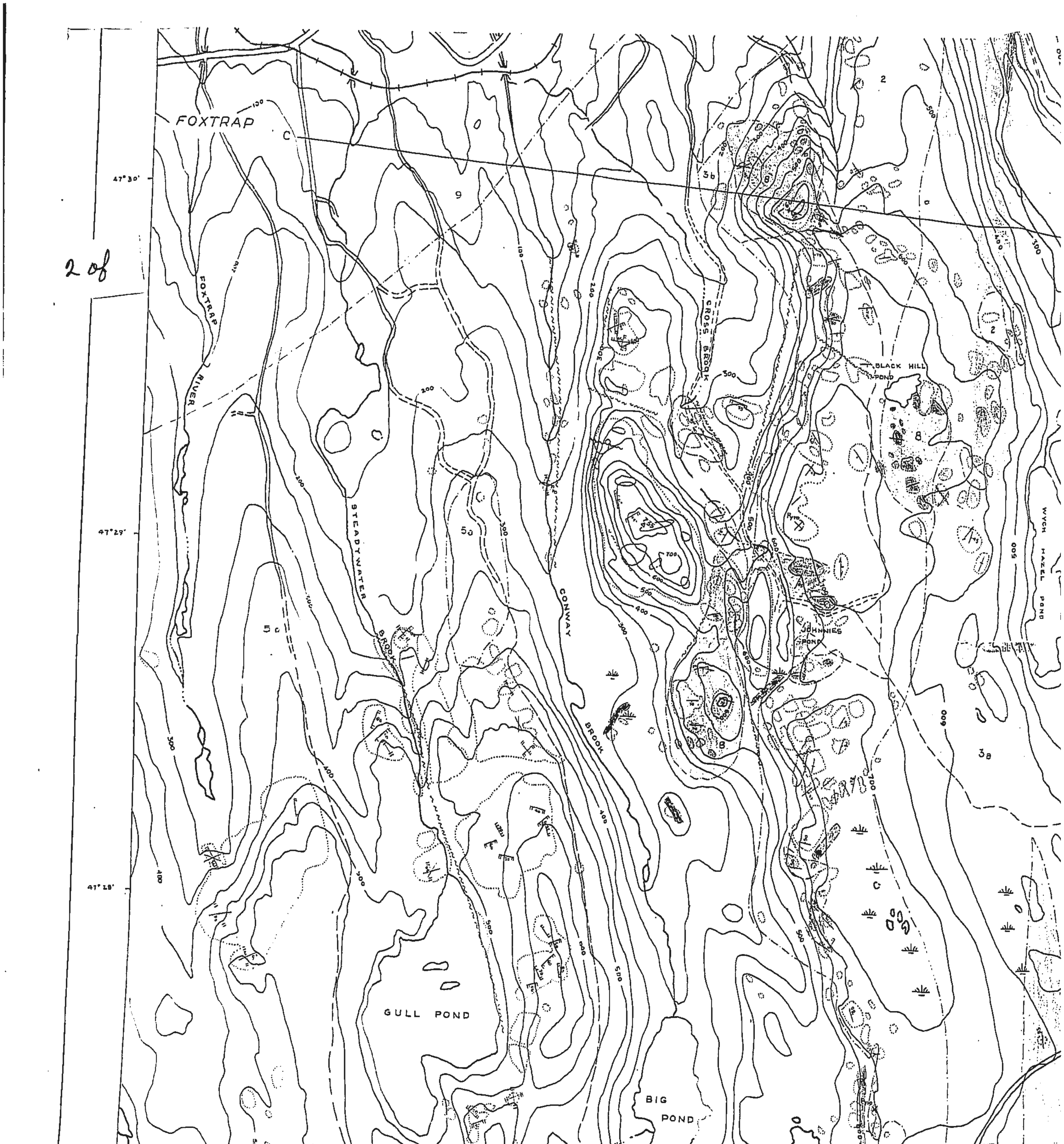
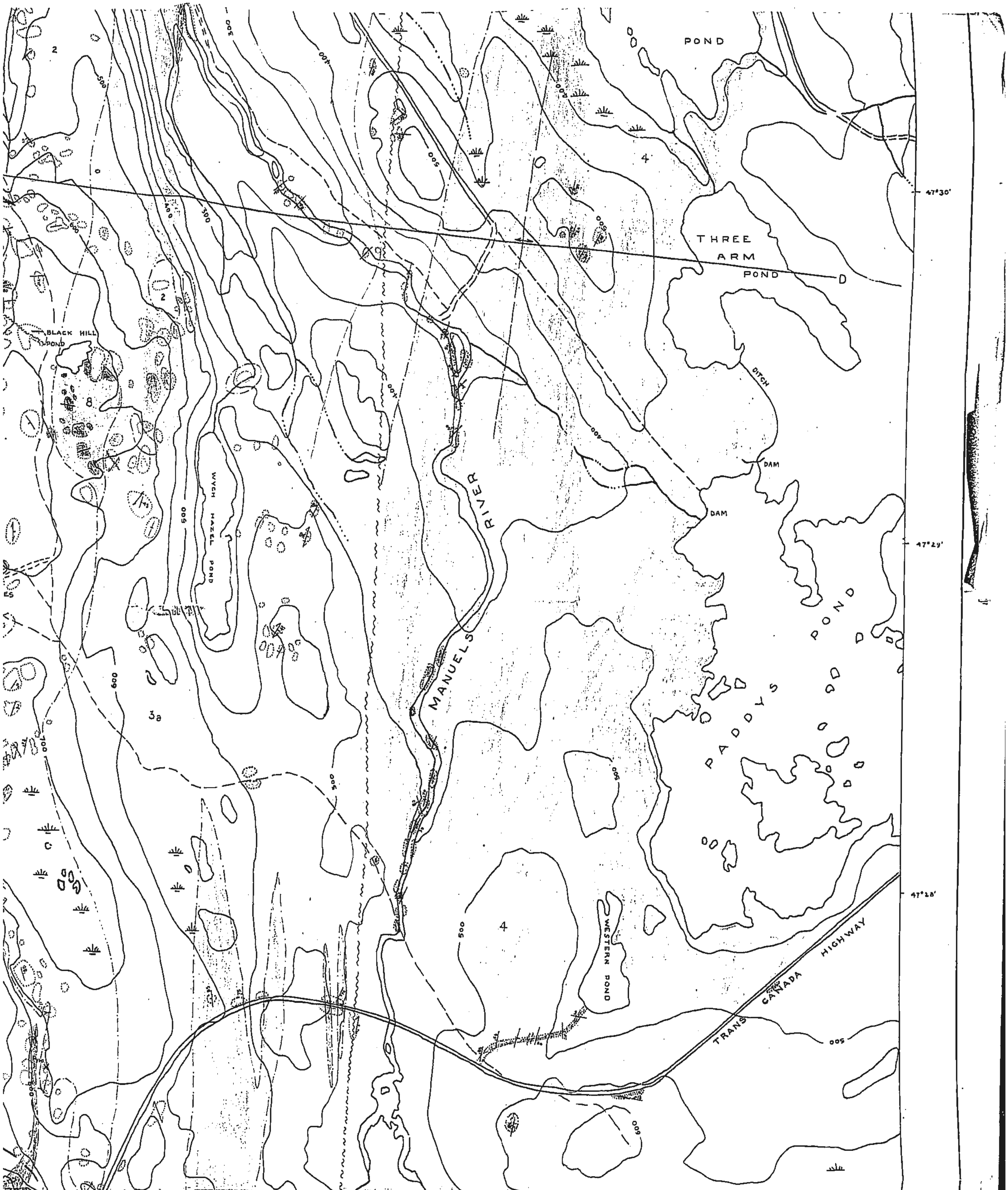
4

