PETROLOGY OF THE SIGNAL HILL AND BLACKHEAD FORMATIONS AVALON PENINSULA NEWFOUNDLAND

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PETROLOGY OF THE SIGNAL HILL
AND BLACKHEAD FORMATIONS
AVALON PENINSULA
NEWFOUNDLAND

BY

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ILLUSTRATIONS

PETROLOGY OF THE SIGNAL HILL AND BLACKHEAD FORMATIONS AVALON PENINSULA, NEWFOUNDLAND. BY C.K. SINGH, 1969.

Abstract

Detailed studies on the Precambrian Signal Hill Formation and the overlying Blackhead Formation exposed between Flatrock and Ferryland reveal minor lithological variations. Lithofeldspathic Sandstone is predominant and forms most of the lower and middle members of the Signal Hill Formation and most of the Blackhead Formation. Conglomerate forms most of the upper member of the Signal Hill Formation. It is composed mainly of pebbles of tuff and rhyolite, sedimentary rocks, granitoid rocks, quartzite, and basic volcanic rocks, in order of decreasing abundance.

The mineralogy of the Signal Hill and Blackhead Formations is similar and indicates common source rocks. Sediments were derived from Harbour Main, Conception and Holyrood - type rocks, exposed at that time somewhere to the north of the site of deposition. Ripple marks and cross-bedding displayed in the sandstone and siltstone of the lower and middle members of the Signal Hill Formations suggest deposition in an environment similar to the undathem environment of Rich (1951). Progressive upward fining of the Signal Hill conglomerate and concomitant change from planar bedding to cross bedding suggest a change in the depositing streams from conditions of predominantly rapid

flow of the upper flow regime to those of tranquil flow of the lower flow regime. The rocks of the Blackhead Formation show features, characteristic of fluvial braided river deposits. These are mainly planar and trough cross-bedding, channels and mud cracks.

CHAPTER 1

INTRODUCTION

Location and Access

The thesis area is located on the eastern part of the Avalon Peninsula of Newfoundland, bounded on the north by Flatrock and on the south by Ferryland (Figure 1-1). It lies within north latitudes 47°OI' and 47°43' and west longitudes 52°38' and 52°52'.

A network of paved and gravel roads provides for transportation within the map area. The northern half of the map area can be reached by the Torbay Road and Logy Bay Road and the southern half by the south shore road, Highway No. 5.

Secondary gravel roads provide further access to numerous "guts" or small bays. Outlying parts of the coastal area can be travelled by foot though walking is difficult in places because of dense vegetation and rough terrain. Because of steep cliffs, some parts of the coastal areas are accessible only by boat.

Physiography

The elevation of the land ranges from sea-level to 887 feet. Northerly trending hills between Torbay Point and Bay Bulls, have flat summits which gradually increase from 400 feet in the north to almost 900 feet in the south. Most of the eastern side of this prominent ridge terminates abruptly in rugged sea-cliffs. The western side consists of hummocky ground with an average elevation of 300 feet.

Evidence of glaciation is shown by widespread glacial striations, crescentic fractures, roches moutonnees, erratic boulders, glacial drift, and valley morphology. Glacial drift occurs in almost all parts of the area and ranges in thickness from a few inches or less to 20 or 30 feet. The glacial drift contains unsorted fragments of Signal Hill sandstones, St.John's shales and green siltstones of the Conception Group. The direction of ice movement, based on a combination of features enumerated above, was towards the east. Ice movement is thought to have occurred during late Pleistocene.

Previous Geological Work

The first geological study of the Avalon Peninsula was made by J.B.Jukes in 1839 and 1840. He divided the rocks of the Avalon Peninsula into two "Formations" equivalent to the Precambrian sedimentary rocks and the early Paleozoic sedimentary rocks .

In 1881 Murray and Howley compiled a geological map of the Avalon Peninsula showing the distribution of formations.

Walcott (1899) grouped all the formations lying between the basal beds of the Cambrian system and the Archaean gneiss of Newfoundland as the "Avalon Terrane", and used the names Signal Hill, Momable (St.John's slate), Conception and Torbay for these formations.

In 1919 Buddington published a paper on "Pre-Cambrian Rocks of Southeast Newfoundland". He proposed the name Signal Hill Series for the strata that correspond with Jukes' and Murray's Signal Hill Sandstone.

Rose (1952) published an account of the Cambro-Ordovician and underlying Precambrian rocks of the Torbay Map Area. He redefined the rock formations, groups and series. His work is the main source of information on the geology of the present map area.

The geology of the Eastern Part of the Avalon Peninsula, Newfoundland has been well summarized by Brueckner (1967, in press). He divided eastern part of the Avalon Peninsula into three fault blocks. The present map area lies in his "Eastern Block" (between the Topsail Fault Zone and the east coast of the Avalon Peninsula).

Present Work

The present study was carried out in order to describe in more detail the lithology, possible source and depositional environment of the Signal Hill and Blackhead Formations.

The field work for this thesis was completed during the summer of 1968. Air photos, approximate scale of 600 feet to 1 inch, were used in locating the exposures. At each locality stratigraphic sections were measured, described and sampled. A total of eleven stratigraphic sections were measured (Fig. I-2); these sections include Flatrock, Logy Bay, Quidi Vidi, Signal Hill, Cape Spear, Petty Harbour, Bay Bulls, Witless Bay, Calvert and Ferryland.

The laboratory work on the samples collected in the field consisted of two main parts: part-I includes the study of pebbles, chiefly their lithological composition, shape and roundness, and part-2 includes petrological study of the sandstones and siltstones. Besides visual estimation of percentage of mineral grains made on all the thin-sections, modal analyses of selected thin-sections were made by measuring the lengths of traverses across the mineral grain using a micrometric attachment. Also supplementary techniques for mineral identification include the use of staining method (Bailey I960, Rosenblum I956) for identification of potash feldspar in thin-section.

Rough estimations of sand size distribution were made from all thin-sections by measuring maximum and minimum sand sizes and approximate modal size. Also about 53 thin-sections from different localities were selected for micrometric analysis.

Roundness of the detrital fractions was estimated using visual estimation chart of Powers (I953).

Acknowledgements

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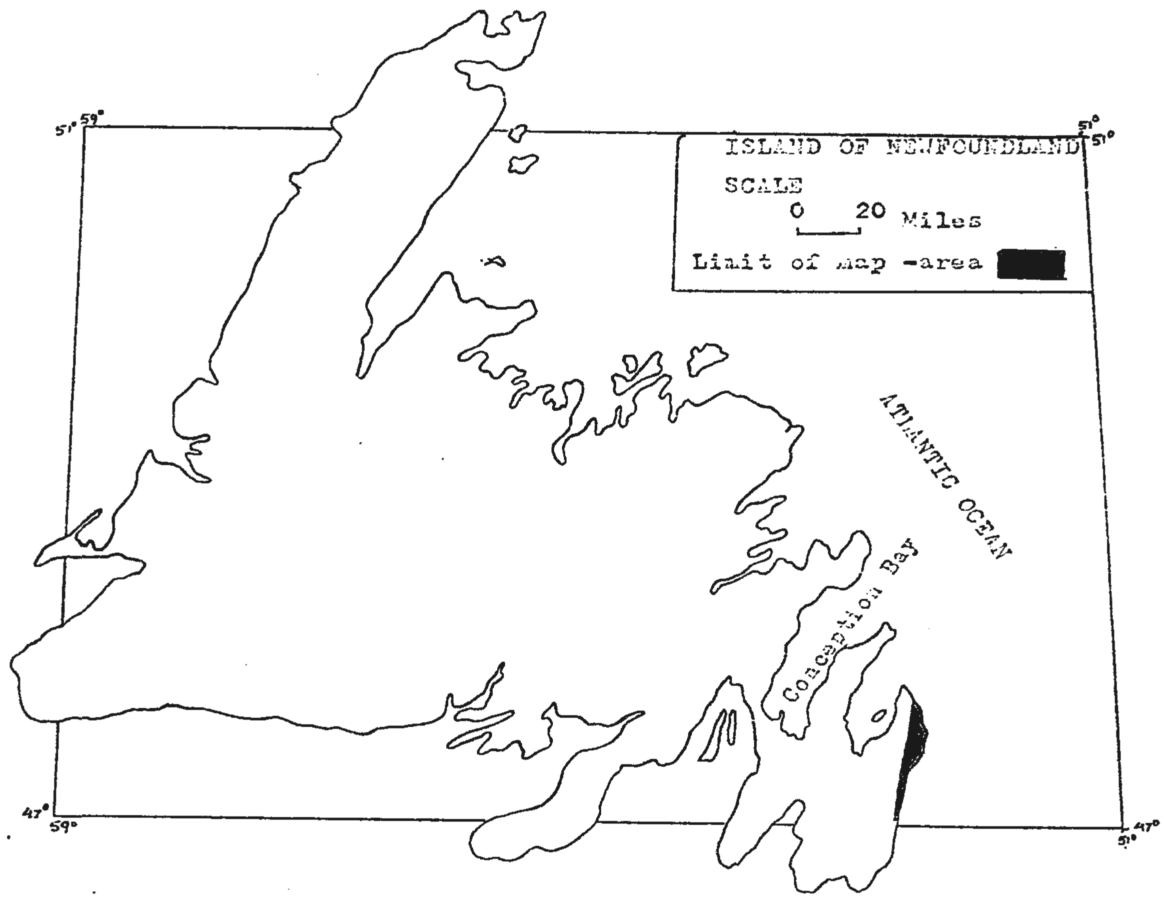


Figure 1-1. Index map showing location of map-area.

FIGURE 1-2 LOCATION MAP.

CHAPTER II

STRATIGRAPHIC FRAMEWORK

Preamble

The Precambrian rocks of the eastern part of the Avalon Peninsula can be divided into three main groups in order of decreasing age (Rose, I952): (I) Harbour Main Group of mainly volcanic rocks, (2) Conception Group of greenish siltstone, argillite and slate, and (3) Cabot Group of sandstone, conglomerate and argillite. These groups are thought to be equivalent at least, in part , to the Love Cove, Connecting Point and Musgravetown Groups respectively (McCartney I967, Rose I952, and Weeks I963). The map-area is underlain by rocks of the Cabot Group.

The stratigraphic section as described in the following pages is complete, except for the top of the Blackhead Formation. The Cabot Group can be divided into three recognizable units (Rose, I952): a lower unit composed of shale and siltstone called the St. John's Formation, a middle unit consisting of sandstone and conglomerate with minor siltstone and argillite called the Signal Hill Formation, and an upper unit composed of sandstone with subordinate siltstone and argillite called the Blackhead Formation.

The present study is concerned with the rocks belonging to the Signal Hill and Blackhead Formations of the Cabot Group (Fig. 2-I).

TABLE 2-I. TABLE OF FORMATIONS (AFTER ROSE I952)

Period and epoch	Rock Units (Thickness in feet)	Lithology
	Cabot Group	
	Blackhead Formation(5500 +)	Red and grey arkosic sandstone; minor slate, argillite and siltstone.
Late Precambrian	Signal Hill Formation ± 7500	Red conglomerate, red and greenish grey arkosic sandstone, minor argillite, slate and siltstone.
	St.John's Formation ± I000	Dark grey to black slate, argillite, and grit, with a few arkosic conglomerate lenses and a transitional zone of grey sandstone at top.

A major NNE trending synclinal axis parallels the coastline and can be traced from Blackhead to Bay Bulls. The rock units in the thesis area are on the west side of this axis and generally dip steeply to the east. Open folds with accompanying slippage along the bedding surfaces and rhombohedral joints are common structural features. Fracture cleavage is most evident in the shaly beds.

The following account of the rock units is based largely on the data obtained from the measured stratigraphic sections (Plate 2-I; Plates 2-2 to 2-5 in pocket).

Signal Hill Formation

The name "Signal Hill Sandstone" was first used by Jukes (I839-I843). Later, the strata were termed "Signal Hill Series" by Buddington and more recently "Signal Hill Formation" by Rose (I952).

The Signal Hill Formation crops out almost continuously along a belt that extends from Red Head southwards to Mobile Bay, Cape Broyle and Ferryland.

The Signal Hill Formation consists of three members: a lower, greenish grey sandstone; a middle, red sandstone and an upper, red conglomerate.

Lower Member

Occurrence

A complete succession of the lower member is present in all the investigated stratigraphic sections, except at Petty Harbour where it is largely covered by glacial drift.

Lithology

Most beds are between four inches to four feet or more in thickness and consist of fine- to very fine-grained greenish grey sandstone with thin beds of greenish grey siltstone and argillite. Intercalations of red beds are locally found in the areas south of Petty Harbour.

An eight feet thick bed of green colored volcanic tuff occurs at Ferryland. Stratigraphically, it lies fifty feet above the base of the Signal Hill Formation.

Stratigraphic thickness

The lower member attains a maximum thickness of 4440 feet at Witless Bay, and thins north and southwards along the strike. It is 420 feet at Flatrock in the north and 1000 feet at Ferryland in the south.

Contact relationships

The contact between the lower member and underlying St.John's Formation is gradational. The boundary has been drawn where more than 50 percent sandstone beds are found interbedded with the shales.

Middle Member

Occurrence

A complete succession of this member crops out almost continuously along a belt that extends from Red Head southwards to Petty Harbour. The succession is incomplete in the localities south of Petty Harbour.

Lithology

This member is comprised of parallel beds up to five feet thick of red sandstone, siltstone and minor argillite. The sandstone is generally medium- to fine-grained with a tendency of coarsening upwards. Sandstone beds are separated by hematitic clay partings and by red siltstone beds ranging from two inches to one foot in thickness.

Towards the top of this member, coarse to very coarse-grained sandstone beds of one inch to six inches thick begin to appear. The red sandstone as a whole becomes coarser grained.

Tabular fragments of red argillite up to six inches long are scattered throughout this member, but they are more abundant in the upper part. In places these argillite fragments are concentrated in pods.

Minor greenish grey beds are found intercalated with the red sandstone in the localities south of Petty Harbour. A four feet thick bed of green colored volcanic tuff is found in the red sandstone member near Sugarloaf Pond. Stratigraphically it lies I075 feet above the boundary between St.John's and Signal Hill Formation.

Stratigraphic thickness

The middle member attains a maximum thickness of 3000 feet at Petty Harbour, and thins north and southwards along the strike. It is 340 feet thick at Flatrock and I350 feet thick at Ferryland.

Contact relationships

The contact between the lower and middle members has been defined by a sharp change in the color from greenish grey to red. The contact is sharp in the localities north of Petty Harbour except where the leaching of red color has obscured the contact; it is transitional in the localities south of Petty Harbour.

Upper Member

Occurrence

Rocks of the upper member are exposed almost continuously along the shore from Red Head to Petty Harbour. A complete succession of this member is present at Logy Bay and Petty Harbour. South of Petty Harbour this member, if present, is concealed beneath the water.

Lithology

Conglomerate with thin sandstone interbeds make up the upper member of the Signal Hill Formation. The middle member passes stratigraphically upwards into the upper member with the appearance of thin beds and lenses of fine grained pebbly beds (average pebble size 5mm.). Moving stratigraphically upward there is a gradual but irregular increase in grain size to pebble and cobble sized (Wentworth's Classification) conglomerates in the top portion of the member.

The pebbles and cobbles consist of rhyolite/tuff, granite, granophyre, basic volcanic rocks, sandstones, chert and quartzite. Tabular fragments of red argillite are also common.

The red conglomerate, in the Flatrock, grades upwards into a greenish grey conglomerate. Moving stratigraphically upwards through the greenish grey conglomerate, the grain size of the constituents gradually decreases with a corresponding increase in the number of coarse- to medium - grained greenish grey sandstone beds. Constituents of this conglomerate are granite, quartzite and fragments of volcanic and sedimentary rocks. Greenish grey conglomerate passes upward into a red breccia conglomerate. The transition zone consists of interbedded, red sandstone, greenish grey sandstone and red argillite. The breccia conglomerate consists of fragments of red siltstone, argillite, chert and volcanic rock fragments up to 5 inches in length.

Stratigraphic thickness

At Petty Harbour the thickness of the upper member is 2480 feet. At Flatrock the thickness of upper member is I727 feet which includes about I227 feet of conglomerate and a minimum thickness of 500 feet for breccia conglomerate.

Contact relationships

The contact between upper and middle members is gradational. The boundary has been drawn where conglomerate comprises more than 50 percent of the thickness in the interbeds of conglomerate and sandstone. The contact between the upper member of the Signal Hill Formation and the overlying Blackhead Formation is gradational; the boundary as seen in Logy Bay, Cape Spear and

Maddox Cove has been drawn where more than 50 percent of the sandstone beds are found interbedded with the conglomerate of the Signal Hill Formation.

Blackhead Formation

Name

The name "Blackhead" was first used by Hayes (I93I) for the dark grey sandstone and slates which conformably overlie the conglomerate of the Signal Hill Formation at the type locality Blackhead Village. Later they were termed "Blackhead Formation" by Rose (I952).

Occurrence

The rocks of the Blackhead Formation can best be seen in the Blackhead syncline exposed between St.John's Bay and Motion Bay. They also crop out to the north between Logy Bay and Small Point.

Lithology

The Blackhead Formation has been divided by Rose (I952) into a lower red sandstone, a middle greyish sandstone, and an upper red sandstone. These rock units can be differentiated by color variations but do not show any compositional or textural variations. Intercalations of red beds are found in the middle greyish member and conversely intercalations of grey beds are found in the lower and upper members. These intercalations of red or grey beds are more common in the Blackhead - Cape Spear area; all the members are exposed except the top of the upper member. In the Logy Bay- Small Point area only the lower member is exposed.

The sandstones of the Blackhead Formation are fine-to coarse-grained with individual beds ranging in thickness from six inches to five feet or more. A few siltstone and argillite beds of two inches to one foot in thickness are found interbedded within the sandstones.

Stratigraphic thickness

The total exposed thickness of the Blackhead Formation in the Cape Spear - Blackhead area is about 5200 feet. At Cape Spear the lower member is about 1800 feet thick, it becomes about 2570 feet thick at Logy Bay - Sugarloaf head area. The thickness of middle and upper members are about 2600 and 800 feet respectively.

Contact relationships

The contact between the Blackhead Formation and the underlying Signal Hill Formation is gradational. The boundary has been drawn where sandstone beds dominate (over 50 percent) over conglomerate beds of the Signal Hill Formation. Based on this criterion, the boundary between Logy Bay and Small Point areas has been placed west of Rose's boundary (Fig. 2-1). The boundary between the lower and middle members is taken where more than 50 percent grey beds make their appearance. The boundary between middle and upper member is drawn where more than 50 percent red reds are found interbedded with the underlying grey sandstone member.

CHAPTER III

PETROLOGY OF THE SIGNAL HILL FORMATION

Problems in Quantitative Analysis of Sandstones

Quantitative data on the grain size, mineral constituents and rock fragments present in the Signal Hill sandstones provide evidence enabling interpretation of the source and depositional environment. During the course of the thin-section study several sources of error became apparent. Alteration of the less stable constituents occur in varying degree in almost all the thin-sections. Fragments of volcanic rocks, argillite, and siltstone show alteration and disintegration into finer grained products. Volcanic rock fragments, mostly very fine grained are difficult to distinguish from siliceous rock fragments and boundaries between rock fragments and interstitial material are vague.

Terminology

For the purpose of present description, sandstones can be divided into grains and interstitial material. The term "grain" is used here for the detrital components above 0.03 millimeters in diameter and the term "interstitial material" is used for all the components which fill the interstices between the grains.

Mineralogical Analysis of Sandstones

With the exception of minor quantitative variations, sandstones of the Signal Hill Formation do not show any significant compositional change either vertically or laterally in the stratigraphic succession. Details of the modal analyses are presented in Table 3-I.

Table 3-1 Thin-Section Mineral
% Composition of the Sandstones of the Signal Hill Formation

	GRAINS														INTERSTITIAL MATERIAL									
		Feldspar			Rock Fragments					Sedim.														
Sample Number	Quartz	K. Feldspar	Plagioclase	Total Feldspar	Tuff & Rhyolite	Granite & Granophyre	Diorite	Basic Volcanic	Metamorphic	Siliceous	Others	Total	Total Rock Frag.	"A"	Hematite	Pyroxene	Chlorite	Biotite & Muscovite	Epidote	Calcite	Magnetite	Zircon	Apatite	Sphene
FS1	37	18	10	28	3	2	–	.	–	15	2	17	22	7	2	–	1	.	2	–	1	.	–	–
FS2	38	12	11	23	3	5	–	–	–	8	4	12	20	16	–	.	2	–	1	–	–	–	–	–
FS5	38	15	8	23	3	2	–	.	–	8	8	16	21	16	.		2	.	.	–	–	–	–	–
FS10	30	10	6	16	6	12	1	2	1	10	8	18	40	12	–	–	2	–	–	–	–	–	–	–
FS18	25	11	6.5	17.5	9	2.5	1	–	.	10	9	19	31.5	20	6	.	–	–	–	–	–	–	–	–
FS21	25	18	8	26	6	8	–	–	.	13	8	21	35	14	.	–	.	–	–	–	–	–	–	–
S60	30	7	4	11	10	4	–	–	2	15	7	22	38	10	7	.	.	.	2	–	1	–	–	–
S62	30	7	8	15	6	10	–	–	1	14	3	17	34	9	4	2	.	1	5	–	–	–	–	–
S64	27	7	2	9	13	2	1	–	.	16	6	22	38	12	6	3	.	1	4	–	–	–	–	–
S65	24	8	3	11	18	5	–	–	–	15	2	17	40	14	5	3	.	1	2	–	–	.	–	–
Z4	38	9	20	29	1	–	–	–	.	10	3	13	14	6.5	10	0.5	2	.	–	–	–	–	–	–
Z3	36	9	17	26	1	.	.			14	2	16	17	11.5	8	0	1	.	–	–	.	–	–	–
Z2	40	12	18	30	–	–	–	–	–	3	3	6	6	8	15	.	1	1	.	–	–	.	–	–
Z1	30	15	25	40	2	–	–	–	–	11	2	13	15	5	10	.	.	.	–	–	.	–	–	–
Z	40	7	23	30	–	.	–	–	–	8	.	8	8	9	10	1	.	.	1	–	1	–	–	–
SW1	35	12	25	37	–	2	–	–	–	10	1	11	13	8	5	.	.	.	2	.	.	–	–	–
K	32	10	20	30	–	–	–	–	–	18		18	18	17	–	1	.	.	2	–	.	–	–	–
G	30	15	20	35	1	–	–	–	–	14	1	15	16	13	.	1	.	.	5	–	.	–	.	–
F	35	10	25	35	–	–	–	–	–	15	–	15	15	14	.	.	.	–	1	–	.	–	–	–
E	30	8	35	43	–	–	–	–	–	15	.	15	15	11	1	.	.	.	.	–	.	–	–	–
S59	25	8	8	16	2	2	–	1	1	20	10	30	36	6	12	2	.	.	3	–	–	–	–	–
S57	28	10	9	19	6	.	.	3	.	18	8	26	35	5	10	1	.	.	2	–	–	.	–	–
S53a	28	7	3	10	6	2	.	1	1	19	9	28	38	11	9	1	1	.	2			.	–	–
S52	30	3	5	8	8	1	.	1	2	22	8	30	42	7	8	1	.	.	3		1	.	–	–
S48	30	6	9	15	5	1	–	–	1	17	5	22	29	19	2	2	.	.	3		.	–	–	–
S41	30	8	18	26	2	.	–	–	–	14	3	17	19	10	8	–	2	2	–		3	–	–	–
S39	26	11	14	25	3	–	–	.	–	16	2	16	19	19	7	.	.	.	2		2	.	–	.
S38	34	8	18	26	–	–	–	–	–	15	2	17	17	12	8	.	1	.	.	–	2	–	–	–
S35	28	9	24	33	2	–	–	1	1	15	1	16	20	10	7	.	1	.	1	–	.	–	–	–
S34	30	10	25	35	–	–	–	–	–	10	3	13	13	15	5	.	1	.	1	–	–	.	–	–
PS7	30	7	13	20	8	1	–	–	–	18	2	20	29	13	5	1	–	.	2	–	.	.	–	–
PS8	28	9	20	29	–	–	–	–	–	12	–	12	12	24	5	1	1	.	.	–	.	–	–	–
PS9	30	8	20	28	–	.	–	–	–	15	–	15	15	15	1	3	1	.	7		.			
PS11	15	7	3	10	–	–	–	–	–	13	–	13	13	42	20	–	–	–	–	–	–	–	–	–
BS4	35	7	18	25	1	–	–	1		10	4	14	16	16	5	.	3	.	.	–	.	–	–	–
BS6	16	–	–	–	–	–	–	–	–	–	–	–	–	55	20	–	2	7	–	–	–	–	–	–
WS1	30	5	25	30	–	–	–	–		12	2	14	14	10	15	.	.	.	.	–	1	–	–	–
WS3	28	5	30	35	3	–	–	–	.	14	2	16	19	6	10	.	2	.	.		.	–	–	–
MS1	27	7	30	37	.	.	–	–	.	8	2	10	10	14	.	3	3	–	5	–	1	–	–	–
MS3	28	5	30	35	–	–	–	–	–	9	–	9	9	18	.	3	1	.	6	–	.	–	–	–
MS44	18	5	15	20	–	–	–	–	–	8	–	8	8	44	.	6	2	.	2		1	–	–	–
MS8	30	5	26	31				1	.	14	1	15	16	11	.	6	1	.	4	–	1	–	–	–
MS14	30	7	25	32	–	–	–	–	–	8	–	8	8	23	.	.	5		2	–	.	–	–	–
LS1	27	7	30	37	–	.		–	–	11	2	15	13	14	.	3	1	.	5	–	.	.	–	–
LS3	30	7	31	38	–	–	–	–	–	8	–	8	8	16	.	2	1	.	5		–	–	–	–
X1	30	12	23	35						5	3	8	8	23	–		3	1		–	–	–	–	–
X	38	6	17	23						10	1	11	11	28	–		.	.	.		–	.	–	–
FS18	25	12	20	32	1	1	.	.	1	10	7	17	20	15			3	.	.	5	–	.	–	–
FS17	30	8	12	20						7	–	7	7	43	–		–	–			–	–	–	–
B	41	10	24	34						5		5	5	15	2	1	.	2			.	.	–	–
S19	30	10	25	35	–	–	–	–	1	8	–	8	9	15	2	3	2	2	2		.	.	–	–
S18	32	15	11	26	–	–	–	–		8	2	10	10	2	–	2	3	5	2		.	–	–	–
S14	35	10	15	25	–	–	–	–	–	9	2	11	11	19	–	1	3	1	5	–	–	–	–	–
S13	35	8	15	23						3	–	3	3	32			3	3	1	–	–	.	–	–
K10	25	10	15	25	–	–	–	–	–	1	–	1	1	43		–	3	2	1	–	–	–	–	–
S10	38	10	25	35	–	–	–	–	–	8	–	8	8	17		1	1	–	.	–	.	.	–	–
K5	35	15	20	35					1	5	–	5	6	21		1	1	.	1			.		.
PS13	30	6	25	31	–	–	–	–	–	11	–	11	11	20		3	2	.	2		.	.	–	–
PS14	35	8	24	32	–	1	–	.	1	8	1	9	11	15		3	2	.	2	–		–	–	–
BSF	35	11	10	21	2	.	–	–		12	4	16	18	21	3		2	.	.		.	.	.	–
BS23	35	7	25	32						15	1	16	16	16	–	.	1	.	.		.	.	–	–
BS22	38	7	22	29	–	–	–	–	–	10	.	10	10	21	–	.	1	.	1		–	–	–	–
BS40	36	6	17	23	–	2	–	–	.	6	2	8	10	22	–	2	2	.	5		–	–	.	.
BS42	35	9	21	30	–	–	–	–	–	12	1	13	13	15	–	1	2	.	3		.	1	.	.
BS45	35	5	18	23						7	–	7	7	18		.	2	.	.	14			.	.
AS10	40	7	20	27						9	–	9	9	18	1	1	2	.	3	–	–	–	–	–
BS38	38	8	20	28						5	–	5	5	17	6	.	3	.	2		1	–	–	–
WS4	28	5	15	20						7	–	7	7	39	.	.	2	.	1		3	–	–	–
WS7	34	3	17	20						7	5	12	12	21		1	2		9	1	.	–	–	–
WS8	32	7	24	31						-10	2	12	12	17	–	.	5	.	1	2	.	–	–	–
WS11	35	5	25	30						9	–	9	9	15	–	.	3	2	6	–	.	.	–	–
WS14	37	7	22	29						7	3	10	10	23		.	1	.	.	–	.	.	–	–
WS18	38	8	22	30						7	4	11	11	20		.	1	.	.		.	.	–	–
MS17	7	3	5	8										85	–	.	.	.	.	–	–	–	–	–
MS19	28	3	29	32						11	–	11	11	18	–		6	.	5			.	–	–
MS33	15	5	7	12						3	–	3	3	67			2	1	.			.	–	–
MS34	38	5	23	28						9	–	9	9	18		.	5	.	2			.	–	–
MS36	20			6						3	–	3	3	69				2	–					
LS14	45	8	20	28						5	–	5	5	14		5		3	.					