2 of



FOXTRAP
FOXTRAP RIVER
STEADYWATER BROOK
CONWAY BROOK
CROSS BROOK
BLACK HILL POND
JOHNNIES POND
WYCH HAZEL POND
GULL POND
BIG POND
TROUT POND
NUT BROOK
47°30'
47°29'
47°28'
47°27'


POND
THREE ARM POND
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47°28'
47°27'
BLACK HILL POND
WYCH HAZEL POND
MANUELS RIVER
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DAM
PADDYS POND
WESTERN POND
TRANS CANADA HIGHWAY
THOMAS POND
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3a
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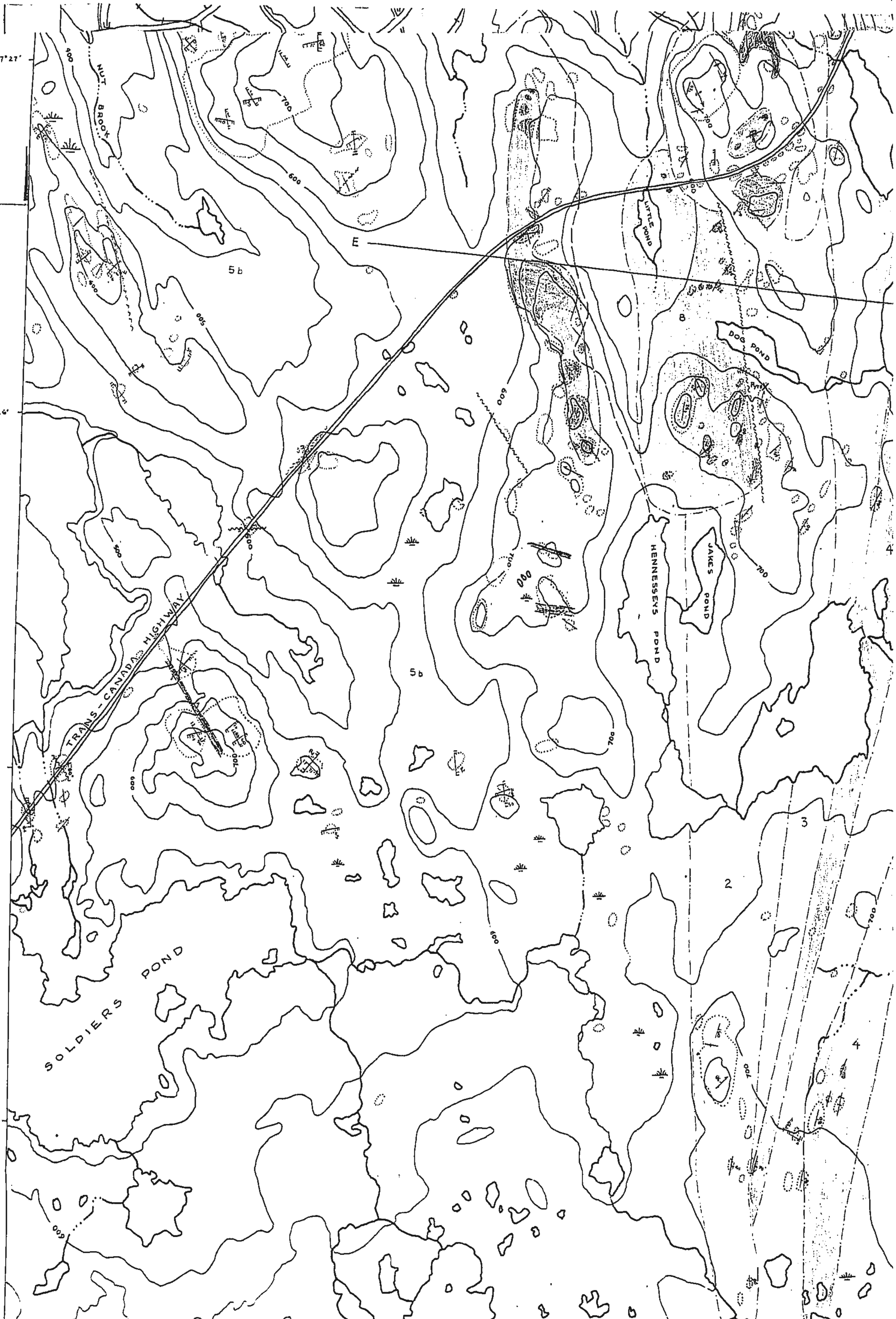
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NUT BROOK