For sample numbers – see Plates 2-2 to 2-5
. – refers to the amount of the component in traces.

The average of the rock constituents can be summarized as follows:

Table 3-2

	Lower Member	Middle Member	Upper Member
	Percent	Percent	Percent
Quartz	34.3	30.40	30.40
Potash Feldspar	8	8.2	11.3
Plagioclase Feldspar	20	20.6	6.6
Rock Fragments	9.4	18.1	31.9
Interstitial Material	28.15	22.7	19.6

A typical sandstone of the lower member is shown in Figure 3-1 and of the middle member is shown in Fig. 3.2.

Quartz Grains

Criteria used in classification

Quartz has been subdivided by Folk (1959, p. 72) into six different extinction types and four inclusion types based on the degree of undulose extinction and the type of inclusions. Extinction is considered straight if the grain extinguishes all over at once and slightly undulose if extinction shadow sweeps smoothly and without breaks across the grains on very slight rotation of the microscope stage. Extinction is considered strongly undulose if a large rotation of microscope stage is required before the extinction shadow sweeps from one end of the grain to the other.

In this study extinction is used in combination with shape of grains (criteria used by Krynine 1950, p. 36-38) to define qualitatively five varieties of quartz grains present in the sandstones.

Common quartz

The most abundant quartz type is the unit grain (Fig. 3-3) with straight to slightly undulose extinction, irregular outline and which contain inclusions sometimes arranged in parallel lines.

Infrequent varieties

Four other types of quartz grains can be recognized as follows: (I) unit grains with strong undulose extinction and few inclusions (Fig. 3-4), (2) composite grains with slightly undulose extinction, (3) "second cycle" quartz grains that are more rounded than other quartz grains and are subspherical, and (4) quartz grains of bipyramidal shape with straight sides and rounded corners and exhibiting straight extinction. The latter are found in traces mainly in sandstones of the middle and upper members (Fig. 3-5).

Feldspar Grains

Content

The feldspar content of sandstones forms about 28 percent of the total rock in the lower and middle members, whereas it decreases to I8 percent in the sandstones of the upper member. With the decrease of total feldspar content in the sandstones of the upper member, there is a corresponding increase of potash feldspar.

Plagiclase

Two types of plagioclase feldspar were differentiated during the course of thin-section study; one, characterized by polysynthetic twinning and the other in which twinning is either absent or obscured by alteration products (Fig. 3-6 and 3-7). The plagioclase appear to be chiefly sodic with an anorthite content up to An 3I.

The plagioclase grains are generally partially altered to sericite and chlorite. Epidote is also common but less abundant as an alteration product and calcite is rare. The degree of alteration varies considerably within a single thin-section, from plagioclase grains having only a few small patches of sericite to grains completely sericitized (Fig. 3-8).

Potash feldspar

Potash feldspar grains were identified in thin-section by staining with sodium cobaltinitrite solution. They are mainly clouded by the alteration products consisting of sericite and chlorite etc. The degree of alteration varies from comparatively fresh to highly altered grains.

Rock Fragments

Categories

All members of the Signal Hill Formation contain rock fragments. They range from 9 percent in the lower member to 3I.9 percent in the upper member. Sedimentary, volcanic, igneous intrusive and metamorphic rocks are all represented.

Sedimentary fragments

The sedimentary rock fragments are most abundant and include sandstone, siltstone, argillite (Fig. 3-I0),and siliceous rock fragments (Fig. 3-9).

Siliceous rock fragments consist of an aggregate of minute low birefringent particles to microgranular quartz. In some cases they contain minute flakes of sericite. These rock fragments could either be chert, or silicified siltstone or silicified argillite, although it is difficult to distinguish them under micrscope.

It is also possible that some grains of siliceous rock fragments are volcanic tuff. Lack of original tuffaceous characters such as the presence of shards, glass and feldspar phenocrysts did not permit an operational definition as volcanic tuff.

Volcanic fragments

Fragments presumed to be basic volcanic rocks are composed of plagioclase laths in a dark unresolvable groundmass. Their specific recognition is difficult because of the alteration of the plagioclase and the impregnation of the groundmass with iron oxide and chlorite. These rock particles are found in sandstones of the middle and upper members.

Fragments of volcanic tuff (Fig. 3-II) and rhyolite are mostly very fine-grained varieties which are difficult to distinguish from siliceous rock fragments unless coarse feldspar crystals or shards are present.

Igneous intrusive fragments

Igneous rock fragments are more common in sandstones of the middle and upper members and include granite and granophyre with minor diorite. All fragments which show a graphic intergrowth of quartz and potash feldspar are considered to have been derived from a granitic suite.

Metamorphic fragments

Metamorphic rock fragments (Fig. 3-9)consist of elongated, interlocking crystals of quartz associated with a few subparallel flakes of chlorite or muscovite.

Interstitial Material

The interstitial material is composed of an almost unresolvable aggregate (Table 3-1 "A") of quartzo feldspathic minerals, hematite, chlorite, epidote and sericite, through which are scattered particles of quartz and feldspar averaging less than 0.03 mm in diameter. This interstitial material varies from 21.7 percent of the total rock in lower member to 13 percent in the upper member.

Some of the recognisable constituents of the interstitial material can be described as follows:

Hematite

This mineral is commonly found in sandstones of the middle and upper members. The distribution of the hematite, even within a hand sample, varies from uniform to patchy, to concentrations in layers parallel to bedding and also as rims around grains.

Chlorite

Pale greenish non pleochroic to slightly pleochroic chlorite occurs chiefly as patches associated with grains of feldspar and rock fragments.

Epidote

This mineral occurs in irregular aggregates and patches, suggesting in some cases an incomplete replacement of feldspars.

Biotite

In color varies from dark reddish brown to green. Some flakes of biotite show various kinds of alteration, slight loss of pleochroism, partial decolorization and alteration to chlorite.

Pyroxenes

In the Signal Hill sandstones the most common pyroxene is enstatite, found as colorless and non pleochroic irregular grains. Colored and pleochroic pyroxenes are rare.

Magnetite and Zircon

Grains of magnetite and zircon are present in almost all the thin-sections studied. Grains of magnetite in the red sandstones of the Signal Hill Formation show sign of alteration into hematite.

Muscovite, apatite and sphene are rare.

Textural Analysis of Sandstones

Grain Size

Method used in determining size parameters

Lithification precluded disaggregation of the sandstones by acids and mechanical crushing; thin-section analysis was therefore undertaken. With the aid of a micrometer eye piece the apparent long diameter of all resolvable grains were measured. Thin-section data were then plotted on graph paper (Figs. 3-12 to 17), using Friedman's (1958) technique to obtain sieve size distribution.

Size parameters were calculated by the methods proposed by Folk and Ward (1957), and the results are shown in Table 3-3.

Each method of grain size analysis has its advantages and limitations. The advantage of the thin-section method is that it can be used for the Signal Hill Sandstones which can not be analysed by the sieving technique. A disadvantage is that the grain size distribution of the pebbly sandstone found in the upper member of the Signal Hill Formation can not be measured without bias because the area is substantially less than the required 100 times the area of the largest particle. Also the size parameters were not obtained for the detrital particles below the size of .04 millimeters, the limit of resolution under low-power.

Graphic Mean

The average of the mean (graphic mean) grain size of the sandstones in the lower member of the Signal Hill Formation is 3.11 phi (very fine sand), although individual samples studied ranged from 2.92 phi (fine sand) to 3.43 phi (very fine sand). This may be contrasted with the overlying sandstones of the middle member, where average mean grain size is 2.50 phi (fine sand) with a range of 1.83 phi (medium sand) to 3.25 phi (fine sand).

Maximum and Minimum Sizes

The maximum sizes in the sandstones range up to about -0.25 phi and 1 phi. The determination of minimum size is not too meaningful, since the lower limit of detrital particle size actually extends down into clay sizes. The grains of feldspar tend to fall in the grain size fraction higher than that of the median diameter for the rock as a whole.

Inclusive Graphic Standard Deviation

Sandstones of the lower and middle members are identical in sorting (inclusive graphic standard deviation). Generally the sandstones are well sorted if the interstitial material is ignored. The mean inclusive graphic standard deviation value for all the sandstones of the Signal Hill Formation is 0.44 phi.

Skewness

The inclusive graphic skewness value for the sandstones of the lower member ranges from-0.25 to +0.25 with a mean of +0.12. The inclusive graphic skewness value for the sandstones of the middle member ranges from -0.09 to +.43; and mean inclusive graphic skewness value for all the samples is +.06.

Kurtosis

The graphic kurtosis value for the sandstones of the lower member ranges from 0.69 to 1.60; the mean graphic kurtosis value for all samples is 1.02. The graphic kurtosis value range is low for the sandstones of the lower member, varying from 0.74 to 1.35 with an average of 1.10.

Trends

The average of mean size, graphic standard deviation and inclusive graphic skewness by localities, as shown in Figure 3-18, do not show any significant linear trend. However, among the sandstones of the lower member, average larger mean sizes are found in Petty Harbour and Ferryland areas; graphic standard deviation is almost uniform throughout the localities. Nearly normal skewness and kurtosis values are found in Witless Bay area. In the sandstones of the middle member the average mean size is larger in the Quidi Vidi area, sorting is better in the Ferryland area and nearly normal skewness is found in Quidi Vidi, Petty Harbour and Bay Bulls areas, where the average skewness value ranges from -0.04 to +0.06; and higher kurtosis values are found in Quidi Vidi and Witless Bay areas. Within each locality there is a general tendency of coarsening upward of the sandstones from the lower to the upper member.

A scatter plot of the skewness versus kurtosis (Fig. -3-20) shows that fifteen samples are normal with regard to skewness and kurtosis. Plot of the mean size versus skewness (Fig-3-19) shows no significant trend.

Table 3-3 - Grain Size Parameter of the Sandstones of the Signal Hill Formation

Sample Number	Median diam. in Phi Units	Graphic Mean diam. in Phi units	Inclusive Graphic Standard deviation in Phi units	Incl. Graphic Skewness
Z4	3.00	2.99	.46	-.09
Z	3.50	3.51	.42	.09
Fs17	4.10	4.01	0.51	-.25
X	2.80	2.83	.40	.19
X1	3.00	3.03	.53	.11
S48	1.50	1.53	.68	.04
S53	1.60	1.63	.44	.11
S65	1.92	1.92	.69	.04
S59	2.29	2.26	.40	.06
K5	3.65	3.59	.40	-.19
S14	2.90	2.86	.34	-.09
S18	4.10	4.05	.36	-.22
S19	3.32	3.36	.53	.13
S10	3.20	3.25	.44	.15
Ps9	2.25	2.24	.43	.04
Ps8	3.08	3.07	.45	.02
Ps7	1.50	1.53	.52	.08
Ps14	2.45	2.51	.39	.25
Ps13	3.40	3.41	.45	.04
B.s4	2.08	2.05	.42	-.04
B.23	2.06	2.06	.41	-.10
B.22	2.32	2.38	.48	.19
Bs.40	2.89	2.99	.50	.22
Bs.42	3.65	3.62	.48	-.11
Bs.45	3.21	3.27	.37	.12
As.10	3.75	3.72	.35	-.12
W.s.1	3.35	3.35	.45	-.02
W.s.3	2.42	2.42	.38	+.08
W.s.4	3.17	3.16	.47	.00
W.s.7	3.10	3.08	.57	.01
W.8	2.99	2.49	.34	.07
W.11	3.79	3.78	.34	-.03
W.18	2.78	2.81	.64	-.03
M.s1	2.55	2.50	.30	-.05
M.3	2.55	2.55	.33	.09
M.8	2.80	2.92	.39	.43
M.19	3.30	3.26	.44	-.03
M.s19	2.80	2.85	.41	.21
M.s34	2.70	2.76	.44	.19
M.s36	3.35	3.34	.44	-.04

Roundness

Method used in determining grain roundness

The study of roundness is not very reliable because of the obscured original detrital boundaries of some of the quartz grains, in some cases, by secondary enlargement and corrosion of the grains by interstitial material. Where the original grain boundaries could be distinguished from these enlargements by dusty inclusions, the grain roundness could be estimated by visual roundness chart of Power (1953).

Qualitative observations

The qualitative observation suggests no significant variation in roundness value among the sandstones of the lower, middle and upper members. Also there is no significant lateral variation from one to the other locality. However, the majority of quartz grains fall within the Power's roundness values of 1 and 3, that is from angular to sub-angular. Some of the quartz grains are subrounded to rounded. The grains of feldspar show slightly higher roundness than those of quartz grains.

Classification of Sandstones

It is difficult to find a genetic classification suitable for the sandstones of the Signal Hill Formation. To overcome this difficulty a non-genetic classification of arenites proposed by Crooks (1960, p 425) is used to describe the sandstones of the Signal Hill Formation. This involves a Q F R diagram with quartz, feldspar and rock fragments plus other labiles as parameters.

Compositional fields occupied by different rock categories are shown in Figure 3-21, and can be tabulated as follows:-

Table 3-4 Sandstone types in the Signal Hill Formation

Rock Units	Sandstone in percentage			
	Feldspathic	Lithofeldspathic	Feldspatholithic	Lithic
Upper Member	0	50	30	20
Middle Member	7.4	66.6	18.5	7.4
Lower Member	35.5	58	6.4	0

Diagenesis of Sandstones

Authigenic growth of quartz

The presence of detrital quartz particles enlarged by secondary silica growth (Fig. 3-22) is a common phenomenon in the sandstones of the Signal Hill Formation. The enlargement is usually in optical continuity with the original grain; coatings of hematite and chlorite have retarded the authigenic growth of quartz. Authigenic growth and pressure solution contact (Figs. 3-2 , 3-22) are more common where the coating is thin or absent. Authigenic growth could be seen in the grains where the coating is thick enough to retard the pressure solution (Fig. 3-2) but discontinuous to allow secondary growth of quartz.

Principal authigenic minerals

The principal authigenic minerals are quartz, chlorite (Fig. 3-7), epidote, sericite (Fig. 3-24), calcite (Fig.3-1) and hematite. Sericite, chlorite, epidote and calcite are commonly seen replacing feldspar grains and rock fragments. Some flakes of biotite show various kinds of alteration, slight loss of pleochroism, partial decomposition and alteration to chlorite.

Textural Features

Textural features such as grains with normal and pressure solution contacts and deformed biotite (Fig. 3-23) are mostly produced by compaction. The following textural features suggest that diagenetic processes have been active in the sandstones of the Signal Hill Formation: Overgrowth of detrital quartz; interpenetration along borders of adjacent grains of interstitial material (Fig. 3-11) such as sericite or chlorite; corrosion of quartz grains; development of ferric oxide, partly forming as coating of detrital grains and partly infilling the pore spaces.

Tension cracks filled with feldspars (Fig. 3-24) suggest that diagenetic processes were also operative especially during deformation of the rocks.

Analysis of Siltstones and Argillites

Terminology

In composition siltstones and argillites closely resemble the sandstones with which they are interbedded but appear to differ from each other only in the size and proportion of same components. The author, therefore prefers the usage of the term siltstone or argillite depending on particle size.

Contents of Matrix

Both the siltstone (Fig. 3-25) and argillite have a matrix consisting of an unresolvable mixture of microgranular quartz, feldspar, chlorite and sericite; hematite is present as streaks in the siltstone and argillite of the lower member, and as dominant matrix forming component in the siltstone and argillite of the middle member. Scattered through the matrix are angular to subangular quartz and feldspars ranging in size from fine silt to fine sand class (Wentworth), grains of magnetite, and flakes of biotite, muscovite, sericite and chlorite. Some of these flaky minerals show a tendency toward uniform orientation parallel to bedding. Also a few of them are bent around the quartz grains. Epidote occurs as accessory and zircon as rare mineral.

Laminations

The main cause of the laminated structure of many argillites and siltstones is the alignment of the grains of quartz or magnetite in streaks and layers; and also streaks and layers of hematite.

Analyses of Tuff

Content

In thin-section green colored tuff is composed of a mosaic of low birefringent particles (Fig. 3-27), producing a so-called pepper and salt appearance which may become locally almost micro- to cryptocrystalline. The groundmass contains varying amounts of sericite and chlorite; sericite locally occurs in patches. A few shards which have retained their triaxial and or sickle shaped appearance are also seen in the groundmass.

Silt size grains of quartz and feldspar are scattered through the groundmass, these make up about 3 percent of the total rock. Calcite is found as patches amounting to about 5 percent of the total rock. Accessory minerals include epidote, amphiboles, zircon and rarely garnet. Cracks filled with microcrystalline quartz occur traversing the rock.

The x-ray diffraction analysis of the rock indicates the presence of quartz, feldspar, sericite and carbonate.

Analyses of Conglomerate

Terminology

An attempt was made to analyse the lithological composition, size, shape and roundness of pebbles in the conglomerate. The use of the term "pebble" denotes the coarse rounded to subrounded fragments of granule and larger size (Wentworth) contained in the conglomerate.

Composition of Matrix

The matrix of the conglomerate is moderately sorted sandstone consisting of subrounded to rounded rock fragments and angular to subangular quartz and feldspar. Rock fragments are mainly of the same types as the pebbles. Cement is chiefly hematite with minor chlorite.

Composition of Pebbles

The conglomerate in polymictic. It is composed mainly of subrounded to rounded pebbles of tuff and rhyolite, minor basic volcanics, granite and granophyre, diorite, metaquartzite, chert and other sedimentary rocks (Table 3-5 and Figures 3-28 to 3-33), embedded in a sandy matrix.

With the exception of minor quantitative variation in the pebble types the conglomerate shows no significant compositional change from locality to locality.

Table 3-5 - Composition of Pebbles

Pebbly types (in percent)	Localities Flatrock	Logy Bay	Quidi Vidi	Signal Hill	Cape Spear	Petty Harbr.
Tuff and Rhyolite	80	82	85	80	80	81
Granite and Granophyre	1	5	9	10	7	3
Diorite			0.5		2.5	
Basic volcanic rocks	Traces	0.5	0.5			
Quartzite	6	3.5	2	4	2	2
Chert	7	4	Traces	0.5	2.5	5
Sandstone	5.5	4	2	1	3	5
Siltstone			.5	2.5		2
Argillite	Traces	0.5	0.5			

Pebble Size

Ten to fifteen apparent maximum diameters of the largest tuff pebbles were measured in two dimensional sections at each locality. The maximum diameter of the pebbles was indeterminable in the field and it was not possible to ascertain the orientation of pebbles. These diameters were averaged for each locality and plotted (Fig. 3-34, in pocket). From 68 millimeters at Flatrock in the north, these averages decrease to about 62 millimeters at Logy Bay, Quidi Vidi and Signal Hill in the central portion, to 56 millimeters at Cape Spear and 50 millimeters at Petty Harbour in the south. The apparent decrease in size from north to south in this linear representation could also be interpreted as a decrease from the northwest or norteast. Further work on sedimentary structures will be required to determine vectors.

This method is only an approximation and pebbles were, therefore, sampled and taken to the laboratory for sphericity and roundness determination.

Sphericity and Roundness

The sphericity of a pebble is defined as the ratio of the surface area of a sphere having the same volume as the pebble to the surface area of the pebble (Wadell, I932). By definition the roundness (Wadell, I932) can be expressed as -

$$\text{Roundness} = \frac{\text{Average radius of corners and edges}}{\text{Radius of maximum inscribed circle}}$$

In the laboratory the roundness of each pebble was compared with the visual estimatinn chart of Krumbein (I94I). The average roundness values are shown in Table 3-6.

Table 3-6

Traverse Number	Locality	Average Roundness
1	Flatrock	0.59
2	Logy Bay	0.60
4	Quidi Vidi	0.60
5	Signal Hill	0.60
6	Cape Spear	0.62
7	Petty Harbour	0.62

Sphericity - The long, intermediate and short axes (a,b,c) of tuff pebbles within the size range of 20 to 30 millimeters were measured with vernier caliper. Two ratios, b/a and c/b from each pebble were determined and located on the axes of a chart given by Krumbein (1941, Fig. 5) from which sphericity values were read directly. The average sphericity values are shown in Table 3-7.

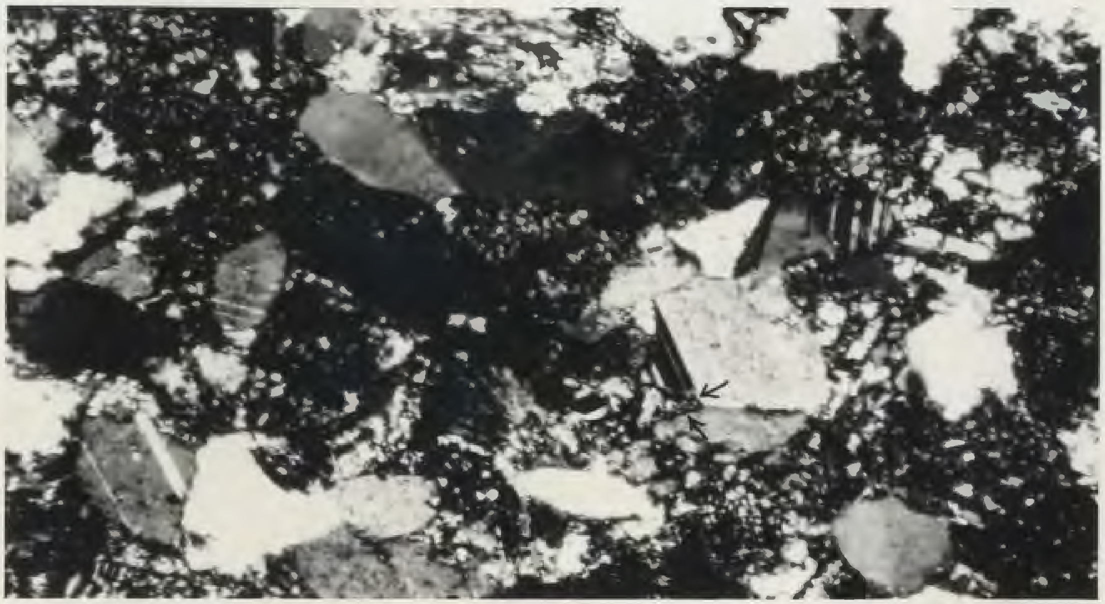
Table 3-7

Traverse Number	Locality	Average Sphericity
1	Flatrock	0.59
2	Logy Bay	0.62
4	Quidi Vidi	0.63
5	Signal Hill	0.64
6	Cape Spear	0.64
7	Petty Harbour	0.65

A progressive increase in the average indices of both roundness and sphericity is apparent from Flatrock in the north to Petty Harbour in the South.

Fig. 3-I - Typical sandstone of the lower member of the Signal Hill Formation. (Bay Bulls). Calcite (arrows). Crossed nicols X 300.

Fig. 3-2 - Typical sandstone of the middle member of the Signal Hill Formation. (Quidi Vidi). Hematite (black), in patches and between grains. Authigenic growth of quartz (A). Crossed nicols X 44.



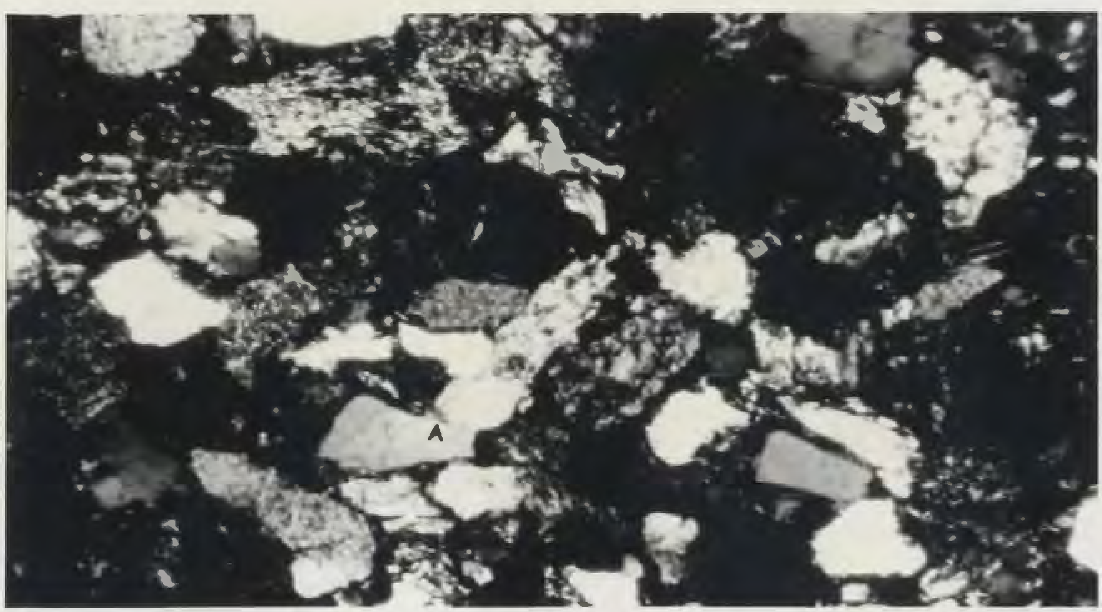

A

Fig. 3-3 - Sandstone of the lower member of the Signal Hill Formation (Quidi Vidi). Unit quartz grains(white) with straight to slightly undulose extinction. Crossed nicols X 88.

Fig. 3-4 - Sandstone of the middle member of the Signal Hill Formation (Petty Harbour). Strong undulatory quartz (X). Crossed nicols X 90.