TRANS-CANADA HIGHWAY
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LITTLE POND
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8
HENNESSEYS POND
JAKES POND
SOLDIERS POND
3
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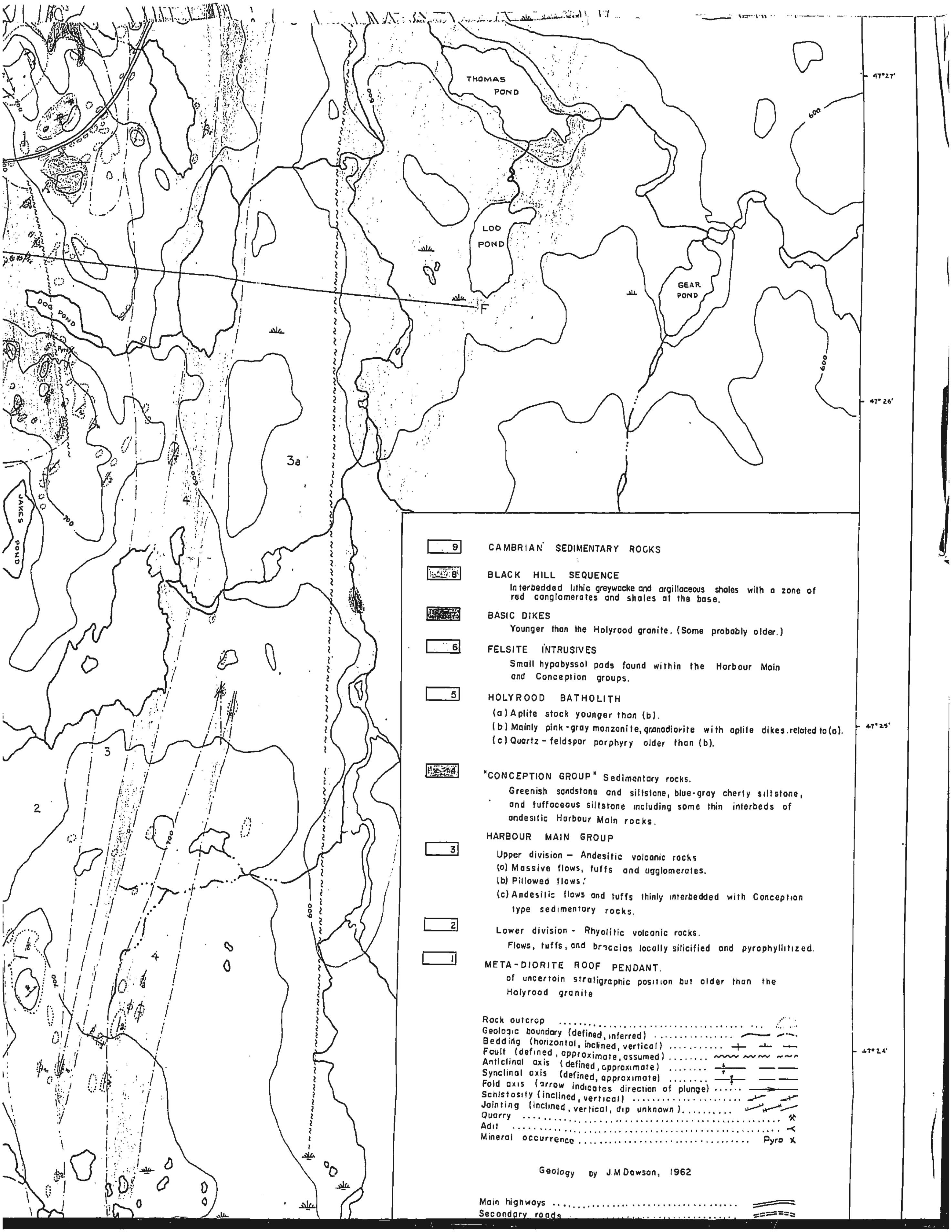
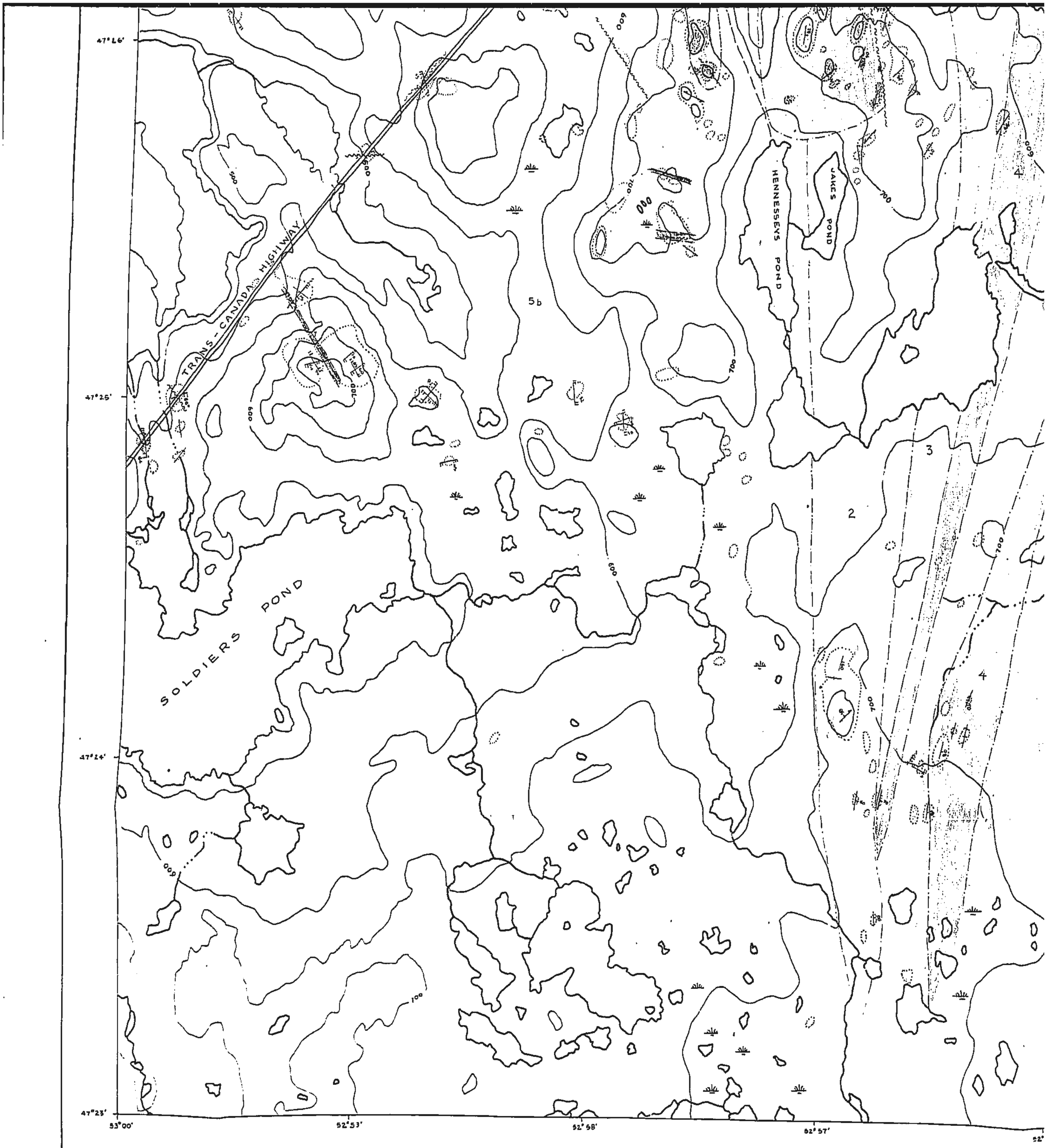