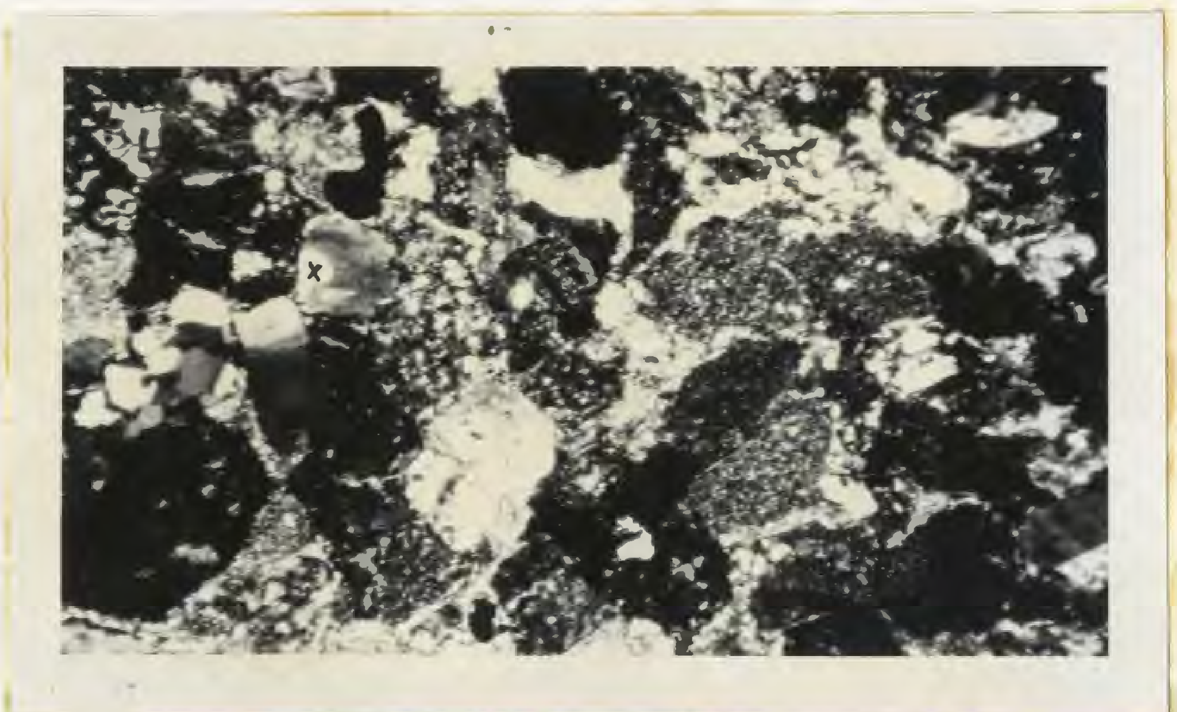
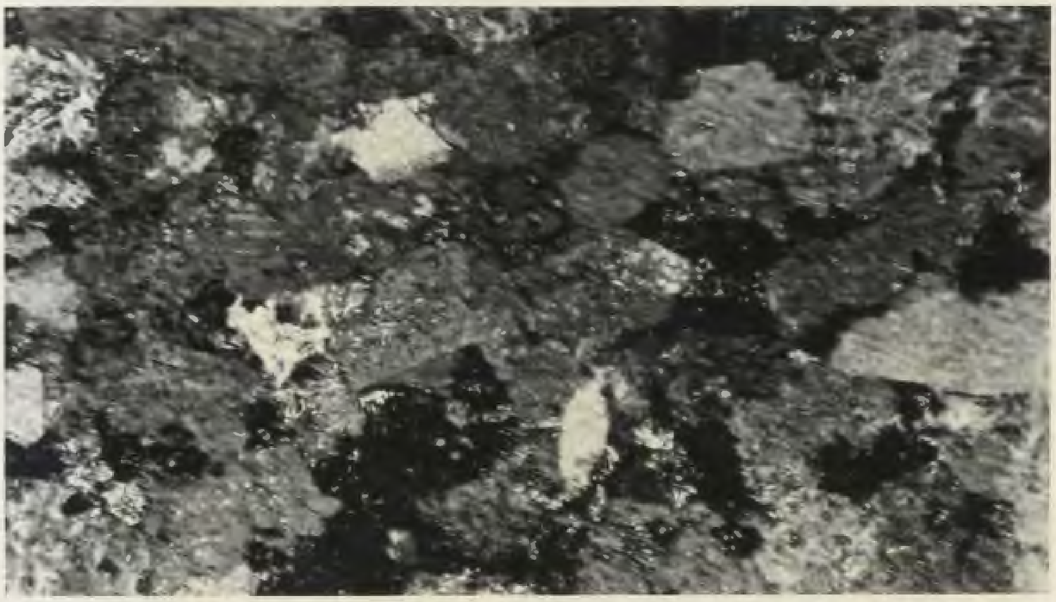


Fig. 3-5 - Sandstone of the middle member of the Signal Hill Formation (Petty Harbour). Volcanic quartz (X). Crossed nicols X 90.

Fig. 3-6 - Sandstone of the middle member of the Signal Hill Formation (Ferryland). Twinned and untwinned weathered feldspar grains (dark grey). Crossed nicols X 300.



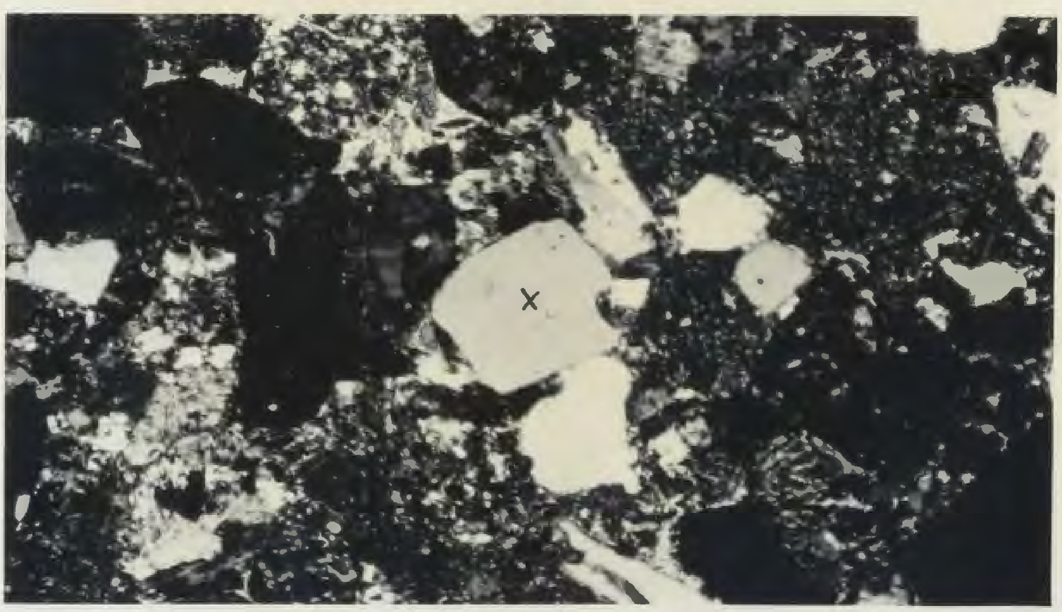
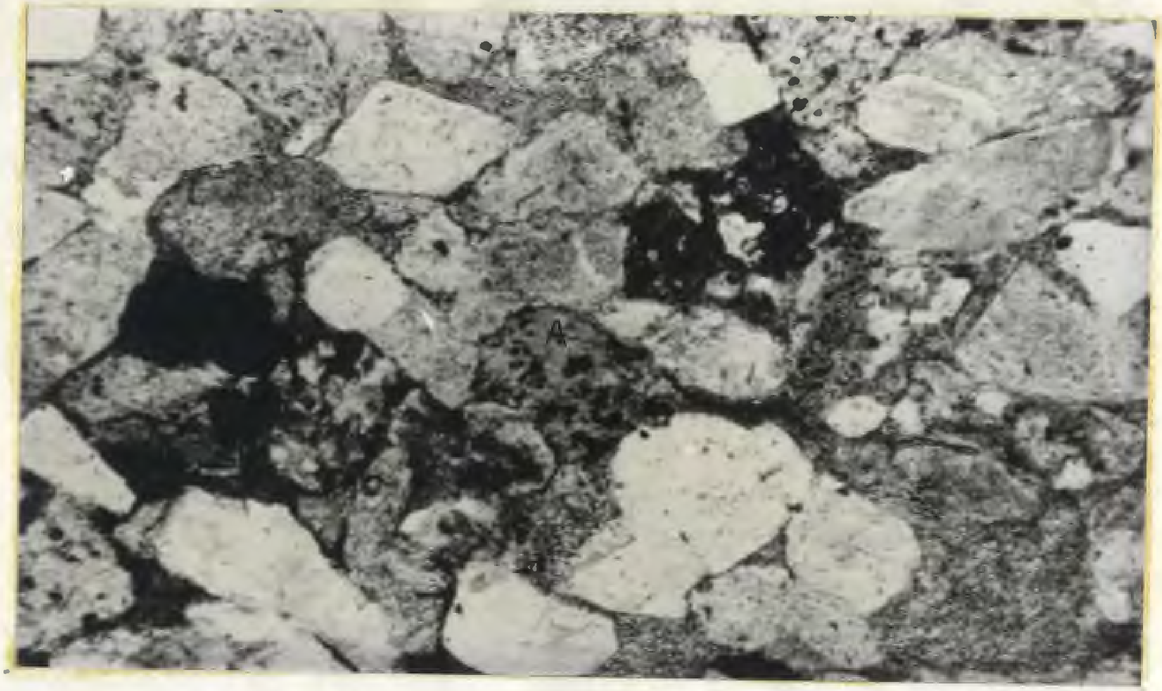


Fig. 3-7 - Sandstone of the lower member of the
Signal Hill Formation (Witless Bay).
Plagioclase grains (mostly untwinned)
are covered by alteration products.
Chlorite can be seen at "A".
Transmitted light X90.

Fig. 3-8 - Sandstone of the lower member of the
Signal Hill Formation(Witless Bay).
Plagioclase feldspar - relatively
fresh (A and D), partially altered
(B) and higly altered (C). Partially
alterdd K.feldspar (E).
Crossed nicols X90.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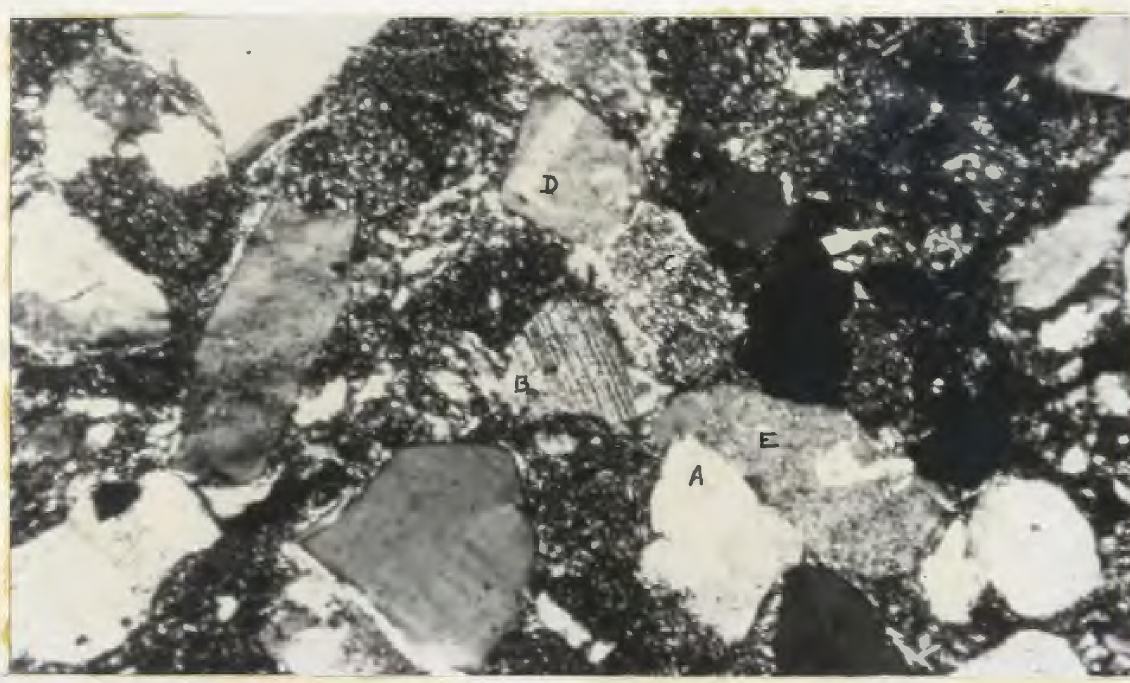
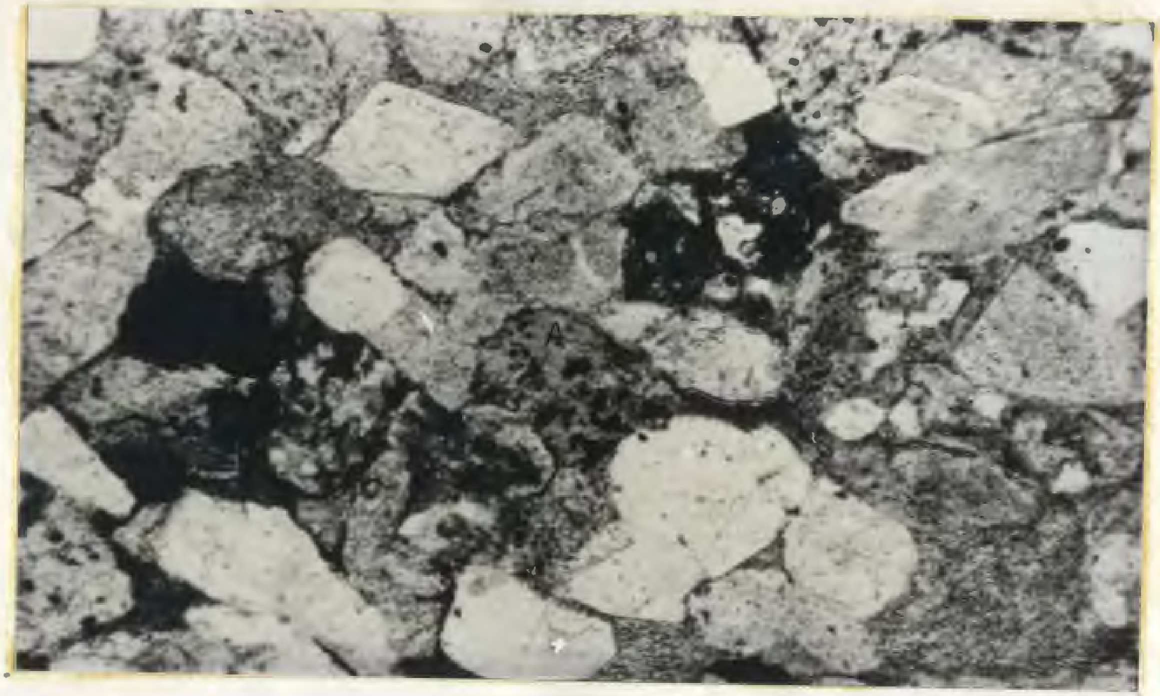

A
E
B
D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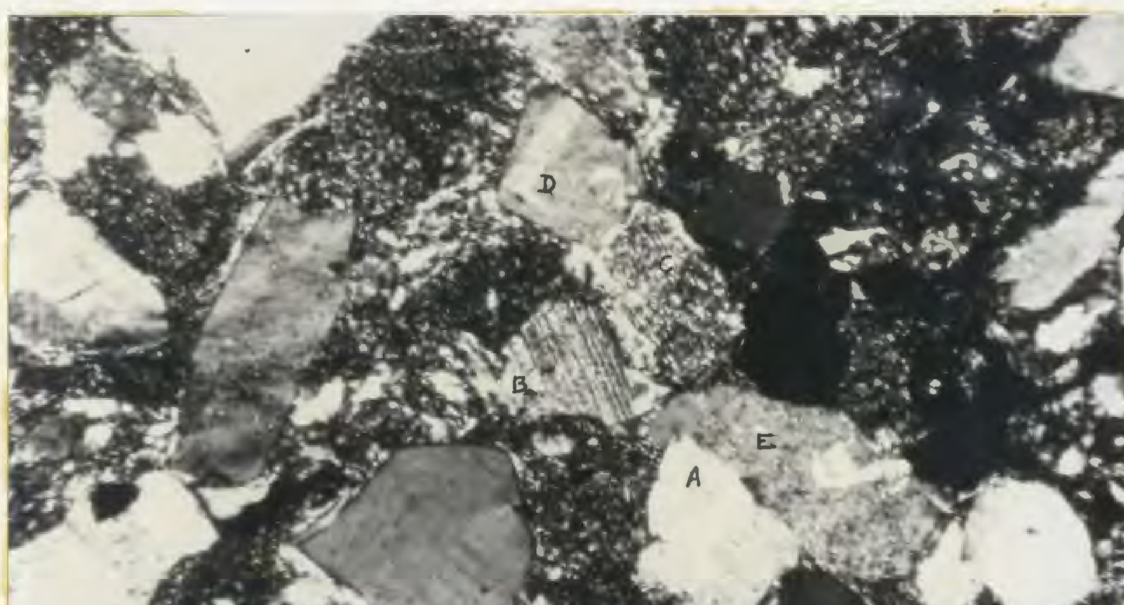
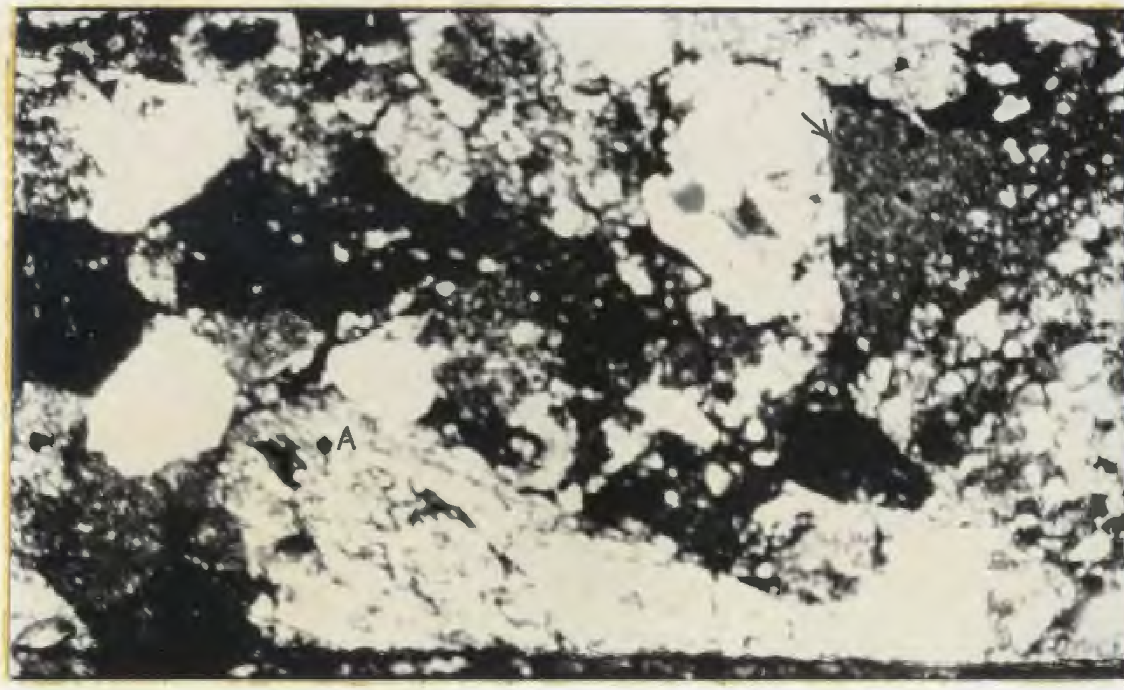

D
C
B
E
A

Fig. 3-9 - Sandstone of the middle member of the Signal Hill Formation (Quidi Vidi). Metamorphic rock fragment (A). Siliceous rock fragment (arrow). Crossed nicols X90.

Fig. 3-I0 - Sandstone of the upper member of the Signal Hill Formation (Quidi Vidi). Red argillite fragment (southwest corner of the photo). Crossed nicols X 90.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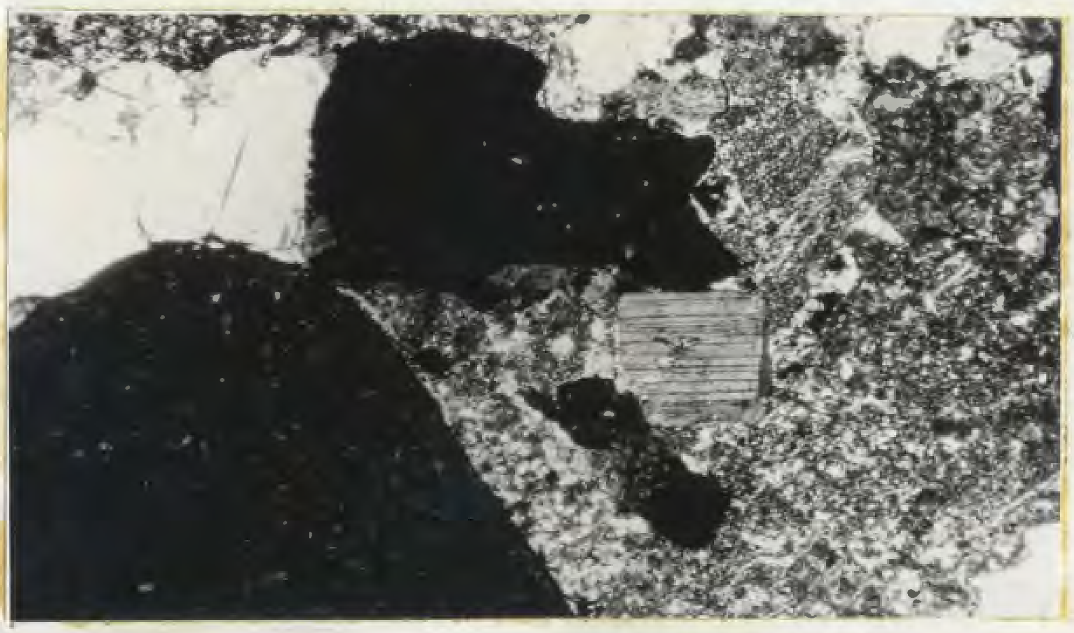


Fig. 3-II - Sandstone of the middle member of the Signal Hill Formation (Petty Harbour). Tuff fragment (A). Interpenetration along borders of adjacent quartz grains of interstitial material (arrow). Crossed nicols X 90.

Fig. 3-12 - Cumulative curves of the Signal Hill

Sandstones.

Explanation:

Curve No. 1 - Sample No. Z1

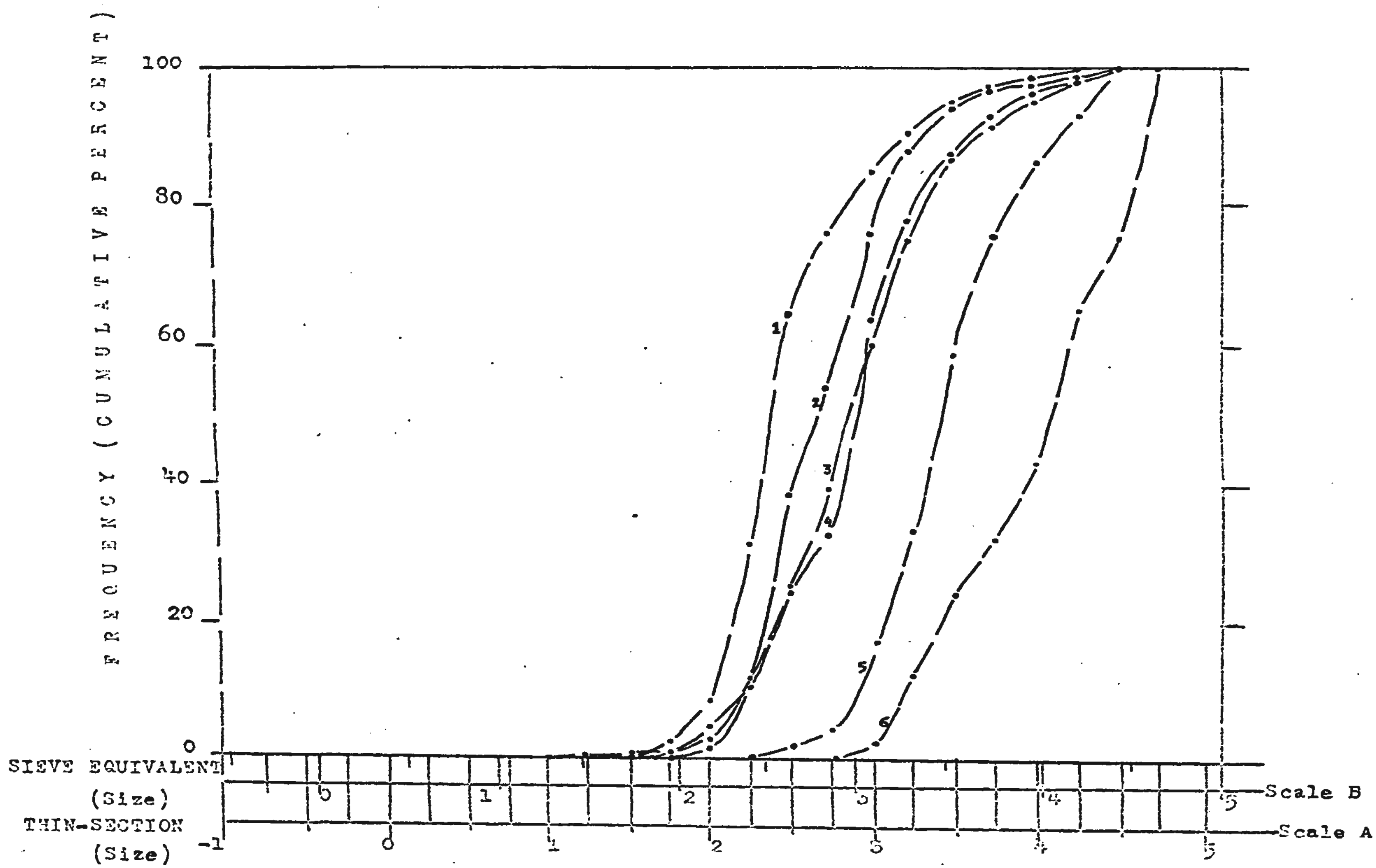
2 - Sample No. x

3 - Sample No. x1

4 - Sample No. Z4

5 - Sample No. Z.

6 - Sample No. FS. 17.



FREQUENCY (CUMULATIVE PERCENT)
100
80
60
40
20
0
SIEVE EQUIVALENT
(Size)
THIN-SECTION
(Size)
Scale B
Scale A
PARTICLE SIZE (Phi Units)

Fig.3-12

Fig. 3-13 - Cumulative curves of the sandstones from the Signal Hill Formation.

Explanation:

Curve No.

1 - Sample No. S 53a

2 - Sample No. S 48

3 - Sample No. S 65

4 - Sample No. S 59

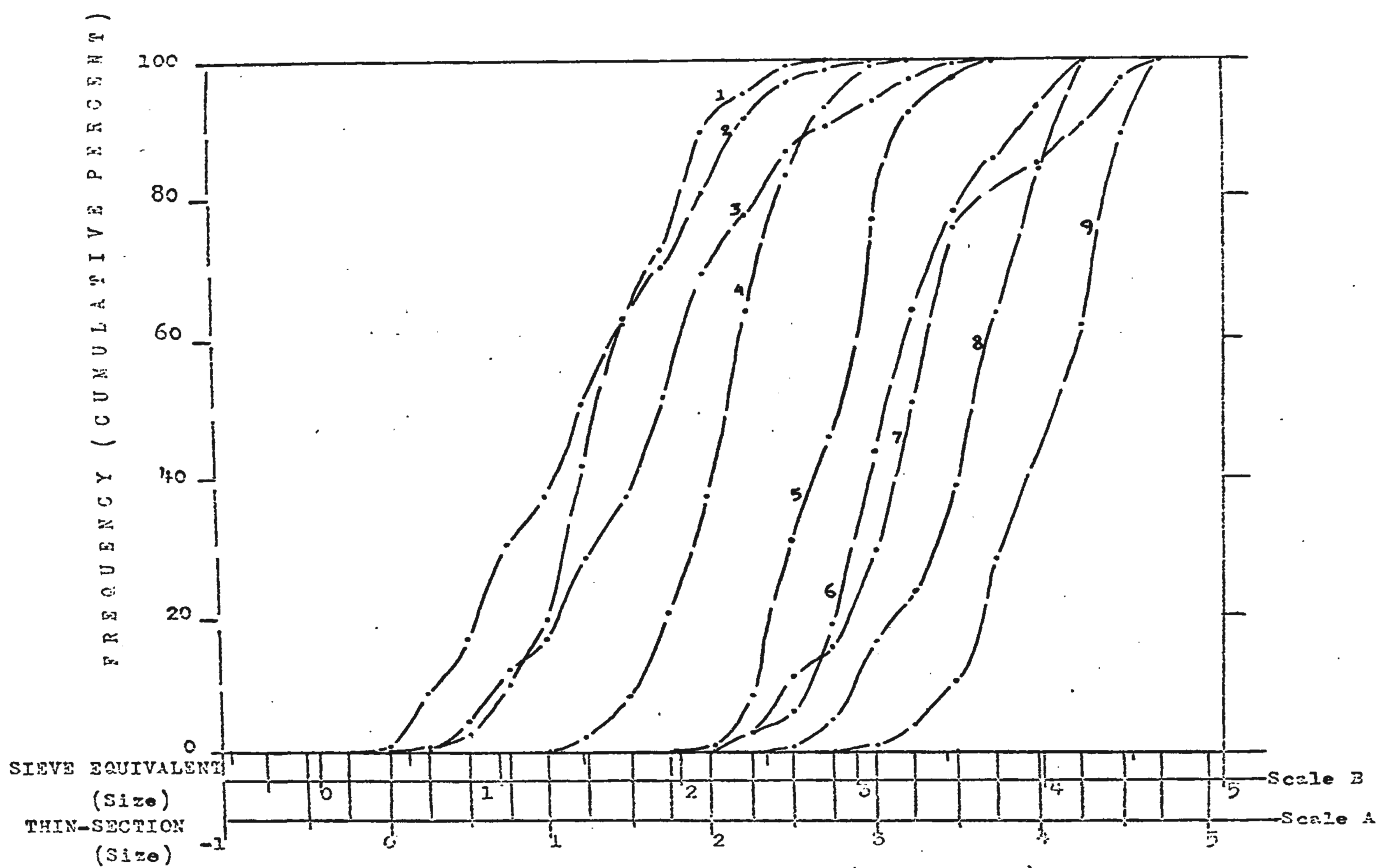
5 - Sample No. S 14

6 - Sample No. S 10

7 - Sample No. S 19

8 - Sample No. K 5

9 - Sample No. S 18



FREQUENCY (CUMULATIVE PERCENT)
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
SIEVE EQUIVALENT (Size)
THIN-SECTION (Size)
0
1
2
3
4
5
-1
Scale B
Scale A
PARTICLE SIZE (Phi Units)

Fig.3-13

Fig. 3-14 - Cumulative curves of the sandstones of the Signal Hill Formation.

Explanation:

Curve No.

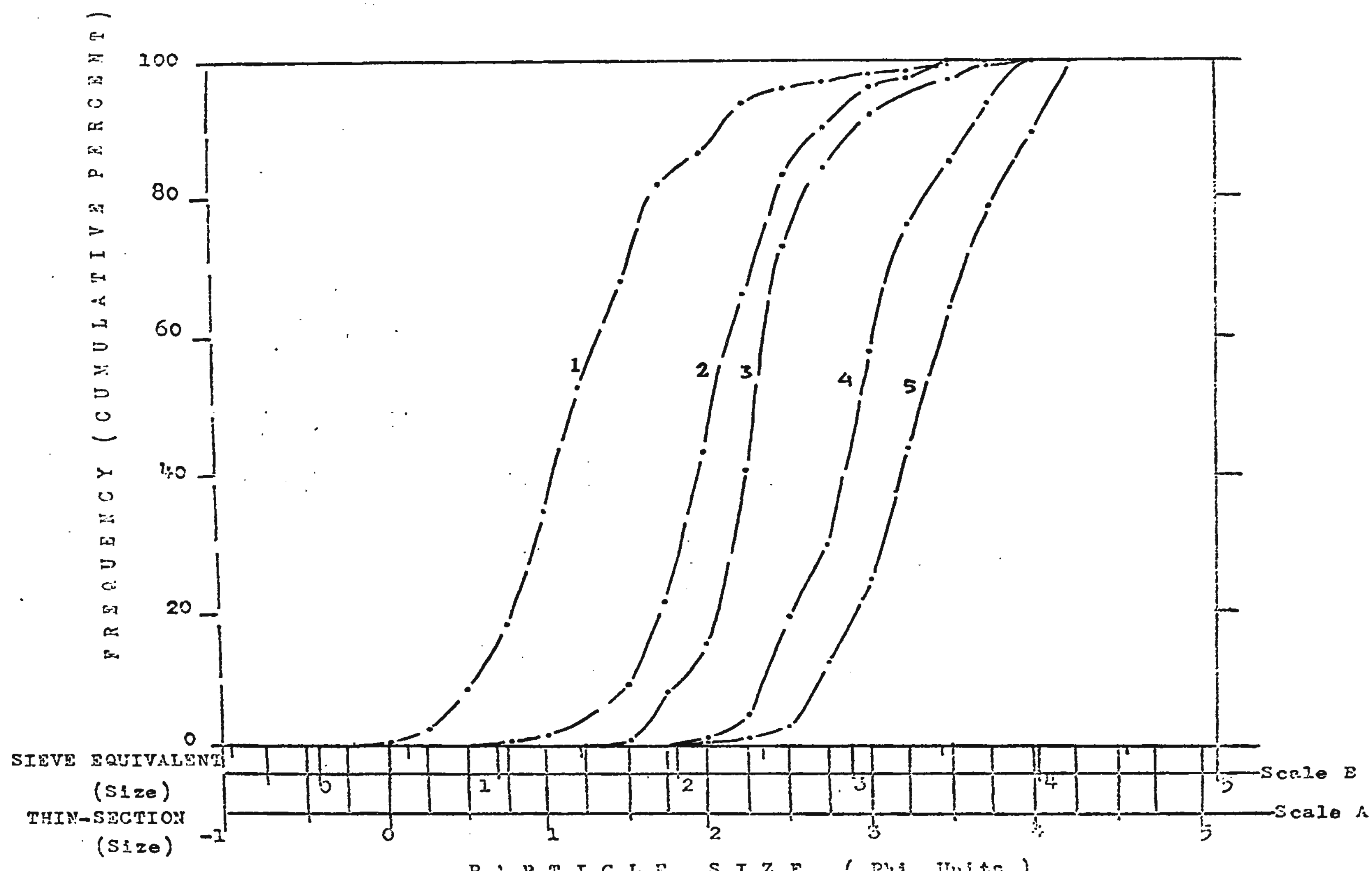
1 - Sample No. P.S.7

2 - Sample No. P.S.9

3 - Sample No. P.S.14

4- Sample No. P.S.8

5 - Sample No. P.S.13


FREQUENCY (CUMULATIVE PERCENT)
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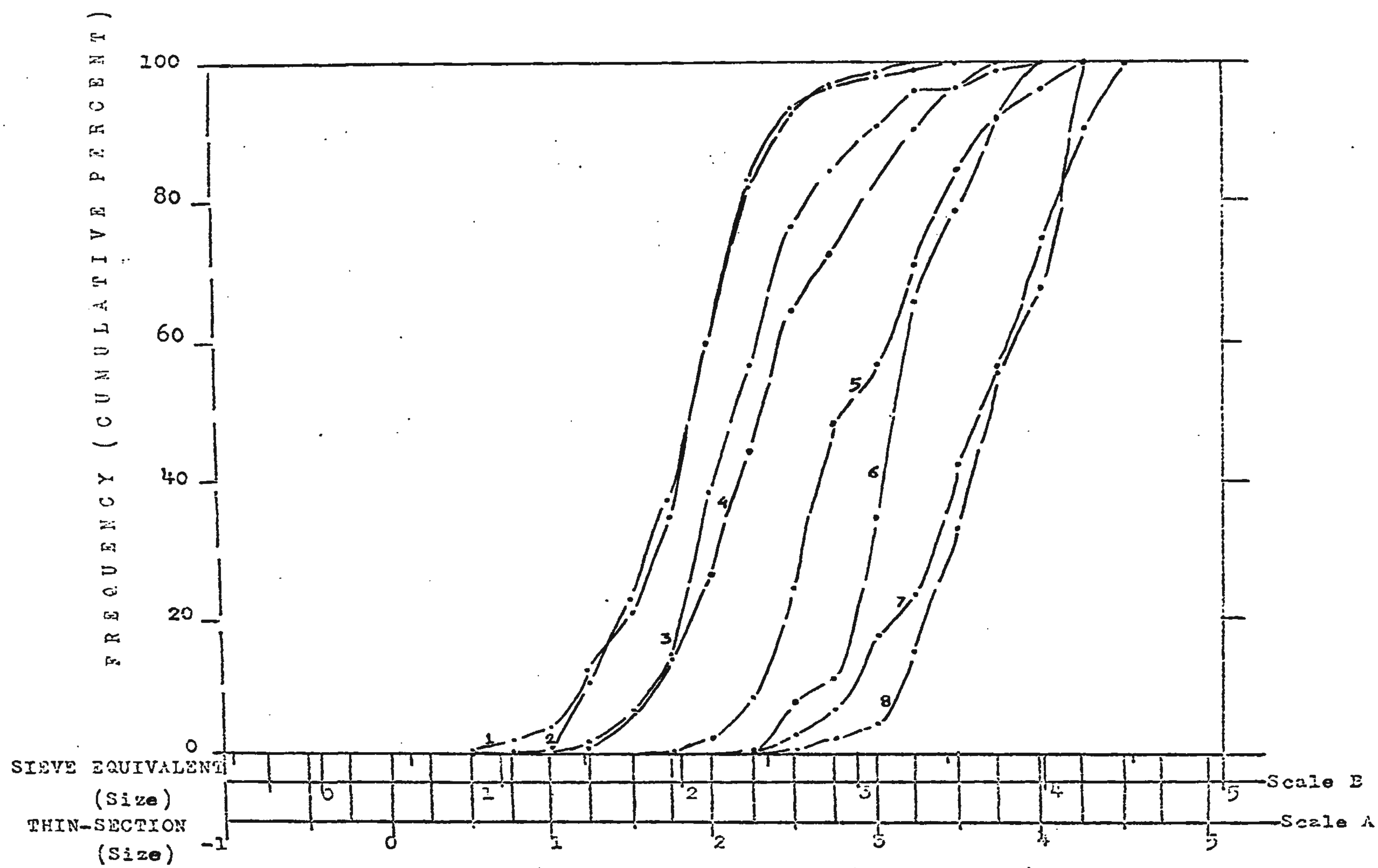
60
40
20
0
1
2
3
4
5
SIEVE EQUIVALENT
(Size)
THIN-SECTION
(Size)
-1
0
1
2
3
4
5
Scale B
Scale A
PARTICLE SIZE (Phi Units)

Fig.3-14

Fig. 3-15 - Cumulative curves of the Signal Hill Sandstones.

Explanation:

Curve No.	1 - Sample No. B.S.22
	2 - Sample No. B.S.4
	3 - Sample No. B.S.22
	4 - Sample No. B.S.7
	5 - Sample No. B.S.40
	6 - Sample No. B.S.45
	7 - Sample No. B.S.42
	8 - Sample No. A.S.10



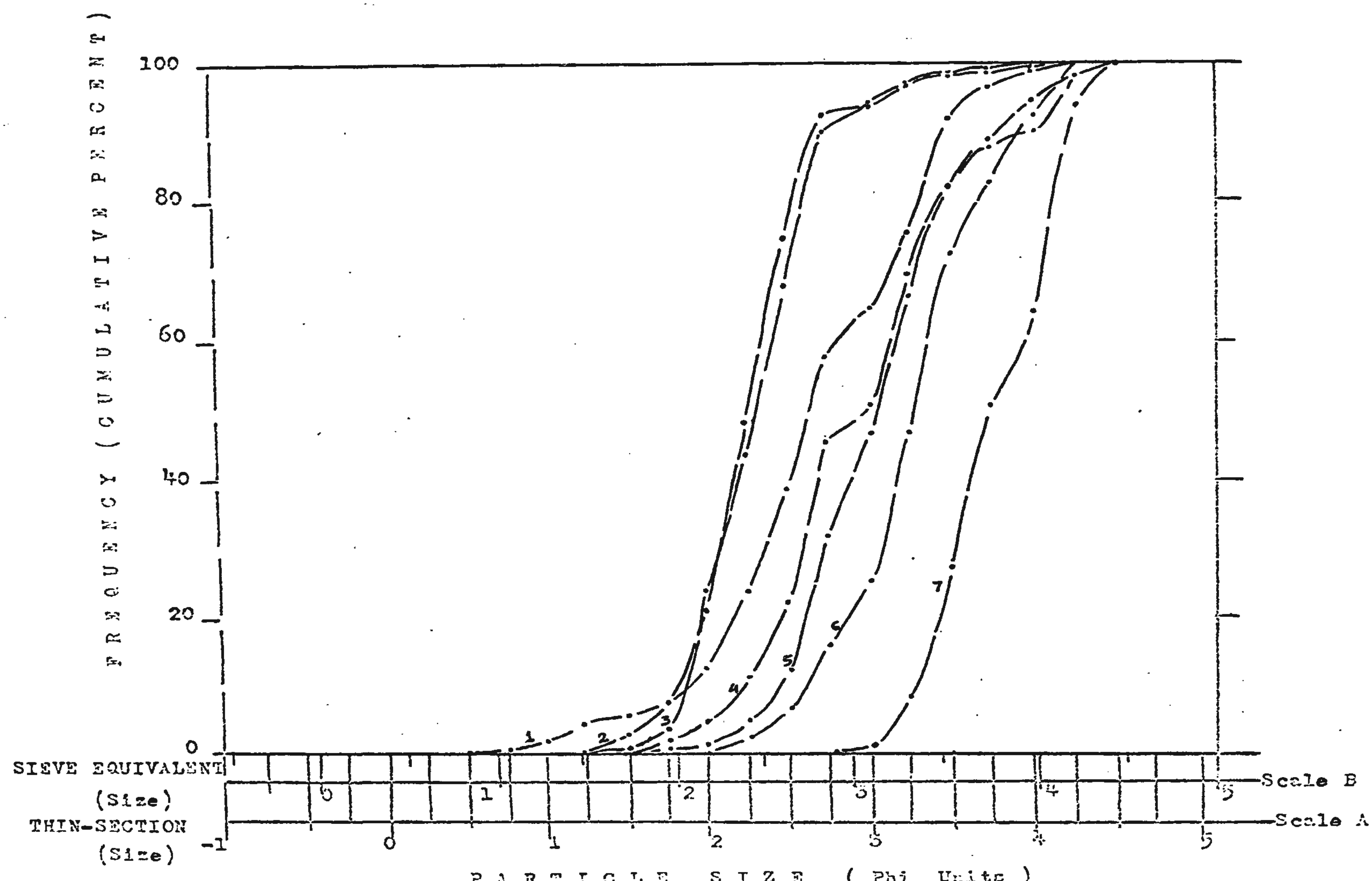
FREQUENCY (CUMULATIVE PERCENT)
100
80
60
40
20
0
1
2
3
4
5
6
7
8
SIEVE EQUIVALENT (Size)
THIN-SECTION (Size)
-1
0
1
2
3
4
5
Scale B
Scale A
PARTICLE SIZE (Phi Units)

Fig.3-15

Fig. 3-16 - Cumulative curves of the Signal Hill Sandstones.

Explanation:

Curve No.	1 - Sample No. W.S.18
	2- Sample No. W.S.3
	3 - Sample No. W.S.8
	4 - Sample No. W.S.7
	5 - Sample No. W.S.4
	6 - Sample No. W.S.1
	7 - Sample No. W.S.11


FREQUENCY (CUMULATIVE PERCENT)
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80
60
40
20
0
1
2
3
4
5
6
7
SIEVE EQUIVALENT
(Size)
THIN-SECTION
(Size)
-1
0
1
2
3
4
5
Scale B
Scale A
PARTICLE SIZE (Phi Units)

Fig.3-16

Fig. 3-17 - Cumulative curves of the Signal Hill Sandstones.

Explanation:

Curve No.	1 - Sample No. M.S.1
	2 - Sample No. M.S.3
	3 - Sample No. M.S.34
	4 - Sample No. M.S.19
	5 - Sample No. M.S.8
	6 - Sample No. M.S.14
	7 - Sample No. M.S.36

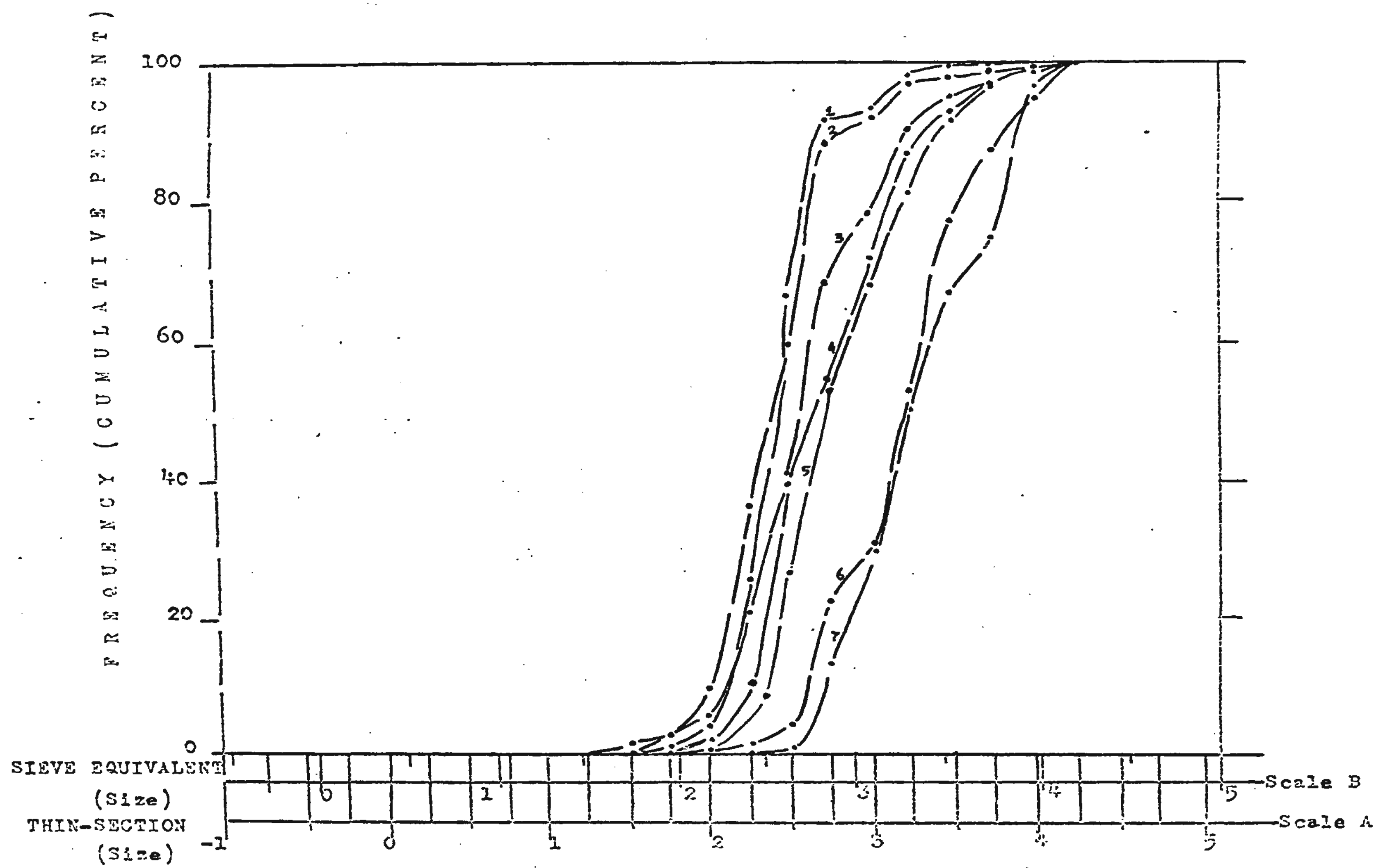
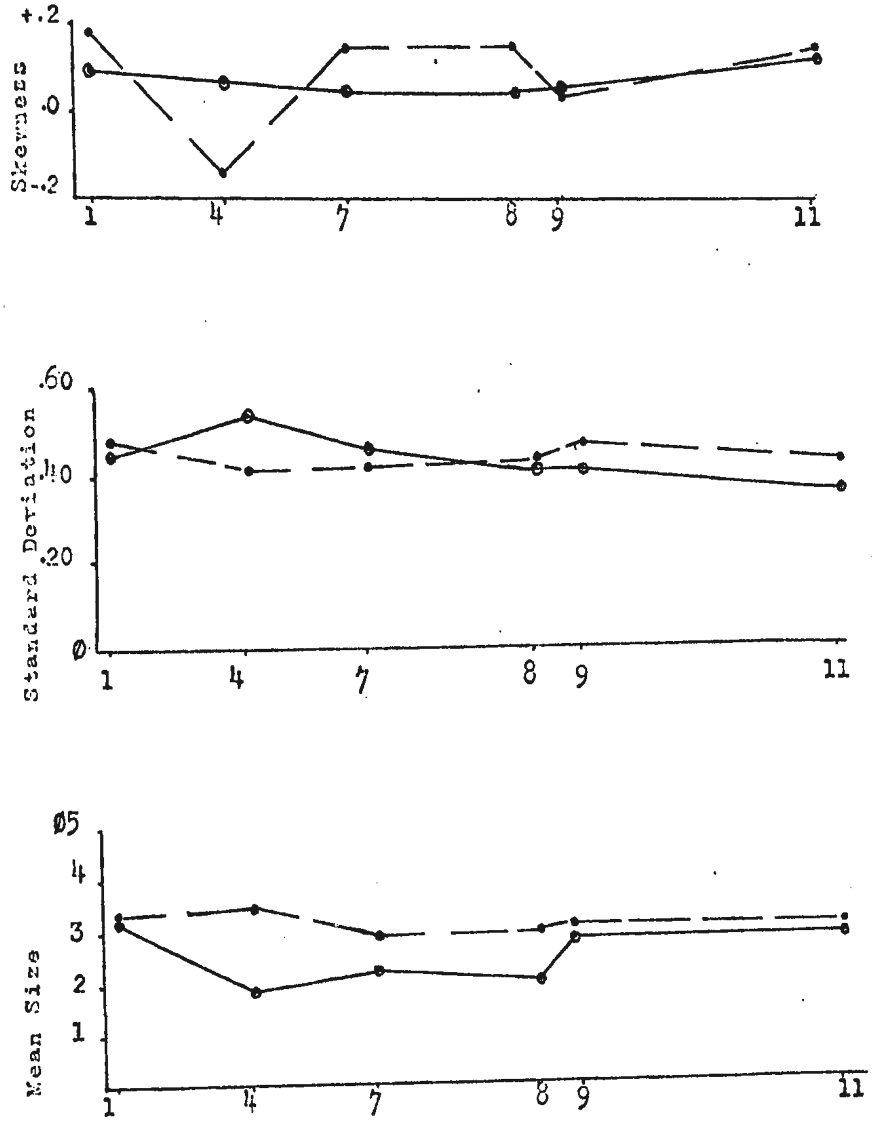

FREQUENCY (CUMULATIVE PERCENT)
100
80
60
40
20
0
1
2
3
4
5
6
7
SIEVE EQUIVALENT
(Size)
THIN-SECTION
(Size)
0
1
2
3
4
5
Scale B
-1
0
1
2
3
4
5
Scale A
PARTICLE SIZE (Phi Units)

Fig.3-17

Fig. 3-18 - Plot of size parameters by localities (numbers on horizontal scale represents traverses marked on figure 1-2. 1-Flatrock, 4-Quidi Vidi, 7-Petty Harbour, 8-Bay Bulls, 9-Witless Bay and 11-Ferryland).

Dots represent sandstone of the middle member and open circle represents sandstone of the lower member.



+.2
.0
-.2
Skewness
1
4
7
8
9
11
.60
.40
.20
Ø
Standard Deviation
1
4
7
8
9
11
Ø5
4
3
2
1
Mean Size
1
4
7
8
9
11

Fig. 3 -18

Fig. 3-I9 - Scatter plot of skewness versus mean. Area here defined as within the range of normal curve (Folk I957, fig. I6, p.2I) is shown by olive green color. Dots represent sandstones of the middle member and open circle represent sandstones of the lower member of the Signal Hill Formation.

Fig. 3-20 - Scatter plot of skewness versus kurtosis. Areas here defined as within the range of normal curve (Folk I957, fig. I6, p.2I.) are shown by olive green color. Dots represent sandstones of the middle member and open circles represent sandstones of the lower member of the Signal Hill Formation.

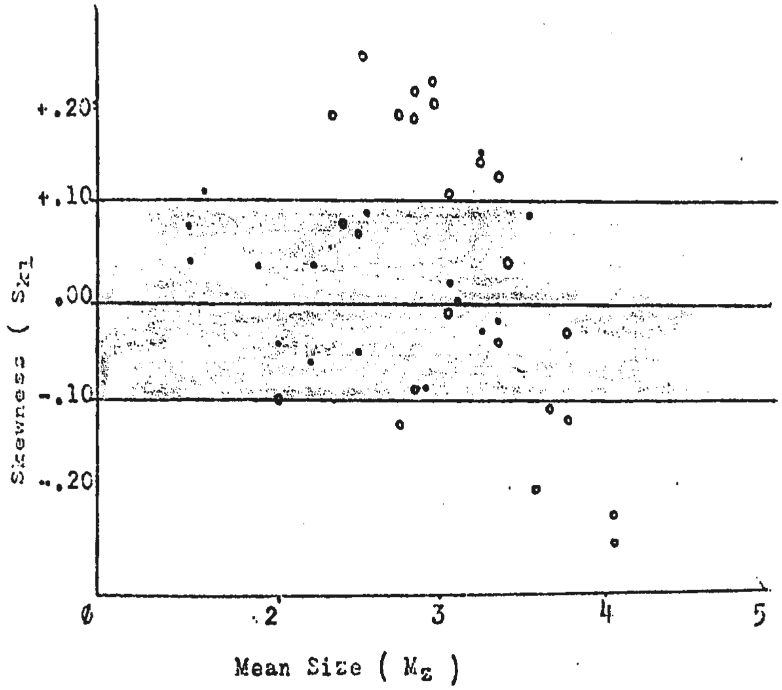


Fig.3-19

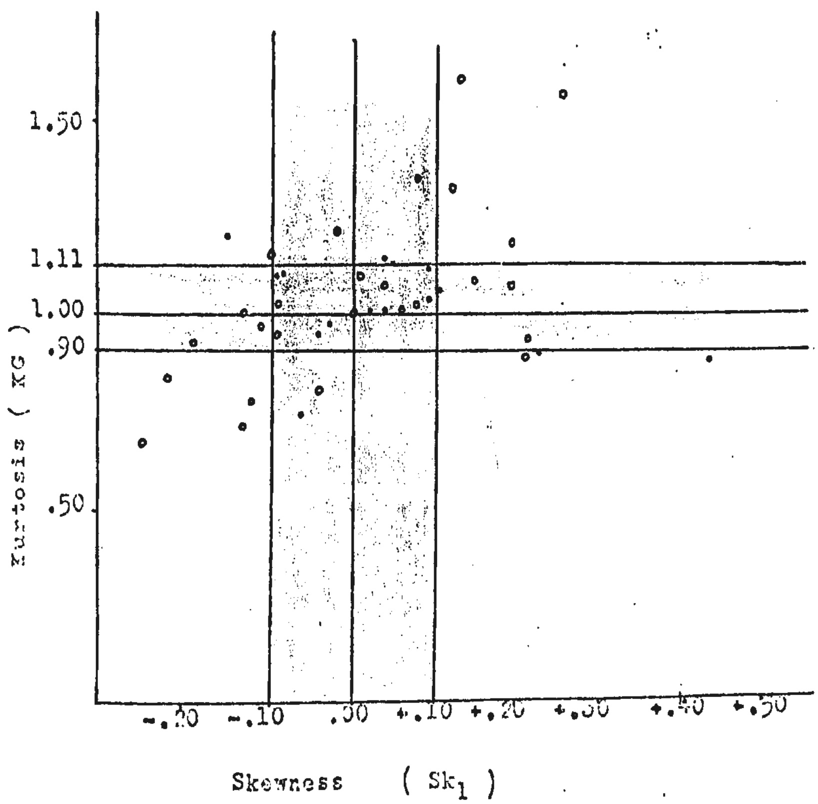


Fig.3-20

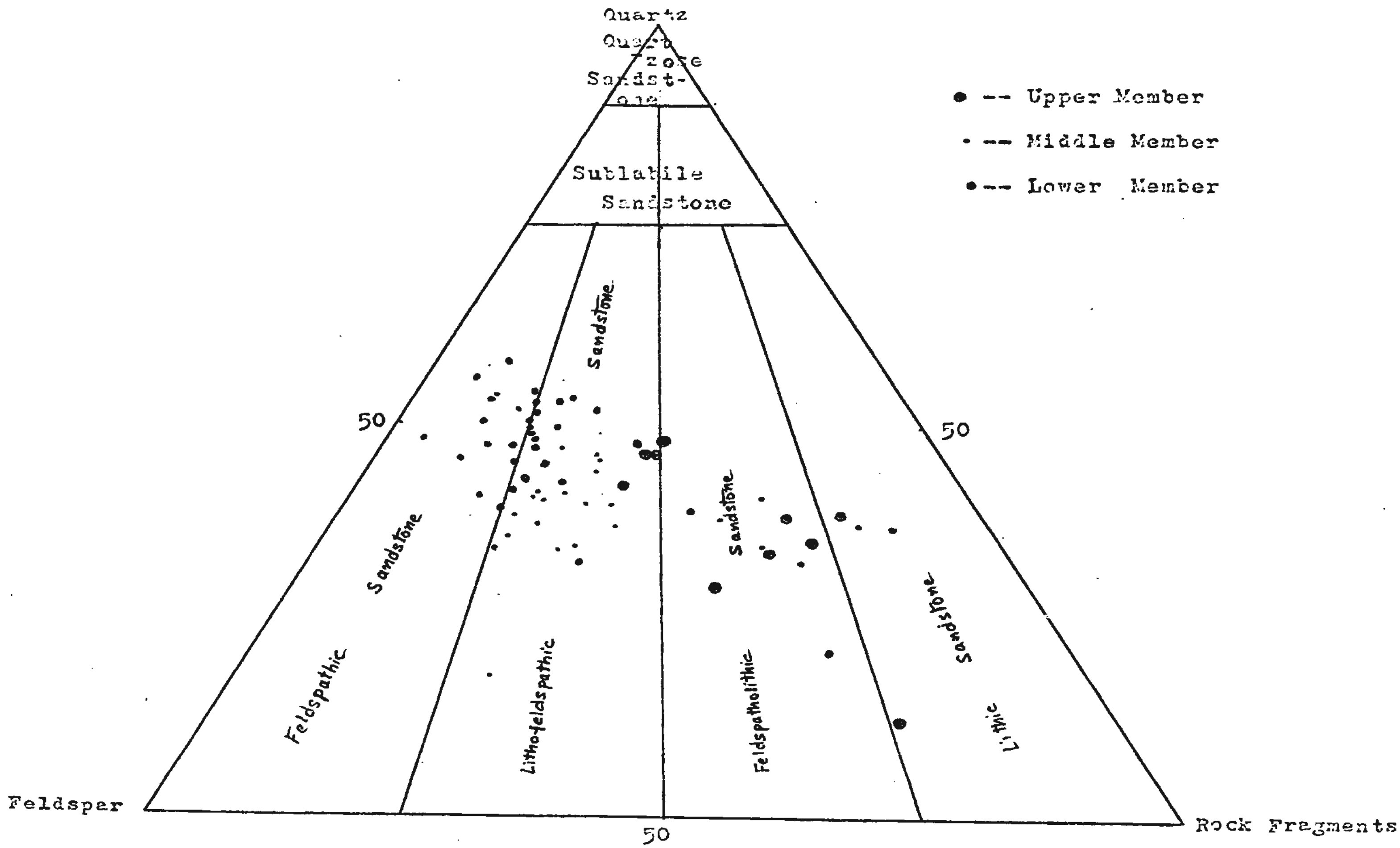


Fig.3-2: Detail composition of sandstones from the Signal Hill Formation.