THOMAS POND
LOO POND
GEAR POND
DOG POND
JAKES POND
47°27'
47°26'
47°25'
47°24'
500
600
700
3a
4
3
2
F
9 CAMBRIAN SEDIMENTARY ROCKS
8 BLACK HILL SEQUENCE
Interbedded lithic greywacke and argillaceous shales with a zone of red conglomerates and shales at the base.
BASIC DIKES
Younger than the Holyrood granite. (Some probably older.)
6 FELSITE INTRUSIVES
Small hypabyssal pads found within the Harbour Main and Conception groups.
5 HOLYROOD BATHOLITH
(a) Aplite stock younger than (b).
(b) Mainly pink-gray monzonite, granodiorite with aplite dikes related to (a).
(c) Quartz - feldspar porphyry older than (b).
4 "CONCEPTION GROUP" Sedimentary rocks.
Greenish sandstone and siltstone, blue-gray cherty siltstone, and tuffaceous siltstone including some thin interbeds of andesitic Harbour Main rocks.
HARBOUR MAIN GROUP
3 Upper division - Andesitic volcanic rocks
(a) Massive flows, tuffs and agglomerates.
(b) Pillowed flows.
(c) Andesitic flows and tuffs thinly interbedded with Conception type sedimentary rocks.
2 Lower division - Rhyolitic volcanic rocks.
Flows, tuffs, and breccias locally silicified and pyrophyllitized.
1 META-DIORITE ROOF PENDANT.
of uncertain stratigraphic position but older than the Holyrood granite
Rock outcrop
Geologic boundary (defined, inferred)
Bedding (horizontal, inclined, vertical)
Fault (defined, approximate, assumed)
Anticlinal axis (defined, approximate)
Synclinal axis (defined, approximate)
Fold axis (arrow indicates direction of plunge)
Schistosity (inclined, vertical)
Jointing (inclined, vertical, dip unknown)
Quarry
Adit
Mineral occurrence Pyro X
Geology by J M Dawson, 1962
Main highways
Secondary roads