Fig. 3-22 - Sandstone of the lower member of the Signal Hill Formation (Witless Bay).
Authigenic quartz (A).
Pressure solution contact (arrow).
Crossed nicols X 44.

Fig. 3-23 - Sandstone of the middle member of the Signal Hill Formation (Flatrock).
Deformed biotite exhibiting strain shadows. Corroded margins of quartz grain (arrows). Crossed nicols X300.


A

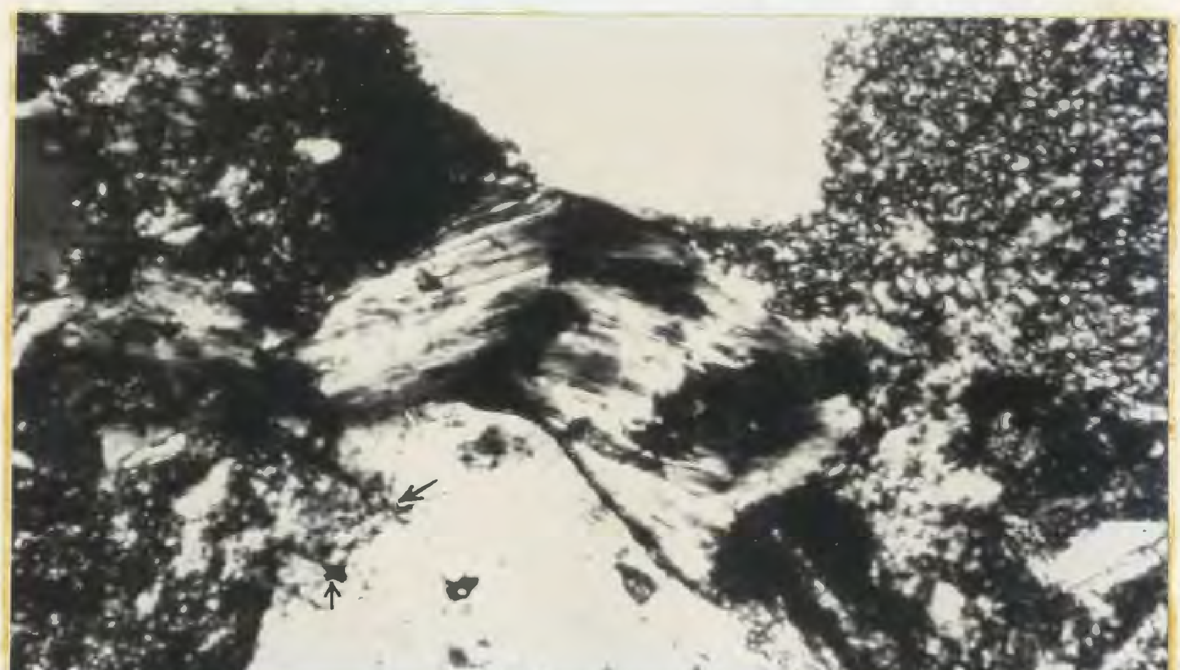


Fig. 3-24 - Sandstone of the lower member of the Signal Hill Fôrmation (Ferryland). Sandstone is exhibiting sericitization of feldspar grains. Tension cracks filled with k. feldspar traverse the rock. Crossed nicols X 44.

Fig. 3-25 - Siltstone of the middle member of the Signal Hill Formation (Petty Harbour). Crossed nicols X 44.

Fig. 3-26 - Argillite of the lower member of the Signal Hill Formation (Witless Bay). Crossed nicols X 60.

Fig. 3-27 - Tuff of the middle member of the Signal Hill Formation (Sugarloaf pond area).

A- Tuff exhibiting deformed shards. Transmitted light X II2.

B - Same tuff showing replacement of groundmass by calcite (left). Crossed nicols X II2.

Fig. 3-28 - COmpact texture in a pebble of welded tuff (upper member, Signal Hill Formation) Crossed nicols X60.

Fig. 3-29 - Rhyolite pebble (upper member, Signal Hill Formation). Phenocrysts of feldspar in a cryptocrystalline groundmass. Crossed nicols X60.

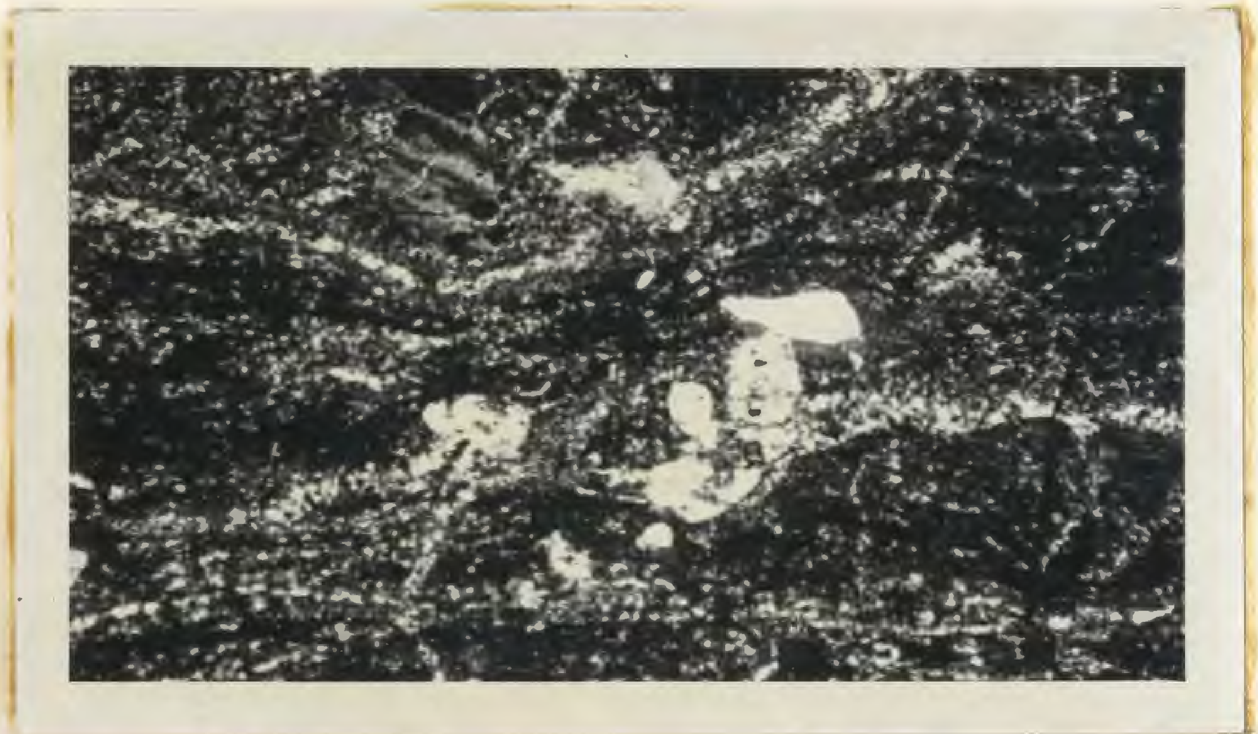
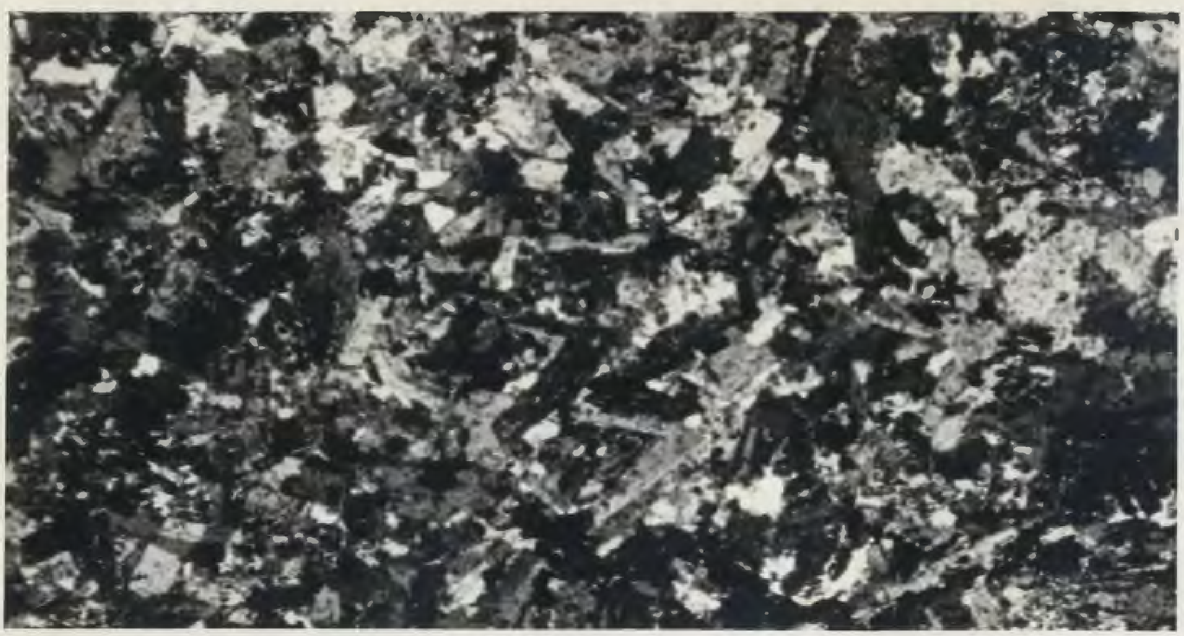


Fig. 3-30 - Tuff pebble showing shards and quartz crystals, in the upper member of the Signal Hill Formation.
Transmitted light X 60.

Fig. 3-3I - Pebble of a basic volcanic rock showing chloritised plagioclase feldspar laths in an altered groundmass, in the upper member of the Signal Hill Formation.
Transmitted light X 60.

Fig. 3-32- Quartzite pebble exhibiting stretched quartz, twinned plagioclase and subparallel arrangement of tiny mica flakes (arrow), in the upper member of the Signal Hill Formation. Crossed nicols X II2.

Fig. 3-33 - Diorite pebble in the upper member of the Signal Hill Formation. Crossed nicols X 60.



CHAPTER IV

PETROLOGY OF THE BLACKHEAD FORMATION

Preamble

In composition the sandstones, siltstones and argillites of the Blackhead Formation closely resemble those of underlying Signal Hill Formation. However, the conglomerate beds and layers of volcanic tuff found in the Signal Hill Formation do not occur in the Blackhead Formation.

The methods of investigation, terminology and classification used for the sandstones of the Blackhead Formation are the same as those used in the study of the Signal Hill Formation.

Mineralogical Analyses of Sandstones

Content

A typical sandstone of the Blackhead Formation, as shown in Fig. 4-1, consists of the following:

Quartz	35.2 percent
Potash feldspar	10.2 percent
Plagioclase feldspar	21.8 percent
Rock Fragments	15.5 percent
Interstitial material	17.3 percent

Details of their modal analysis is shown in Table 4-1.

Table 4-1 Thin-Section Mineral
% Composition of the Sandstones of the Blackhead Formation

	GRAINS											INTERSTITIAL MATERIAL										
				Rock Fragments					Sedim.													
	Quartz	k.Feldspar	Plagioclase	Tuff & Rhyolite	Granite & Granophyres	Diorite	Basic Volcanic	Metamorphic	Siliceous	Others	Total	"A"	Hematite	Chlorite	Pyroxene	Biotite & Muscovite	Calcite	Magnetite	Zircon	Apatite	Sphene	
R.S.2	29	10	18	2	3	-	-	Traces	10	3	13	8	7	Traces	.	.	.	-	.	-	-	-
R.S.3	30	10	28	2	3	-	-	-	10	1	11	8	7	1	.	.	.	-	.	.	-	-
R.S.5	40	12	21	.	.	.	.	.	14	3	17	9	1	.	-	-	.	-	.	.	-	.
R.S.8	42	9	19	2	2	.	-	-	8	2	10	11	2	2	.	.	1	-	-	.	.	-
C.S.2	33	12	20	1	1	-	-	.	15	2	17	9	5	1	1	-	.	-	.	.	-	-
C.S.6	28	17	20	1	3	.	1	-	8	5	13	9	2	3	.	2	-	-	1	-	-	-
C.S.13	36	8	27	1	1	-	-	.	8	3	11	7	7	.	2	-	.	-	.	.	-	-
C.S.14	40	10	25	1	2	1	0.5	.	10	2	12	7	.	2	.	.	.	-	2	.	-	-
C.S.16	33	7	25	-	-	.	.	-	7	2	9	14	5	5	.	.	.	-	1	-	-	-
C.S.20	35	8	20	-	-	-	.	.	9	1	10	10	5	3	2	.	.	5	2	-	-	-
C.S.25	38	8	17	.	2	.	-	-	12	4	16	9	5	1	2	.	0.5	-	1	-	-	-
C.S.28	35	15	24	-	5	.	-	-	7	-	7	7	2	3	1	.	.	-	1	-	-	-
C.B.S.1	28	8	23	1	1	1	-	.	12	3	15	11	10	1	-	1	.	-	.	-	-	-
C.B.S.3	30	10	20	1	4	.	.	.	7	2	9	11	8	4	2	1	.	-	.	-	-	.
C.B.S.4	32	10	24	3	4	-	-	-	6	5	11	11	2	.	2	1	.	-	.	.	-	-
C.B.S.8	33	10	21	1	5	.	1	.	5	7	12	7	1	6	3	.	.	.	.	.	.	-
C.B.S.10	35	10	20	3	6	2	1	.	4	6	10	6	2	3	.	.	2	.	.	-	.	
C.B.S.5	38	10	20	.	1	.	.		7	4	11	9	2	5	3	-	.	1	-	.	-	-
C.B.S.18	35	10	22	-	2	-	-	-	10	2	12	9	7	1	2	.	.	-	.	-	.	

For explanation of sample number see Plate 2-3 (in pocket)

. - refers to the amount of the component in traces.

Variations found in the grain constituents and interstitial material in the lower, middle and upper members of the Blackhead Formation are listed below:

Grain Constituents

There is a progressive increase in the percentage of quartz (Fig. 4-2) from 32 percent in the lower member to 36 percent in the upper member. Feldspar grains show no significant change. However, rock fragments (Figures 4-1 to 4-4) exhibit a decrease from 16.8 percent in the middle member to 15.8 percent in the lower member and 12.9 percent in the upper member. Within rock fragments, the grains derived from granitic suite show a significant quantitative variation, they reach a maximum of 4 percent of the total rock in the middle member and decrease both in the lower and upper members.

Interstitial Material

The interstitial material is almost the same percentage in the sandstones of the lower, middle and the upper members, except hematite and chlorite which show quantitative variations among the sandstones of the lower, middle and upper members. Hematite averages approximately 5 percent of the total rock in the sandstones of the lower member and decreases to 1.7 percent in the sandstones of the middle member. Chlorite averages 3.5 percent of the total rock in the sandstones of the middle member and 2 percent in the upper member.

Textural Analyses of Sandstones

Grain Size

The sandstones of the Blackhead Formation are in general slightly coarser grained than those of the underlying Signal

Hill Formation. The cumulative grain size distribution of the sandstones of the Blackhead Formation obtained from thin-sections are shown in Figures 4-5 and 4-6, and the grain size parameters are given in Table 4-2. The grain size parameters do not show any significant variation from lower to upper member. The average of the graphic mean (mean) grain size of the sandstones in the Blackhead Formation is 2.30 phi (fine sand) although individual samples studied ranged from 3.30 phi (very fine sand) to 1.60 phi (medium).

Inclusive Graphic Standard Deviation

The sorting (inclusive graphic standard deviation) value for the sandstones of the Blackhead Formation is 0.64 phi with a range of 0.30 phi to 0.75 phi. According to Folk's classification (1957) these sandstones are moderately sorted if the interstitial material is ignored.

Skewness

The inclusive graphic skewness values for the sandstones range from -0.20 to +0.20 with a mean of 0-.09.

Kurtosis

The graphic Kurtosis value is 1.1 with a range of 0.99 to 1.70. It is apparent that the sandstones of the Blackhead Formation are in general near-symmetrical and mesokurtic according to Folk's verbal limit (1957).

Trend

The trend between skewness and mean size (Fig. 4-7) demonstrates that finer grained sandstones are fine-skewed. The trend between skewness and kurtosis (Fig. 4-8) exhibits that only two samples are nearly normal with respect to kurtosis and skewness. These trends compare in part with the river laid deposits of Folk (1957) and river sand of Friedman (1967).

Table 4-2 Grain size parameters in the Sandstones of the Blackhead Formation

Sample Number	Median diameter	Graphic mean	Inclusive Graphic Standard deviation	Inclusive Graphic Skewness	Graphic Kurtosis
C.B.S. 1	2.25 phi	2.25 phi	0.45 phi	- 0.20	1
C.B.S. 3	2.79 phi	2.80 phi	0.35 phi	+ 0.13	1.3
C.B.S. 8	2.55 phi	2.52 phi	0.32 phi	- 0.13	1.3
C.B.S. 10	1.70 phi	1.60 phi	0.57 phi	- 0.21	1.7
C.S. 2	2.65 phi	2.63 phi	0.38 phi	- 0.01	1.3
C.S. 14	2.0 phi	2.00 phi	0.36 phi	- 0.04	1.0
C.B.S. 18	2.93 phi	2.90 phi	0.36 phi	- 0.01	0.99
C.S. 25	3.30 phi	3.30 phi	0.46 phi	+ 0.1	1.1
R.S. 3	2.48 phi	2.48 phi	0.75 phi	+ .03	1.0
R.S. 2	2.10 phi	2.05 phi	0.67 phi	+ 0.05	1.2
R.S. 8	2.30 phi	2.39 phi	0.52 phi	+ 0.2	1.1

Roundness

The roundness of the detrital grains in the sandstones of the Blackhead Formation is more or less uniform throughout. Most grains fall within the range of 1-3 on Powers roundness scale, though few grains are subrounded to rounded.

Classification

Ninety percent of the total samples examined are litho-feldspathic sandstones and the remaining 10 percent are

Feldspathic sandstones (Fig. 4-9). The Blackhead Formation lacks in lithic sandstones and Feldspatholithic sandstones in contrast to the underlying Signal Hill Formation.

Diagenesis

Evidence of diagenetic changes in the sandstones of the Blackhead Formation can be summarised as follows:
(a) secondary enlargement of quartz grains (Fig. 4-10), (b) pressure solution contacts (c) presence of authigenic minerals such as sericite, chlorite, epidote and calcite, (d) deformation of schist fragments (Fig. 4-3 and 4-11) (e) alteration of magnetite into hematite (f) corrosion of quartz grains with interstitial material (Fig. 4-11).

Petrographic comparison of the Signal Hill and Blackhead Formations

Sandstones

Microscopically the grains and interstitial material in the sandstones of the Blackhead Formation closely resemble those of the underlying Signal Hill sandstones. But the sandstones of the Blackhead Formation have a higher percentage of quartz and feldspar grains and correspondingly lower amount of rock fragments and interstitial material (Table 4-3).

Siltstone and Argillites

The Blackhead Formation has a slightly higher percentage of siltstone and argillite than does the underlying Signal Hill Formation. In composition, and texture, siltstones and argillites are identical to those of the Signal Hill Formation described on pages 31 to 32 , Chapter III.

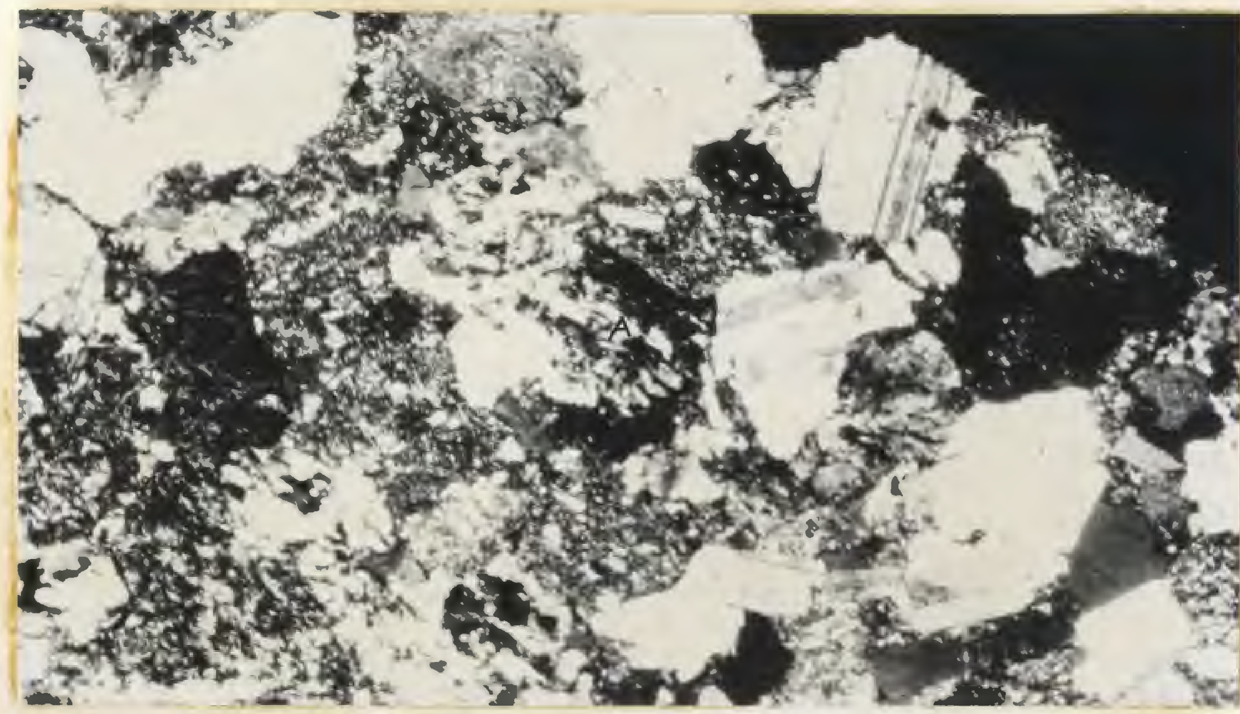
Table 4-3

Showing the variation in the composition of the sandstones of the Signal Hill and Blackhead Formations

	G R A I N S											INTERSTITIAL MATERIAL										
FORMATION				Rock Fragments					Sedim.													
	Quartz	k.Feldspar	Plagioclase	Tuff & Rhyolite	Granite & Granophyre	Diorite	Basic Volcanics	Metamorphic	Siliceous	Others	Total of Rock Frag.	"A"	Hematite	Chlorite	Epidote	Pyroxene	Biotite & Muscovite	Calcite	Magnetite	Zircon	Apatite	Sphene	Total
Blackhead Formation	34.21	10.2	21.8	1.0	2.36	0.22	0.18	Traces	8.89	3.00	15.65	9.1	4.21	2.16	1.00	0.25	0.15	0.31	0.36	Traces	Rare	Rare	17.54
Signal Hill Formation	31.72	9.3	15.7	3.0	1.30	0.10	0.15	Traces	13.1	3.28	20.93	15.0	2.81	1.2	1.8	0.89	0.31	0.24	0.20	Traces	Rare	Rare	22.35

Fig. 4-1 - Typical sandstone of the Blackhead Formation (Logy Bay). Sandstone contains abundant feldspar, quartz and rock fragments. Basic volcanic rock fragment (A). Hematite (black patches). Crossed nicols X 44.

Fig. 4-2 - Sandstone of the Blackhead Formation (Logy Bay). Unit quartz (white) with straight extinction. Undulose quartz (A). Siliceous rock fragment (B). Arrow points to interpretation of quartz grain along their border with interstitial material. Crossed nicols X 44.


A


A
B

Fig. 4-3 - Sandstone of the Blackhead Formation (Logy Bay). Deformed schist fragment in the centre. Crossed nicols X 44.

Fig. 4-4 - Sandstone of the Blackhead Formation (Blackhead - Cape Spear).

A - Tuff fragment in the centre with a big feldspar grain (A). Crossed nicols X 44.

B - Rhyolite pebble.
Crossed nicols X 44.


A

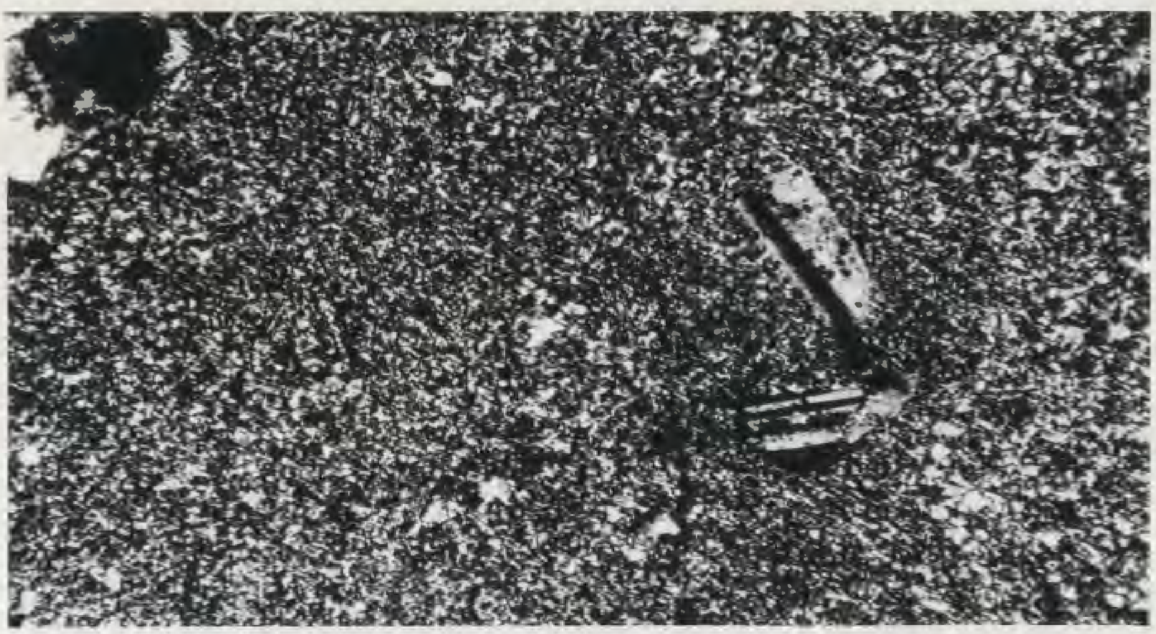


Fig. 4-5 - Cumulative curves of the Blackhead Sandstones.

Explanation:

Curve No.	1 -	Sample No. R.S.2
	2 -	Sample No. R.S.3
	3 -	Sample No. R.S.8
	4 -	Sample No. C.B.S.8
	5 -	Sample No. C.B.S.3

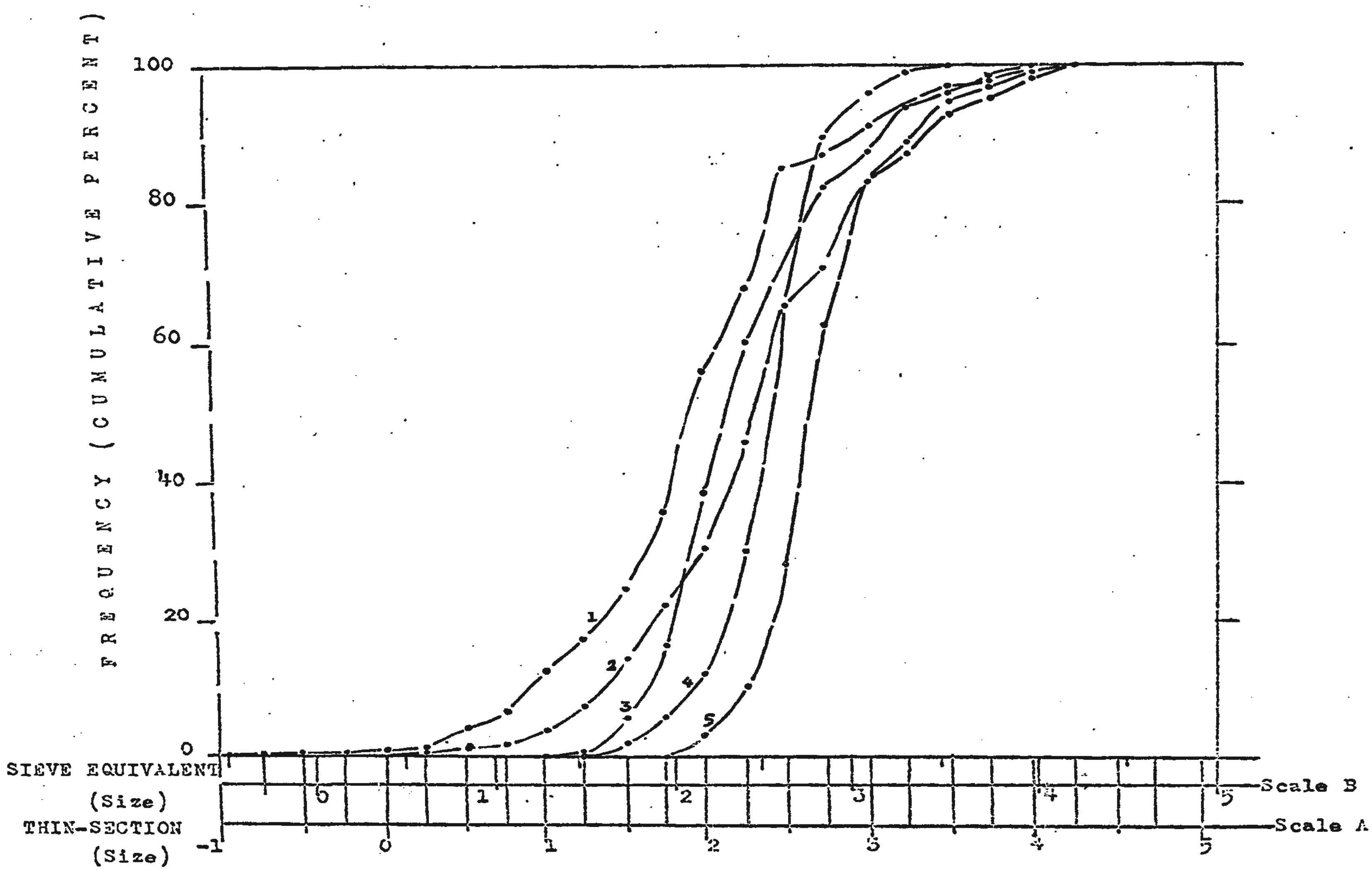

FREQUENCY (CUMULATIVE PERCENT)
100
80
60
40
20
0
1
2
3
4
5
SIEVE EQUIVALENT
(Size)
THIN-SECTION
(Size)
Scale B
Scale A
PARTICLE SIZE (Phi Units)

Fig.4-5

Fig. 4-6 - Cumulative curves of the Blackhead Sandstones.

Explanation:

Curve No. 1 - Sample No. C.B.S.10

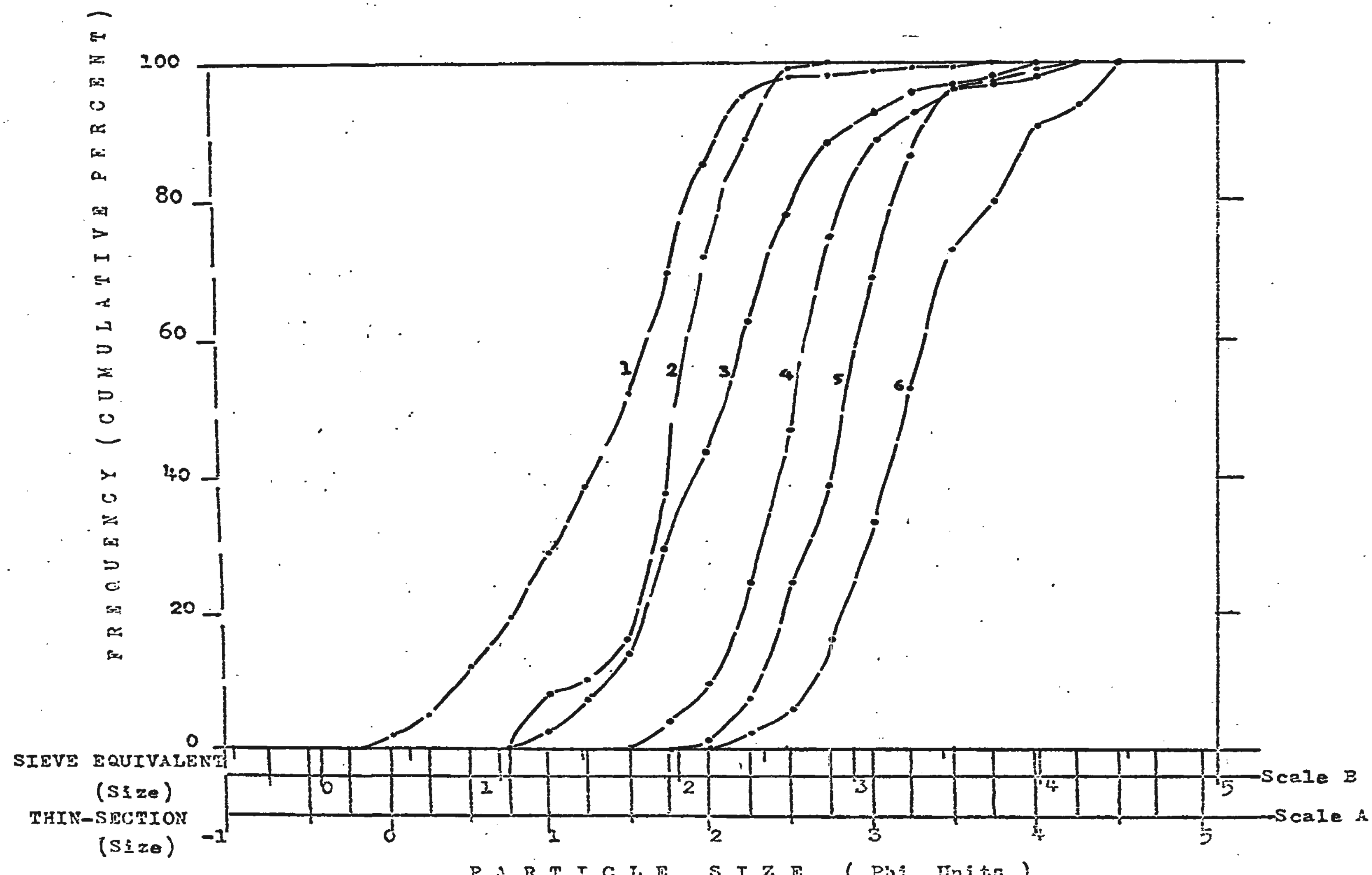
2 - Sample No. C.S.14

3 - Sample No. C.B.S.1

4 - Sample No. C.S.2

5 - Sample No. C.B.S.18

6 - Sample No. C.S.25

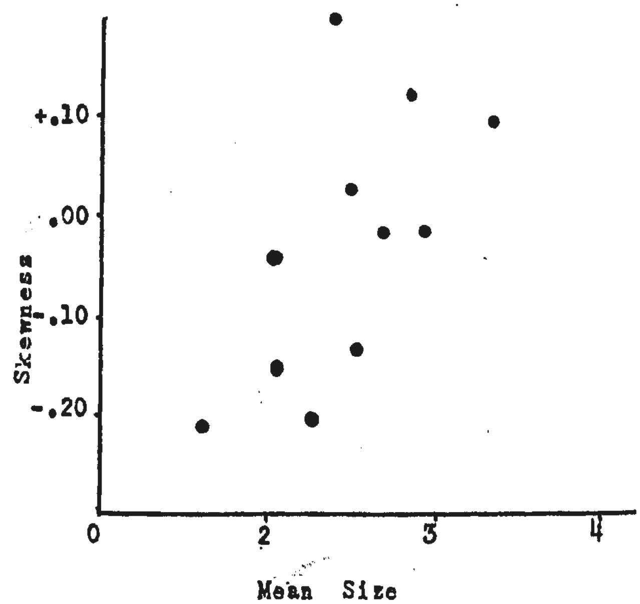


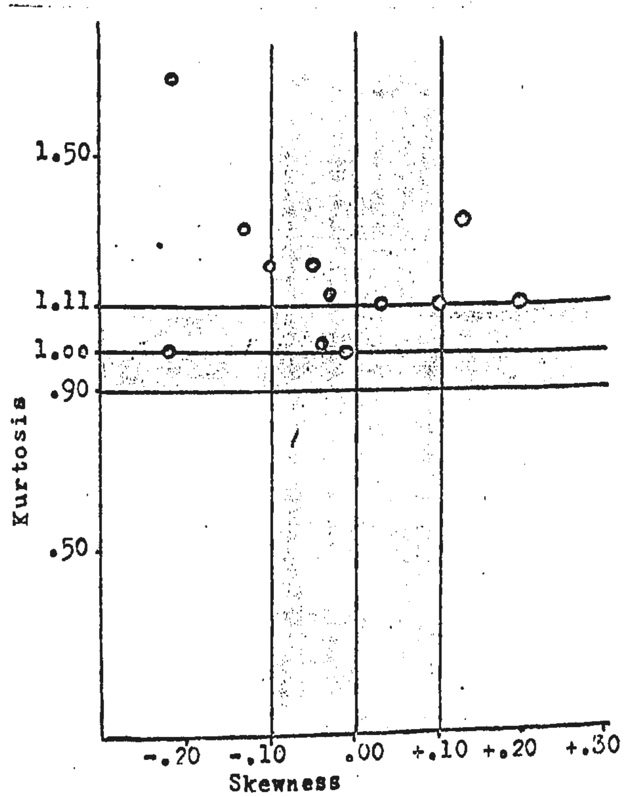
FREQUENCY (CUMULATIVE PERCENT)
100
80
60
40
20
0
1
2
3
4
5
6
SIEVE EQUIVALENT
(Size)
0
1
2
3
4
5
Scale B
THIN-SECTION
(Size)
-1
0
1
2
3
4
5
Scale A
PARTICLE SIZE (Phi Units)

Fig.4-6

Fig. 4-7 - Scatter plot of skewness versus mean size.

Fig. 4-8 - Scatter plot of skewness versus kurtosis. Areas defined as within the range of normal curve (Folk 1957, fig. 16, p.21) as shown by olive green color.


+.10
.00
-.10
-.20
Skewness
0
2
3
4
Mean Size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1.11
1.00
.90
.50
Kurtosis
-.20
-.10
.00
+.10
+.20
+.30
Skewness

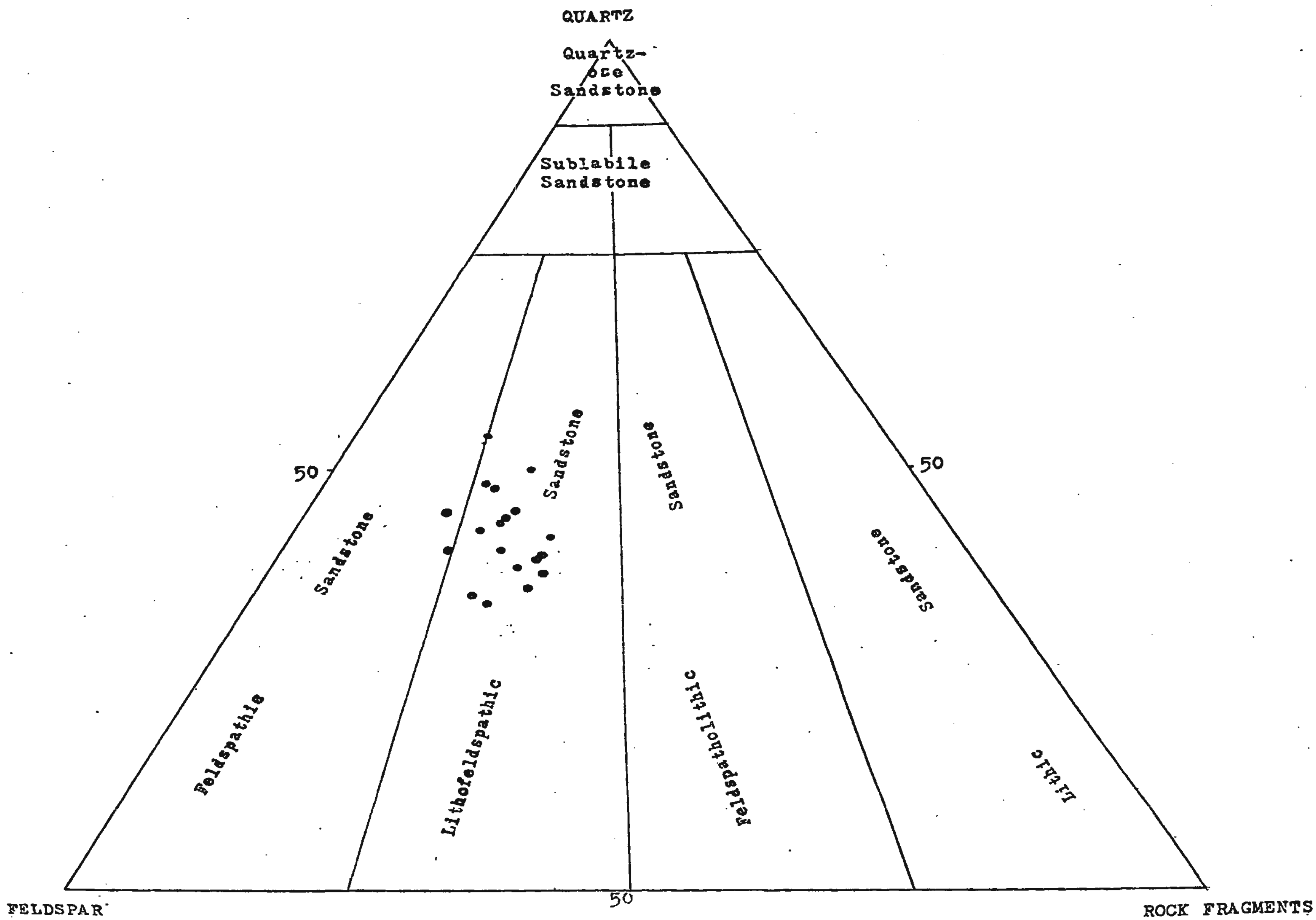
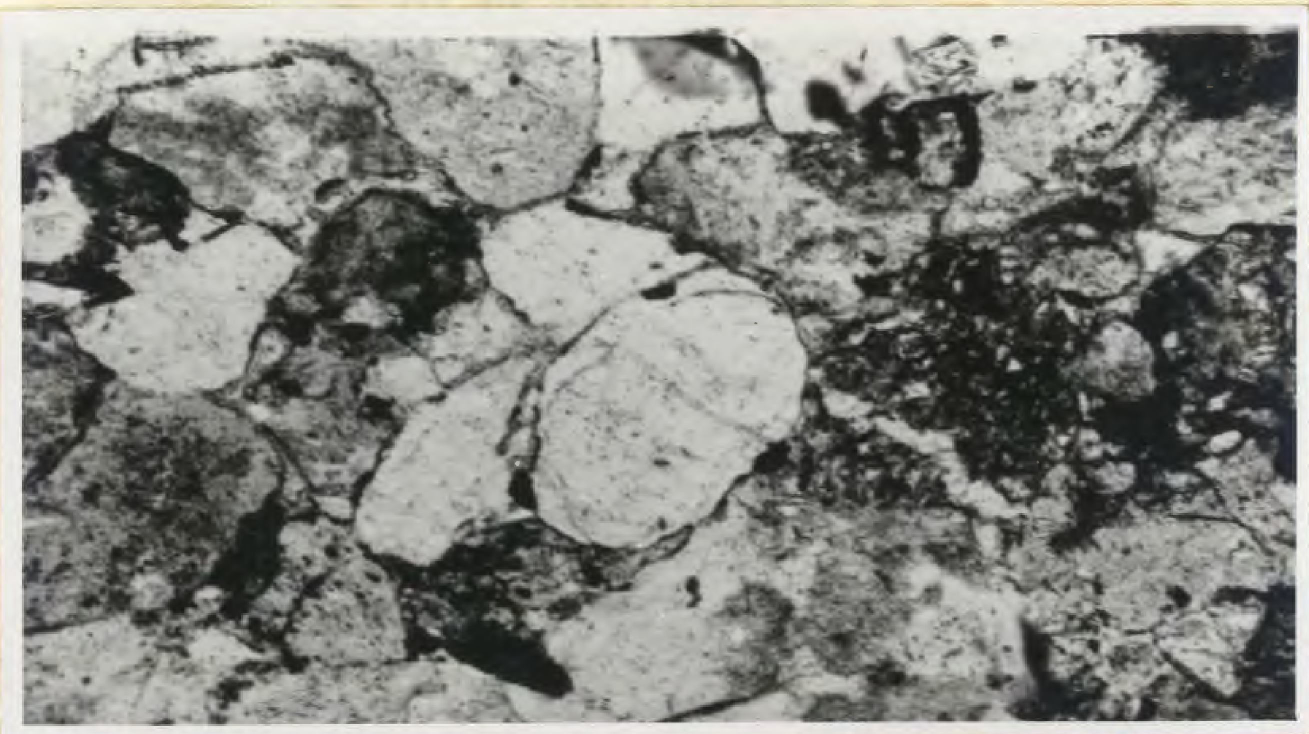


Fig.4-9. —Detail composition of sandstones from the Blackhead Formation.

Fig. 4-10 - Sandstone of the Blackhead Formation (Blackhead - Cape-Spear). Quartz grain in the centre exhibiting authigenic growth. Transmitted light X 90.

Fig. 4-11 - Sandstone of the Blackhead Formation (Logy Bay). Schist fragment in the centre. Corroded quartz grain. Crossed nicols X 300.



CHAPTER V

ENVIRONMENT OF DEPOSITION AND SOURCE OF THE SIGNAL HILL AND BLACKHEAD FORMATIONS

Preamble

The rocks of the Signal Hill and Blackhead Formations have received very little attention in the literature. Buddington (1919), Rose (1952) and Brueckner (1967) made only brief mention of the depositional environment.

The Signal Hill and Blackhead Formations, which crop out along a linear belt were examined by the author in many surface exposures; a complete three dimensional study of the vertical and lateral stratigraphic-sedimentary variations can not be undertaken because of the nature of the exposure.

An attempt has been made in the following pages to describe the depositional environment of the Signal Hill and Blackhead Formations in a most detailed manner, based on the characteristics (Table 5-1) which are considered to be more diagnostic.

Signal Hill Formation

Lower Member

Production of detritus

Folk (1959, p.5) showed that, in general, there are three size ranges of terrigenous detritus supplied in abundance by the natural processes of weathering and erosion. These three size ranges are:

(1) Gravel, medium to large pebbles (> 4mm)	Released by mechanical breakdown of rocks.
(2) Coarse sand to silt (1-.02 mm)	Liberated by granular dissintegration of rock fragments into component grains of quartz and feldspars, etc.
(3) Clay particles (<.004 mm)	Formed by chemical weathering of silicate minerals.

The sandstones of the lower member are fine to very fine grained with a higher amount (28.15%) of interstitial material, which probably reflects the inherent nature of the clastic population or mode supplied by the weathering and erosion of the source rocks and lack of sorting in the sediments that is typical of a low energy environment. The thick accumulation of the fine to very fine grained sandstones and absence of much coarser material may further imply (1) predominance of chemical weathering, and/or (2) source area far from the site of deposition, or (3) predominance of fine textural clastic rocks in the source and (4) moderate to high rate of subsidence in the depositional site and moderate to low rate of uplift in the source area. No doubt some of these factors have been important to deposition of fine grained sediments. However, comparatively higher amount of relatively unweathered feldspars indicates a lack of or insignificant chemical weathering in the source area; and the angular to subangular detrital grains and the size of the feldspar grains which are larger than the average grain-size of the sediments do not record much transport.

The possible source rocks, north and west of the map-area are composed of sedimentary and volcanic rocks which when weathered could produce fine grained sediments.

Evidence of subsidence

Observed grain size, general angularity of the grains, a higher amount of feldspar, and sorting indicate a moderate to high rate of subsidence in the depositional site and a moderate to low rate of uplift in the source area. Moderate to high rate of subsidence suggests moderate to high rate of burial (deposition) and less reworking. It also seems to indicate that sedimentation and subsidence continued in such balance that the depositional site remained shallow but was covered by a permanent sheet of water.

Currents

The general fineness of grain size and the maximum thickness of this member as seen in the Witless Bay area is fair evidence that average currents were weaker and rate of subsidence (in the Witless Bay area) was probably higher than elsewhere.

General angularity of the grains, absence of trough-cross-stratification and turbidity current structure, and the presence of ripple marks, - suggest that water in the depositional site was not deep and traction currents were dominant. The energy of these currents, however, was not sufficient to effectively abrade the grains or to produce trough-cross-stratification or to sort out the sediments. Localized occurrence of ripple drift cross laminations probably indicates rapid deposition in a comparatively quite waters.

Conclusion

A subsiding basin probably occupied the map-area in which at-least 4440 feet of fine to very fine grained sandstones, interbedded subordinate argillites and siltstones were deposited in late Precambrian times. The upward change from dominantly black and grey rocks of the St. John's Formation to greenish grey rocks of the Signal Hill Formation probably resulted from continued uplift in the source area coupled with a great influx of coarser grained sediments in the depositional basin, marking the beginning of the Signal Hill Formation.

Middle Member

Sediment Supply

The average coarser grain size of the sediments of the middle member as compared to the underlying lower member may indicate a progressive increase in the rate of sediment supply. The latter reflects an increase in the rate of uplift and erosion at the source area. An increase in the rate of sediment supply resulted in gradual filling of the depositional basin and establishment of good circulation, as indicated by the red color.

Currents

The lithology, relatively low amount of interstitial material (22.7% as compared to 28% in the lower member) and associated sedimentary structures (table 5-1) suggest transportation and deposition probably by traction currents of comparatively higher velocity. However, the laminations may indicate either fluctuations in the rate of sediment supply or a period of quiet deposition.

Thixotropic deformation

During or shortly after deposition, sedimentary structures, such as sandstone dykes and convolute laminations which probably resulted from soft sediment deformation, developed. Selley and others (1963, p. 237-243) have described structures (from shallow water deposits) similar in many ways to those recorded from this member. They proposed that these structures probably formed insitu by the shifting and re-arrangement of quick sands. The overturned flame structure found in one bed at Petty Harbour may indicate rapid deposition of sand onto a water saturated hydro-plastic layer (Kuenen and Menard 1952, p. 90), and later slippage along the bedding planes.

All these features of soft sediment deformation perhaps indicate that sediment accumulated rapidly with loose packing and so trapped large volumes of water.

Argillite fragments of intraformational origin

Minor interruptions in the sedimentation are indicated by the presence of red argillite fragments in the upper part of the middle member. The intraformational origin of the red argillite fragments is demonstrated by (1) their angular edges, (2) their lithology which is identical to that of red argillite interbedded with the sandstones and (3) bent fragments indicate that argillite was probably weakly lithified at the time of deposition.

Conclusion

In summary, it is assumed that rocks of the lower and middle members of the Signal Hill Formation were deposited in an environment similar in many ways to Rich's (1950) undathem environment (wave zone) where sediment is under the influence of direct wave action.

Localized occurrence of tuff beds in the lower and middle members suggests a period of volcanic activity during the deposition of the sediments in which they are intercalated, at a far distant source.

Progressive infilling of the depositional basin with some 3000 feet of sediment (middle member), and reduction in subsidence probably resulted in the development of a fluviatile environment in which conglomerate and sandstones of the upper member were deposited.

Upper Member

Production of detritus

It is presumed that material of the conglomerates originated in a elevated area. Large amounts of detritus would have been supplied by weathering, mass-wasting and abrasion by streams. The detritus thus produced, was transported and deposited probably under varying conditions as reflected in the grain size and bedding characters of the resulting deposits.

Coarsening upwards sequence

The coarsening upward of the sequence (Plates 2-2 to 2-4) may imply a combination of: (1) gradual increase in the rate of sediment supply which reflects an increase in the rate of uplift at the source area and (2) a steady increase in the power of streams, which at first permitted transport and deposition of sand and small pebbles and later predominantly pebble and small sands. Much later, deposition of coarse pebbles and cobbles resulted from the most powerful streams which moved material from the headwaters of the valley.

Fining upwards sequence

Higher up in the stratigraphic sequence (Plates 2-2 to 2-4) progressive decrease in the grain size suggests a decrease in the gradient of the stream supplying the material due to a reduction in elevation of the adjacent source by erosion. A similar upward variation in the grain size and bedding character in a non marine clastic wedge has been explained by Gwin (1964, p. 657) as a change in the depositing streams from the conditions of dominantly shooting flow of the upper flow regime to those tranquil flow of the lower flow regime.