TOPSAIL – FOXTRAP

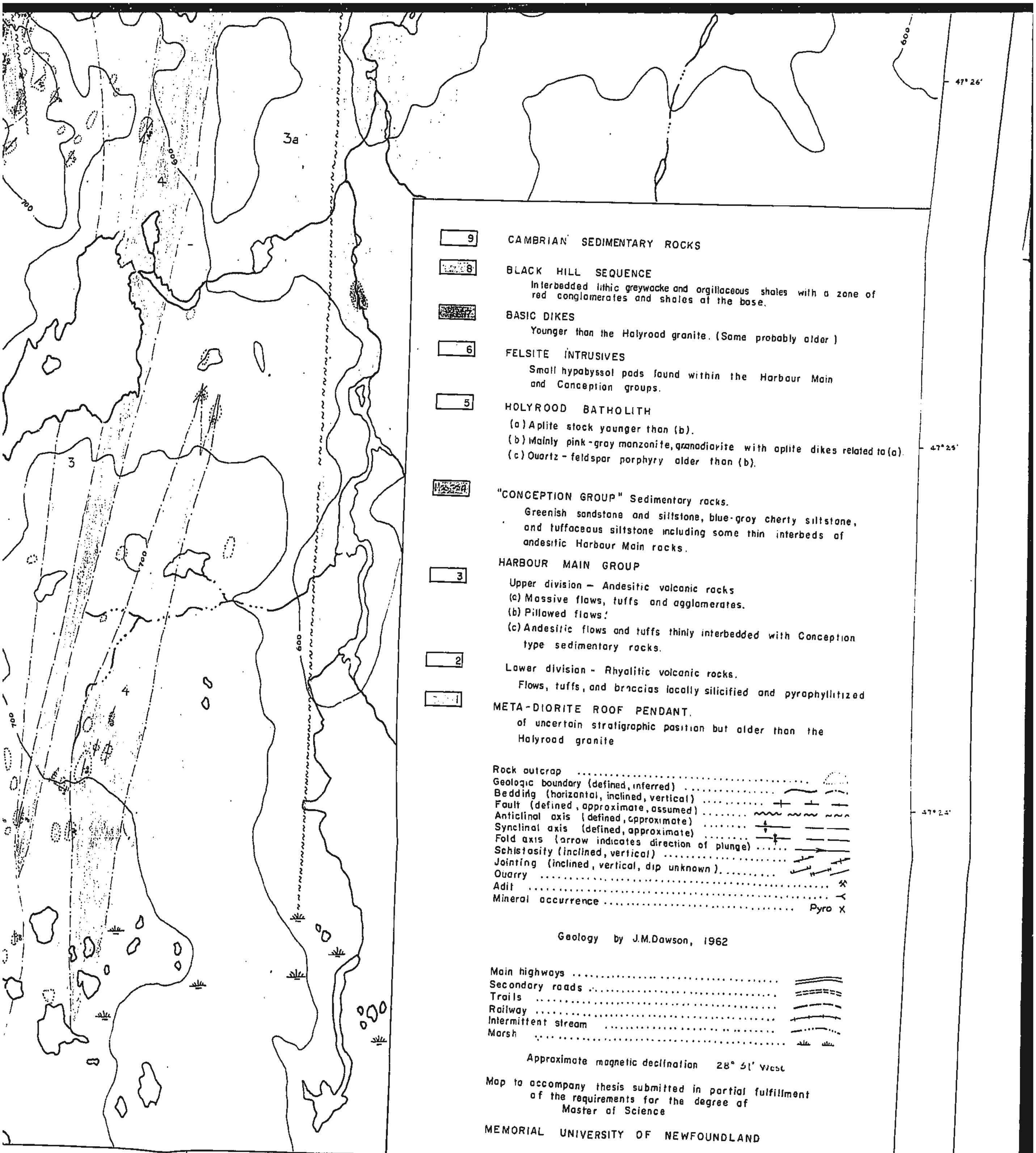
AVALON PENINSULA

NEWFOUNDLAND

Contour interval ...... 50'

Scale : One inch = 1000 feet or 1/12,000

4 of 4



FOXTRAP AREA

LON PENINSULA

NEWFOUNDLAND

ntour interval ...... 50'

: One inch = 1000 feet or $\frac{1}{12,000}$

34