The upward variation in the characters of the Torridonian Applecross Group in Northern Scotland has also been attributed to the same mechanism by Williams (1966 p. 1303). Some of the features which he describes, such as gradual decrease in the pebble size and thickening of the group southwards, are similar in many ways to those recorded from the upper member of the Signal Hill Formation. Williams suggests a retreating mountain front (1966, Fig.-3, p. 1305) to explain lateral and vertical variations within the group. The idea of a retreating mountain front could also be used to explain the variations within the upper member of the Signal Hill Formation. However, data on current direction is lacking which could have further strengthened this assumption.

<u>Conclusion</u>

The writer is of the opinion that the sediments of the upper member originated under fluviatile conditions, with rapid erosion and rapid deposition of pebbles and sands by a depositional mechanism in a subsiding basin. The climate was probably semiarid (Buddingtom, 1919) favouring gravel production and incomplete weathering. The depositional mechanism must have been capable of (1) moving large quantities of coarse clastic material during each depositional event, (2) of creating planar and trough-cross-stratification and channels, and (3) of sorting and abrading the grains. These conditions would have been fulfilled by river currents, such as sheet floods associated with alluvial fans, depositing gravels at the base of an elevated landmass or scarp.

The breccia conglomerate at Flatrock probably represents a local alluvial fan (Brueckner 1967) as the components of this deposit are angular red fragments of Conception type rocks that can only have travelled a very short distance.

Blackhead Formation

General account (members undifferentiated)

Sediment supply

The sedimentation history of the map area during Blackhead times probably started with the supply of sand mode detritus in the depositional site. Apart from minor fluctuations, the rate of sediment supply was probably continuous but relatively slow as compared to the period during which conglomerates of the Signal Hill Formation were deposited. Also, a higher amount of granitic rock fragments and potash feldspars in these sandstones, compared with the underlying Signal Hill Sandstones, is suggestive of progressive uncovering of the granitic rocks in the source area.

Currents

The lithology and associated sedimentary structures (Table 5-1), a higher amount of feldspars, moderate to poor sorting and general angularity of the grains, point to an environment in which traction currents were active but relatively weak to sort out and effectively abrade the grains. Partings and thin beds of argillite and siltstone probably indicate relatively quiet waters of deposition.

Thixotropic deformation

The locallized occurence of sedimentary structures attributed to flow of quicksands is perhaps an indication that the sediments accumulated rapidly with loose packing and in doing so, trapped large volumes of water.

Environment

A fluviatile environment therefore seems probable for sediments of the Blackhead Formation. Also, they resemble other ancient fluviatile deposits such as the Hants Facies of Wolfville Formation, Triassic, Canada (Klein 1962) and the Devonian Old Red Sandstone (Friend 1961; Allen, J.R.L. 1962a and b). The rocks of the Blackhead Formation are similar in parts to the Red Facies of the Torridonian described by Selley (1965, p. 377). Selley on the basis of coarseness, thickness (2000 m) and unidirectional current pattern suggests that the rocks of the Red Facies were probably deposited by braided rivers. It is therefore, reasonable to assume that if the underlying conglomerate of the Signal Hill Formation represents an alluvial fan, then the sandstones of the Blackhead Formation which gradationally overlies them may possibly represent a braided river deposit.

Pigmentation

In reference to his Signal Hill Series Buddington (1919) States:

> "that the red color of the brown sandstones is due to hematite and to the oxidation of its iron content is evident from a comparison of the ferrous and ferric contents of the red and green sandstones. Although both have similar total contents of iron, 4.74 and 5.11 percent respectively, expressed in terms of ferrous iron, the brown sandstone shows 4.75 percent of ferric oxide and only 0.46 percent of ferrous oxide, whereas the green sandstone shows 2.54 percent of ferric oxide and 2.82 percent of ferrous oxide.

> The red color of the sandstones depends in varying degree upon the primary deposition of hematitic mud in the interstices of the sand grains; deposition of hematite as a cement around the sand grains, upon hematite existing in the grains themselves as in the cleavage cracks of feldspar, or in oxidized basalt and rhyolite; and upon the hematite resulting from the oxidation of magnetite grains *in-situ*".

Provenance

The mineralogical composition of the sediments in a depositional site is largely determined by the nature of the rocks in the source area. A mineral assemblage such as detailed in Chapter 3 (Tables 3-1 and 4-1) indicates common source rocks for the Signal Hill and Blackhead Formations.

The probable provenance of the rock types based on the composition of sandstones and conglomerate are described; four terrains or major lithologic units are thought to have formed the source area and are outlined below:

(1a) A terrain of sedimentary rocks, to provide siliceous rock fragments, fragments of sandstone, siltstone and argillite and "second cycle quartz".

(1b) A local sedimentary source, suggested by Brueckner (1967) for the sedimentary rock fragments in the breccia conglomerate at Flatrock.

(2a) A volcanic source, in which rocks of acid and basic volcanics are exposed to supply fragments of the rhyolite, tuff and basic volcanics; also much of the plagioclase feldspars and inclusion free, non-undulatory extinguishing quartz grains with straight sides.

(2b) A far distant volcanic source, to account for the occurrence of local tuff beds at Ferryland and Sugarloaf Pond areas.
(3) A plutonic terrain, in which rocks such as granite, granophyre, granodiorite and diorite are exposed to provide much of the straight to slightly undulose extinguishing quartz, potash and plagioclase feldspars. Fragments of these rock in the Signal Hill and Blackhead Formations are direct evidence of the presence of such rock types in the source region.
(4) A metamorphic terrain, to account for strong undulose extinguishing quartz grains, fragments of quartzite and schists.

The nearness of the source area to the depositional site is indicated by the general angularity of the grains and the size of the detrital plagioclase (relatively larger than the average grain size of the sediments). The sediments were deposited by a main current flowing from a general northerly direction as indicated by qualitative analysis of current beddings (Brueckner 1967).

Because of their lithologic similarity to the underlying rocks, the most likely source of sediment would be the Harbour Main, Conception and Holyrood rocks now exposed to the north and west of the map-area (Rose 1952, Brueckner 1967). An increased amount of granite rock fragments and potash feldspar in the Blackhead Formation, compared with the underlying Signal Hill Formation may indicate a progressive uncovering of Holyrood type granite.

TABLE 5-1

Formation	Member	Color	Texture	Composition	Bedding	Deformational Structures
BLACKHEAD FORMN.	Upper Middle Lower	Red Grey Red	Dominantly medium to fine sand grade grains. Grains range in size from coarse sand to clay grade.	Sandstones. Minor siltstones and argillites.	Planar-cross-stratification (Fig.5-3B). Trough-cross-stratification (Fig.5-2).Rare channels,ripple laminations and trough - structures (Fig. 5-3A).	Localized sandstone dykes and mudcracks.
SIGNAL HILL FORMN.	Upper	Red	Grains dominantly pebble grade. Grains range in size from sand to cobble grade.	Dominant conglomerate. Sandstones, rare siltstones and argillites.	Planar-stratification in the lower part. Planar-cross-stratification(Fig.5-1). Trough-cross-stratification and rare channels in the upper part.	
	Middle	Red	Dominantly fine to med. sand grade grains. Grains range from v.coarse sand to clay grade.	Dominant sandstone, Siltstones and argillite.	Laminations,planar-cross stratification and ripple laminations (Fig.5-5).	Localized sandstone dykes(Fig.5-5).Convolute laminations(Fig.5-9). Overturned flame structure.
	Lower	Greenish grey.	Dominantly fine-v. fine sand grade grains.Grains range from c.sand to clay grade.	Dominant sandstone. Siltstones and argillites.	Current ripple marks(Fig.5-4). Rare cross-stratification and ripple drift-cross-laminations (Fig.5-6).	

Fig. 5-1 - Planar cross-stratification in pebbly sandstones of the upper member of the Signal Hill Formation (Cape Spear).

Fig. 5-2 - Trough Cross-stratification (right centre of the photo) and structures produced by soft sediment deformation in the sandstones of the Blackhead Formation, (Blackhead).

Fig. 5-3 A - Trough structure in the sandstones of the Blackhead Formation (Blackhead - Cape Spear).

Fig. 5-3 B - Part of trough structure (left margin of photo) and planar cross-stratification in the sandstones of the Blackhead Formation (Blackhead - Cape Spear).

Fig. 5-4 - Current ripple marks in the sandstone of the lower member (Signal Hill Formation), Bay Bulls.

Fig. 5-5 - Current ripple laminations in the sandstone of the middle member (Signal Hill Formation), Ferryland.

Fig. 5-6 - Ripple drift-cross laminations in the sandstone of the lower member (Signal Hill Formation), Witless Bay.

Fig. 5-7 - Sandstone dyke intruding through the laminated sandstone of the middle member (Signal Hill Formation), Ferryland.

Fig. 5-8 - Deformation in the middle horizon produced by quick sand activity in the middle member (Signal Hill Formation), Ferryland.

Fig. 5-9 - Convolute laminations in the sandstones of the middle member (Signal Hill Formation), Ferryland.

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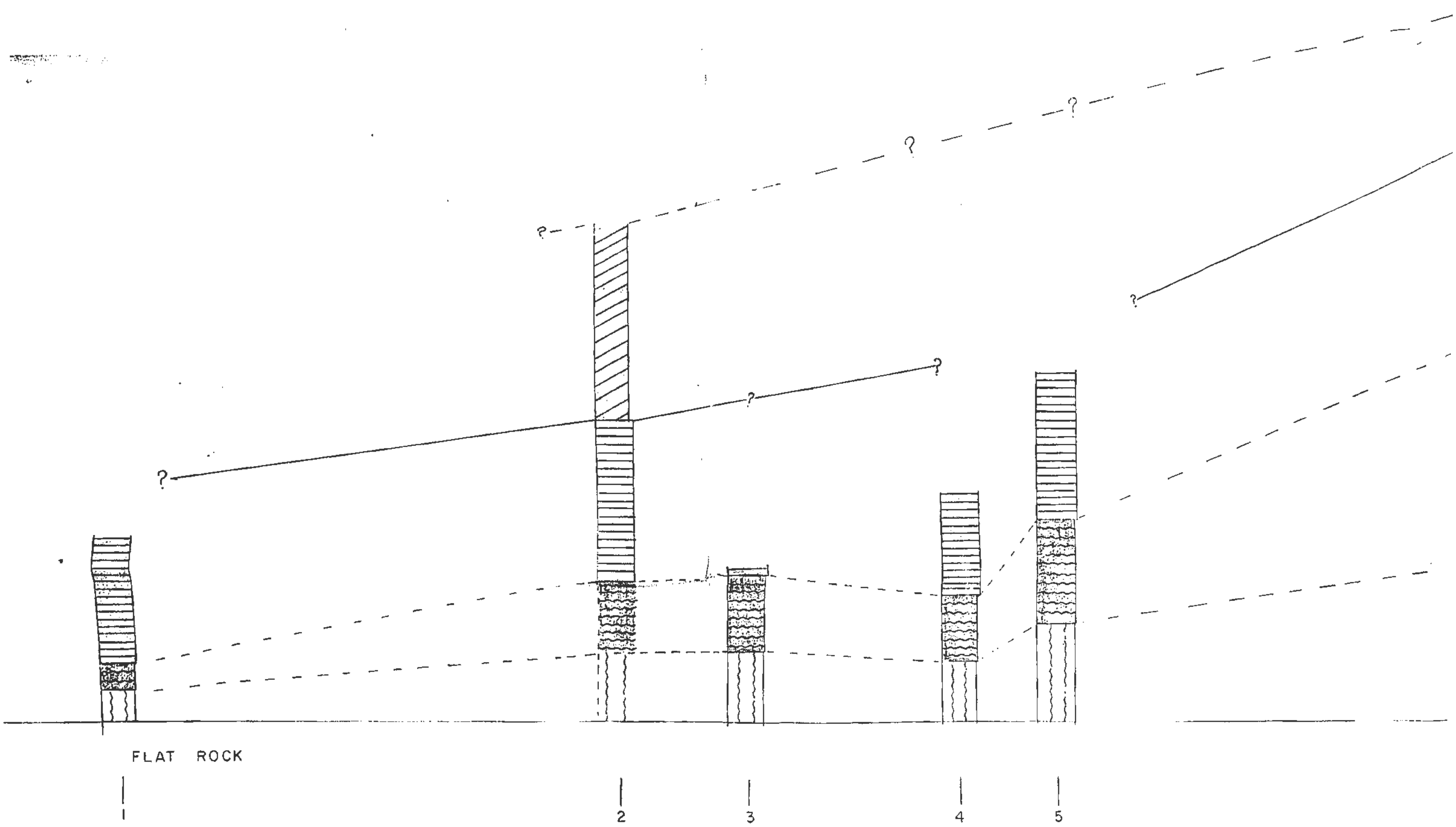
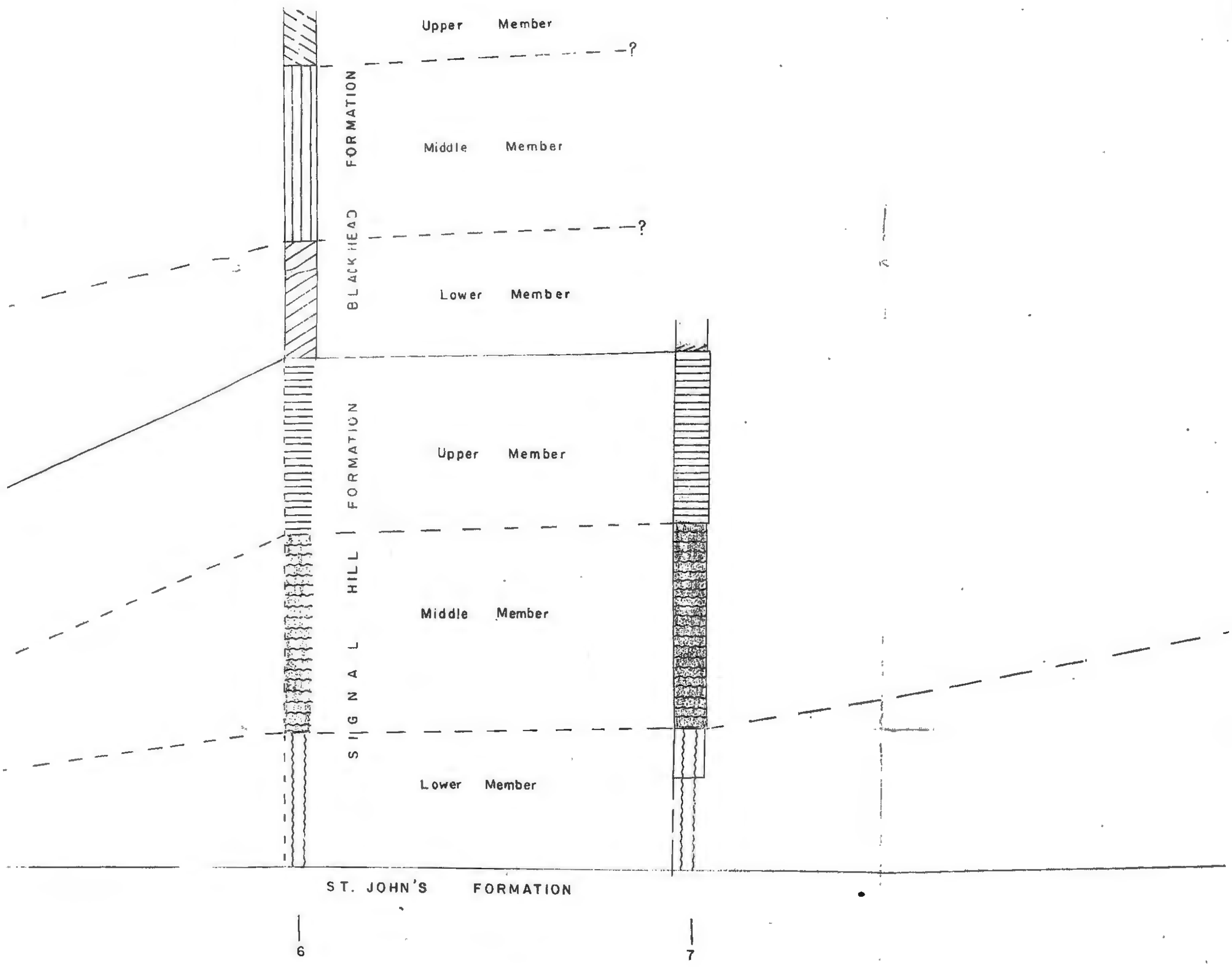




Upper Member
Middle Member
Lower Member
BLACK HEAD FORMATION
Upper Member
Middle Member
Lower Member
SIGNAL HILL FORMATION
ST. JOHN'S FORMATION
6
7

2 of

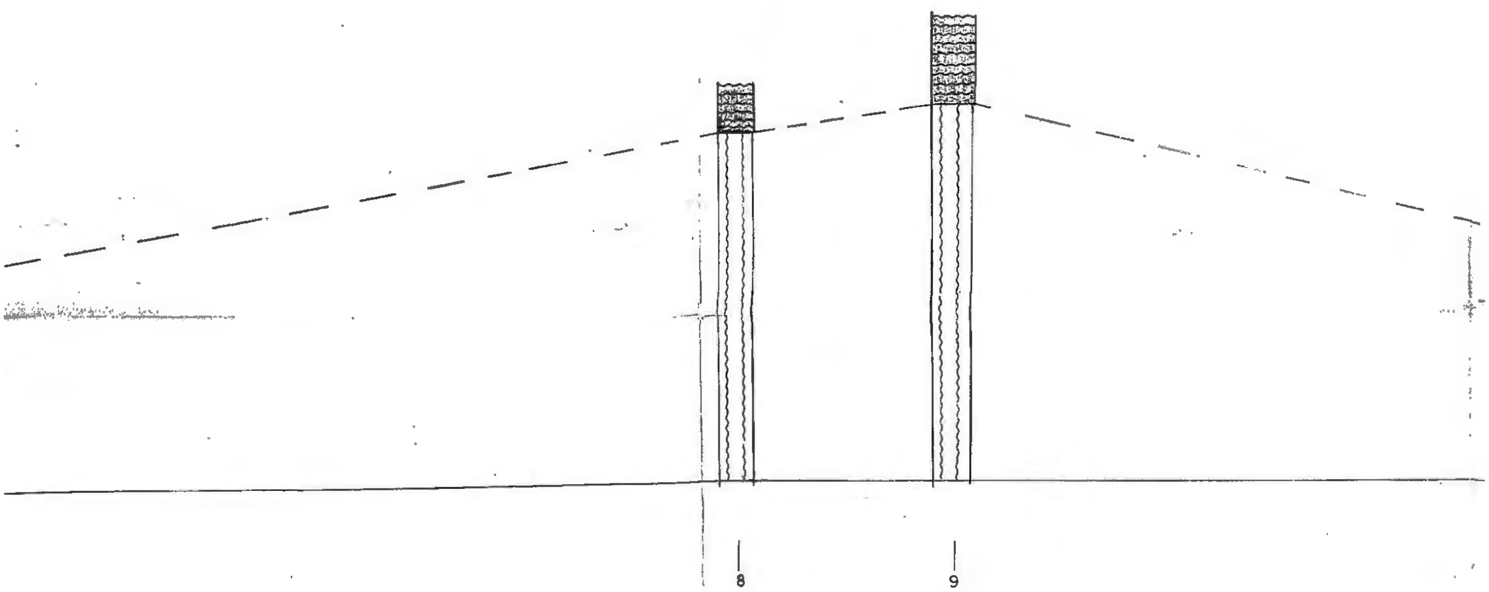


Plate 2-1- STRATIGRAPHIC CORRELATION OF THE SIGNAL HILL AND BLACKHEAD FORMATIONS BETWEEN FLAT ROCK AND FERRYLAND

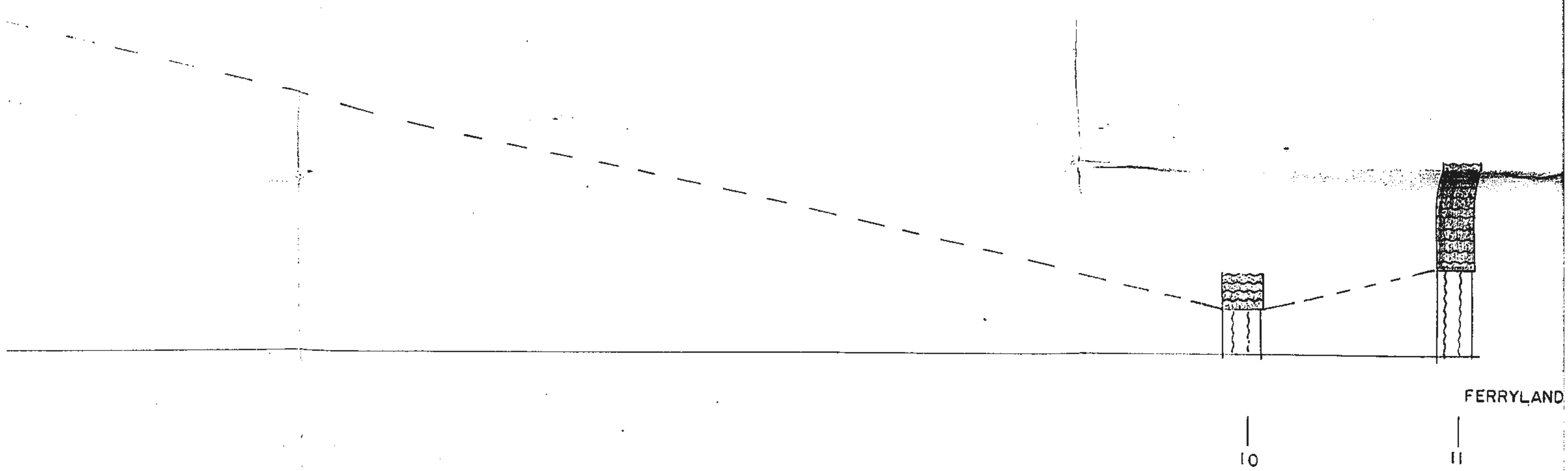


Plate 2-1- STRATIG

AND

FLAT

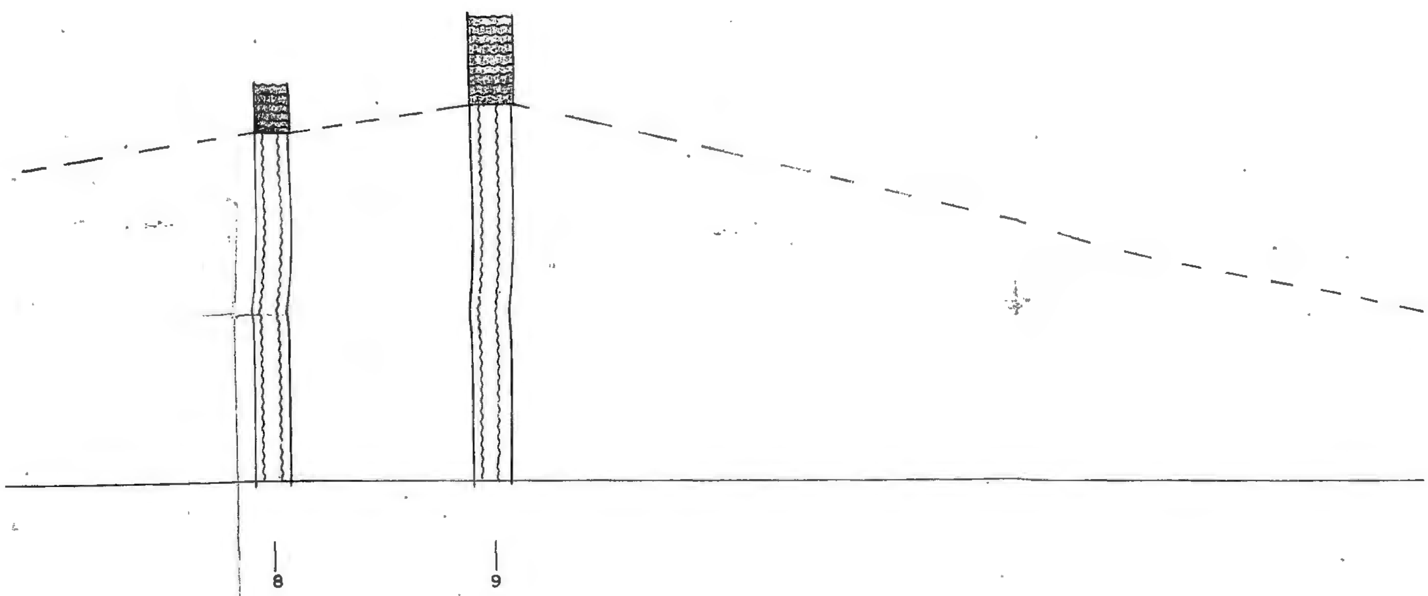
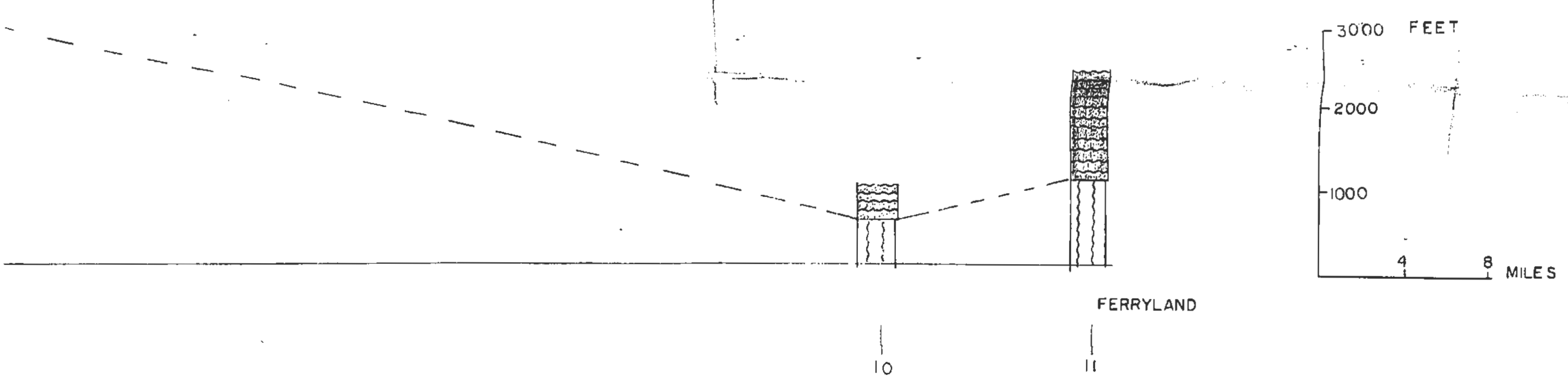


Plate 2-1 - STRATIGRAPHIC CORRELATION OF THE SIGNAL HILL AND BLACKHEAD FORMATIONS BETWEEN FLAT ROCK AND FERRYLAND



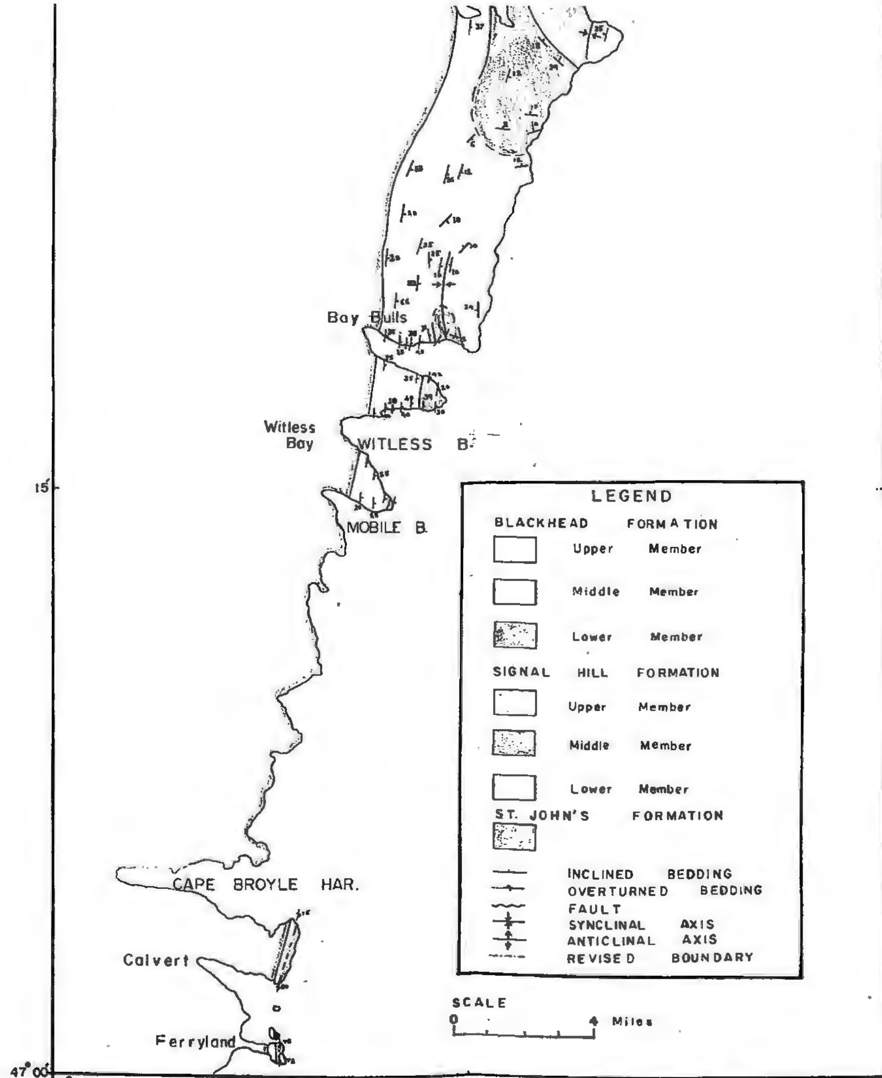
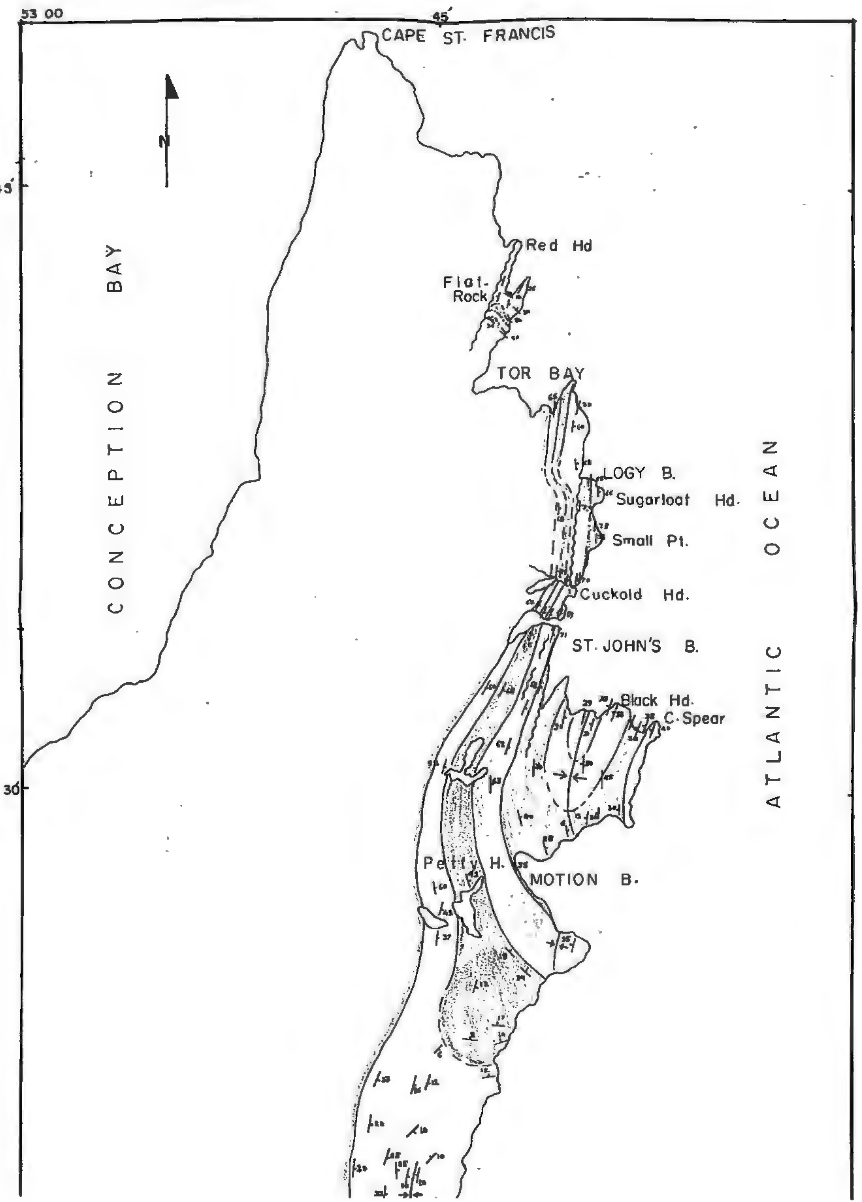
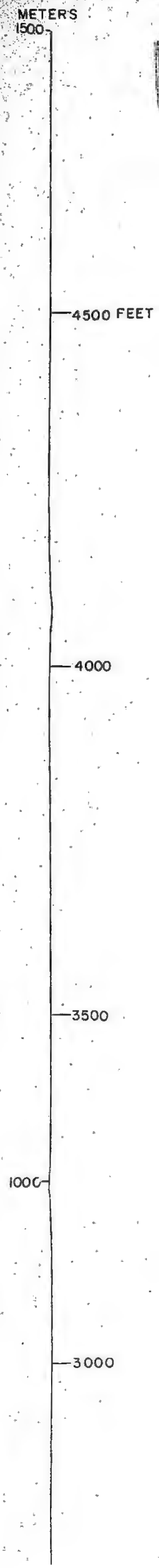
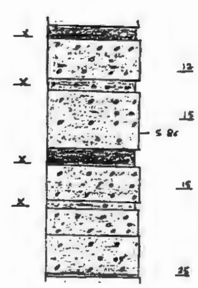


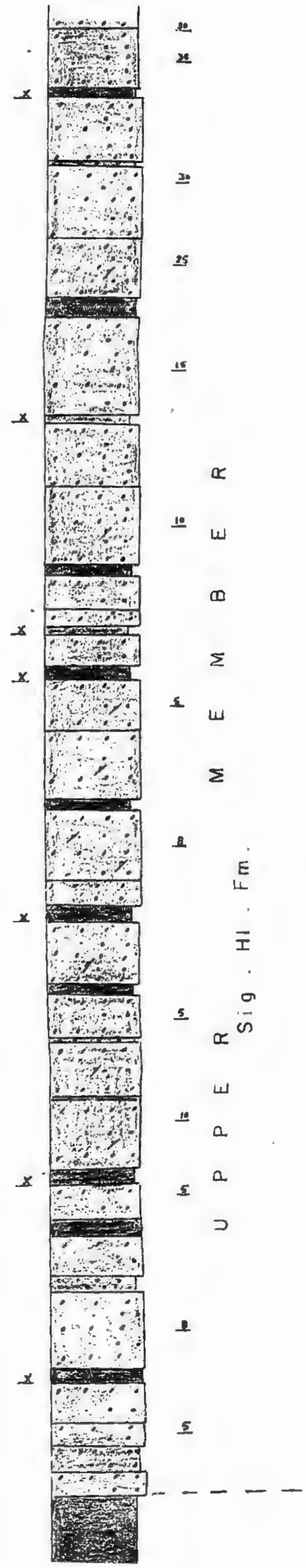
FIGURE 2-1 GEOLOGICAL MAP OF THESIS AREA
(Based on Rose 1952)


53 00
45'
45'
30'
CAPE ST. FRANCIS
Red Hd
Flat-Rock
TOR BAY
LOGY B.
Sugarloaf Hd.
Small Pt.
Cuckold Hd.
ST. JOHN'S B.
Black Hd.
C. Spear
Petty H.
MOTION B.
CONCEPTION BAY
ATLANTIC OCEAN
N

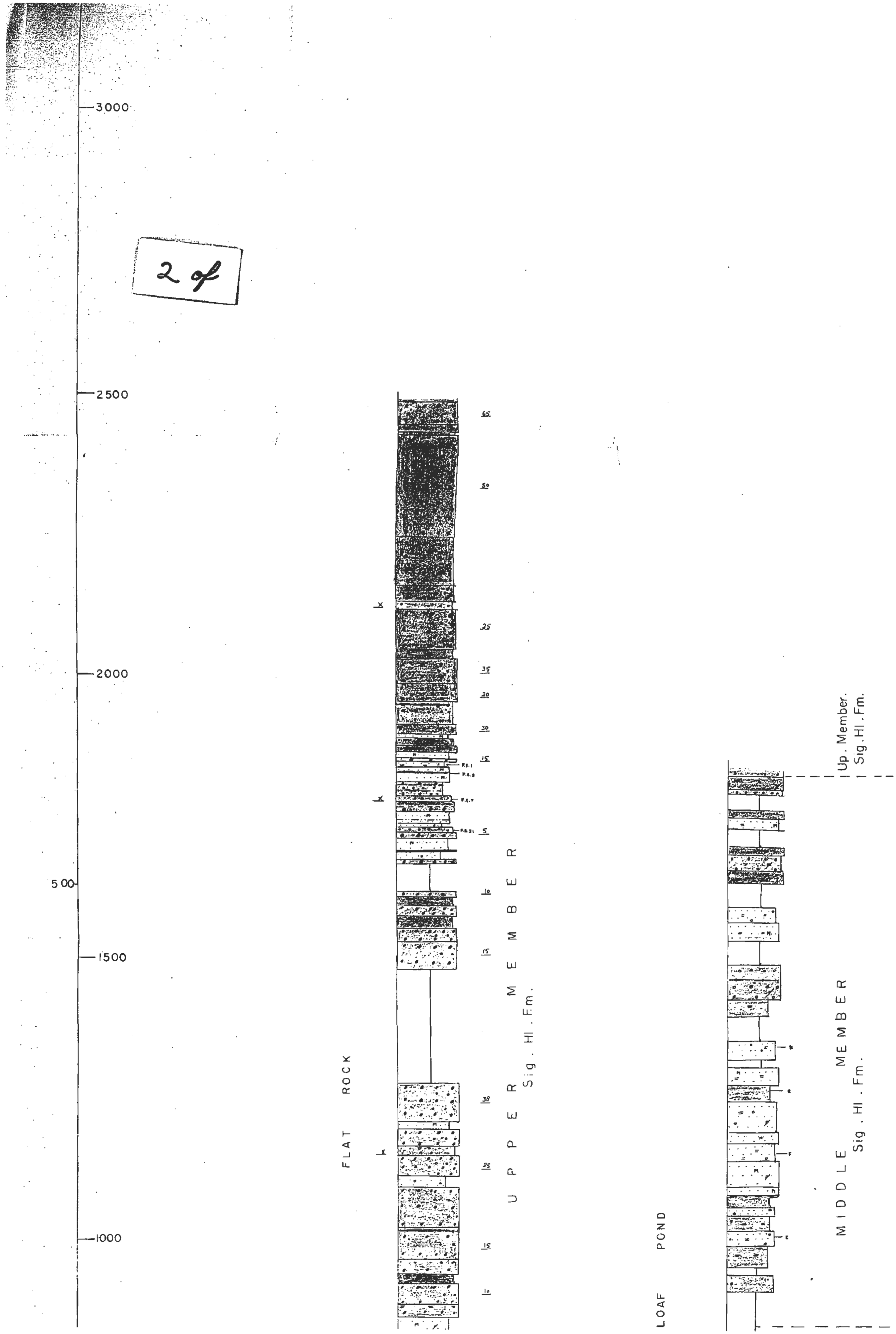
1 of

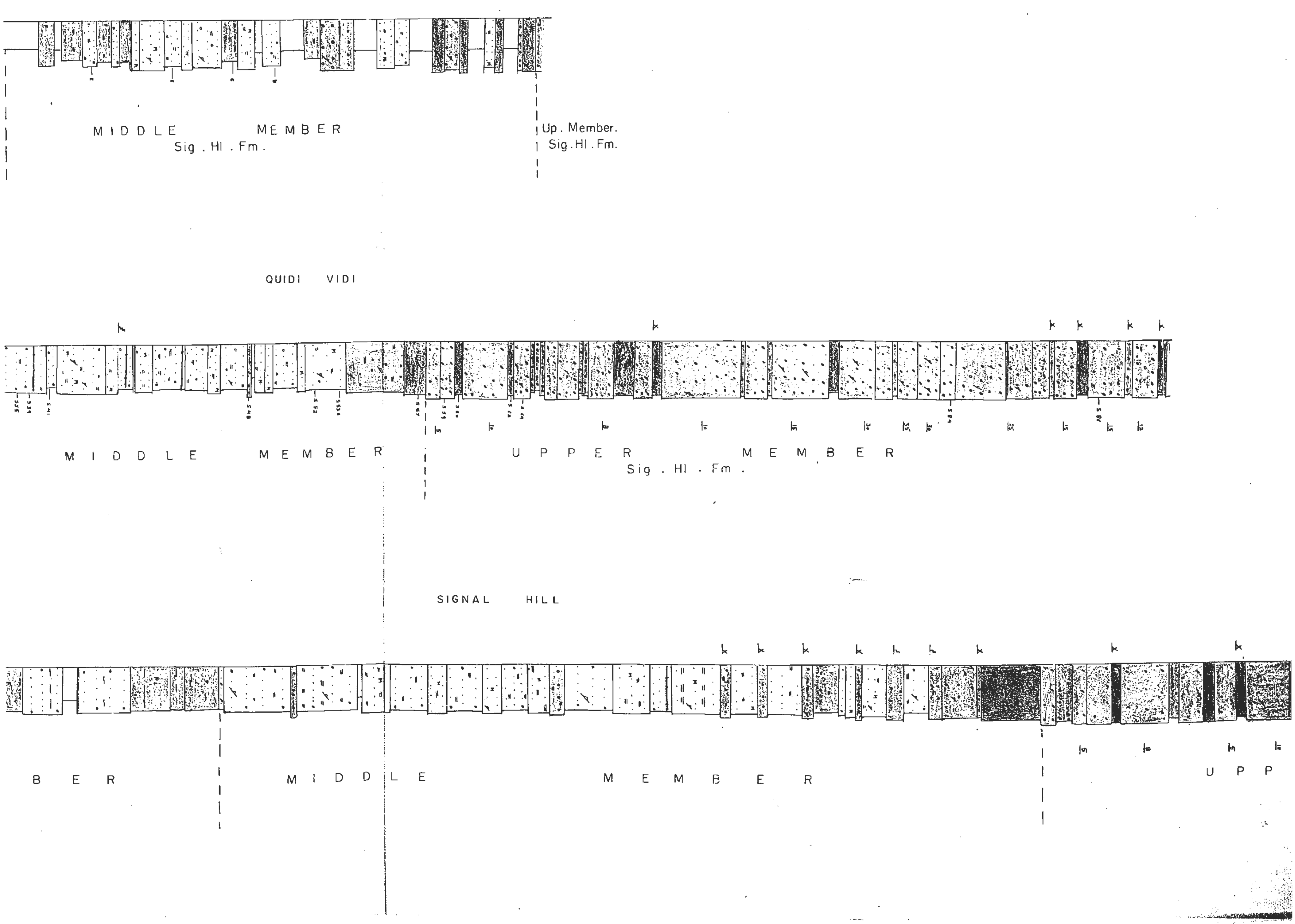


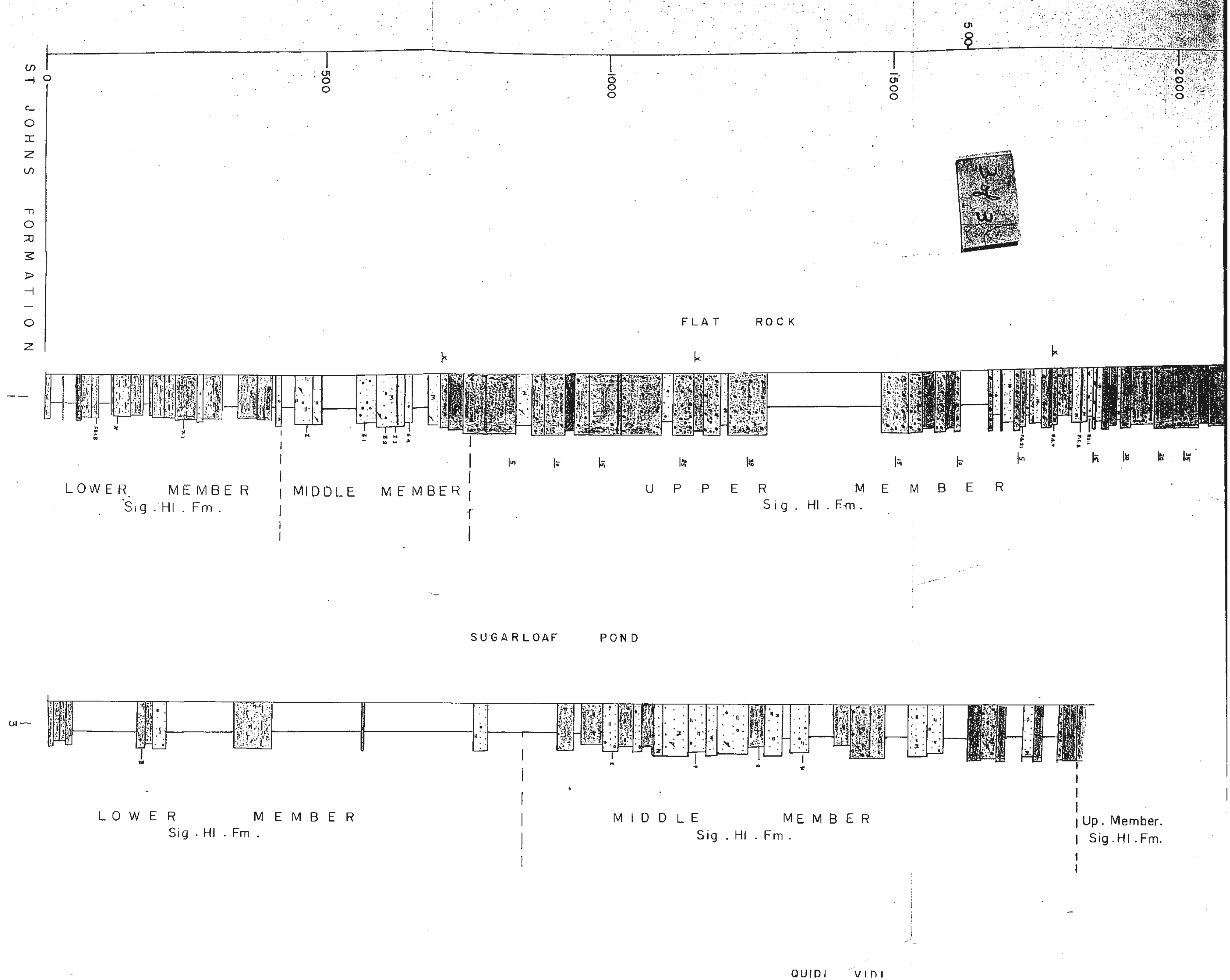



UPPER MEMBER
Sig. Hl. Fm.

2 of


3000
2500
2000
500
1500
1000
FLAT ROCK
UPPER MEMBER
Sig. Hl. Fm.
LOAF POND
MIDDLE MEMBER
Sig. Hl. Fm.
Up. Member.
Sig. Hl. Fm.
65
50
25
35
20
30
15
5
10
15
30
25
15
10


MIDDLE MEMBER
Sig. Hl. Fm.
Up. Member.
Sig. Hl. Fm.
QUIDI VIDI
MIDDLE MEMBER
UPPER MEMBER
Sig. Hl. Fm.
SIGNAL HILL
BER
MIDDLE MEMBER
UPP


ST JOHNS FORMATION
0
500
1000
1500
2000
FLAT ROCK
LOWER MEMBER
Sig. Hl. Fm.
MIDDLE MEMBER
UPPER MEMBER
Sig. Hl. Fm.
SUGARLOAF POND
LOWER MEMBER
Sig. Hl. Fm.
MIDDLE MEMBER
Sig. Hl. Fm.
Up. Member.
Sig. Hl. Fm.
QUIDI VIDI

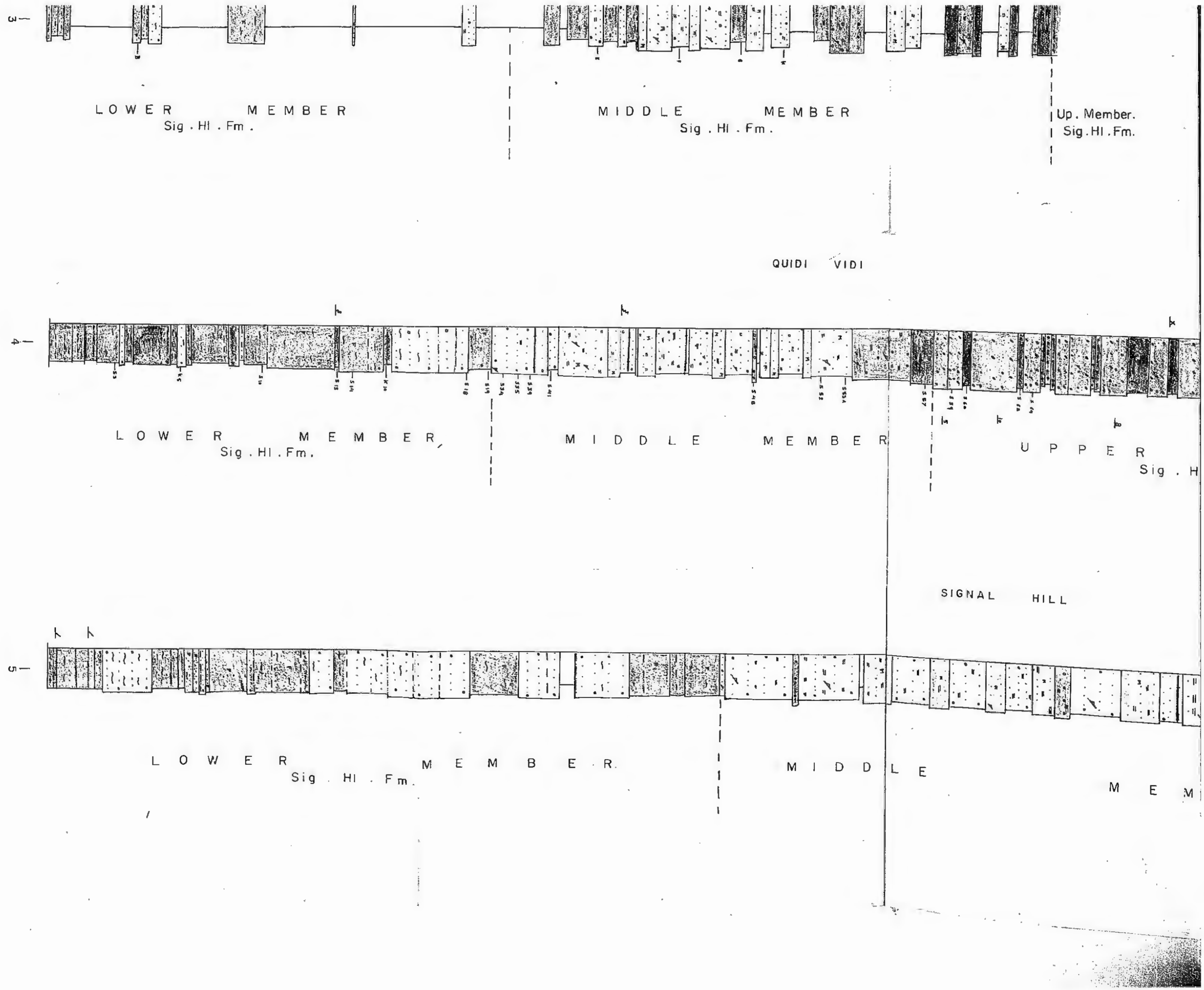
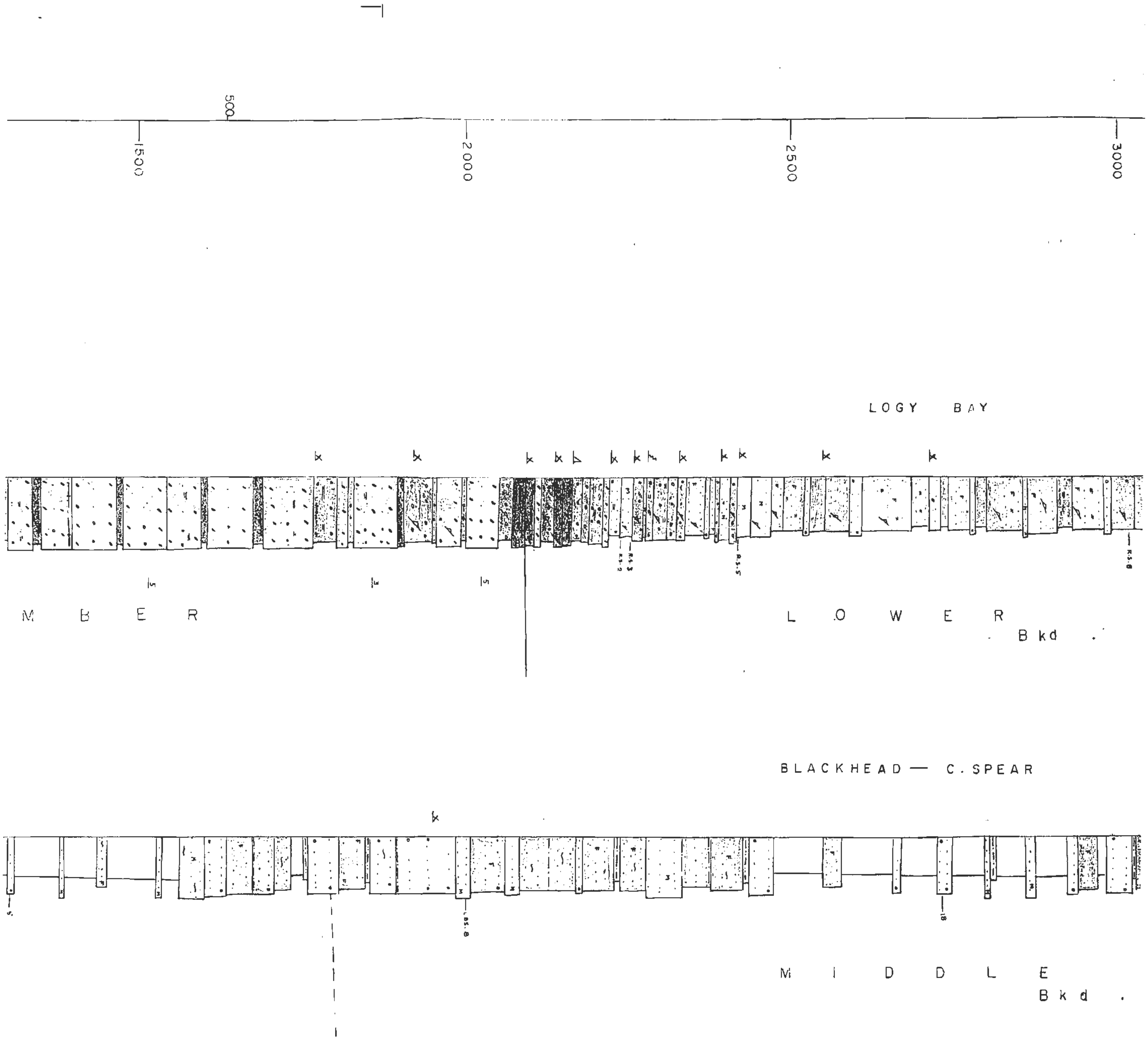
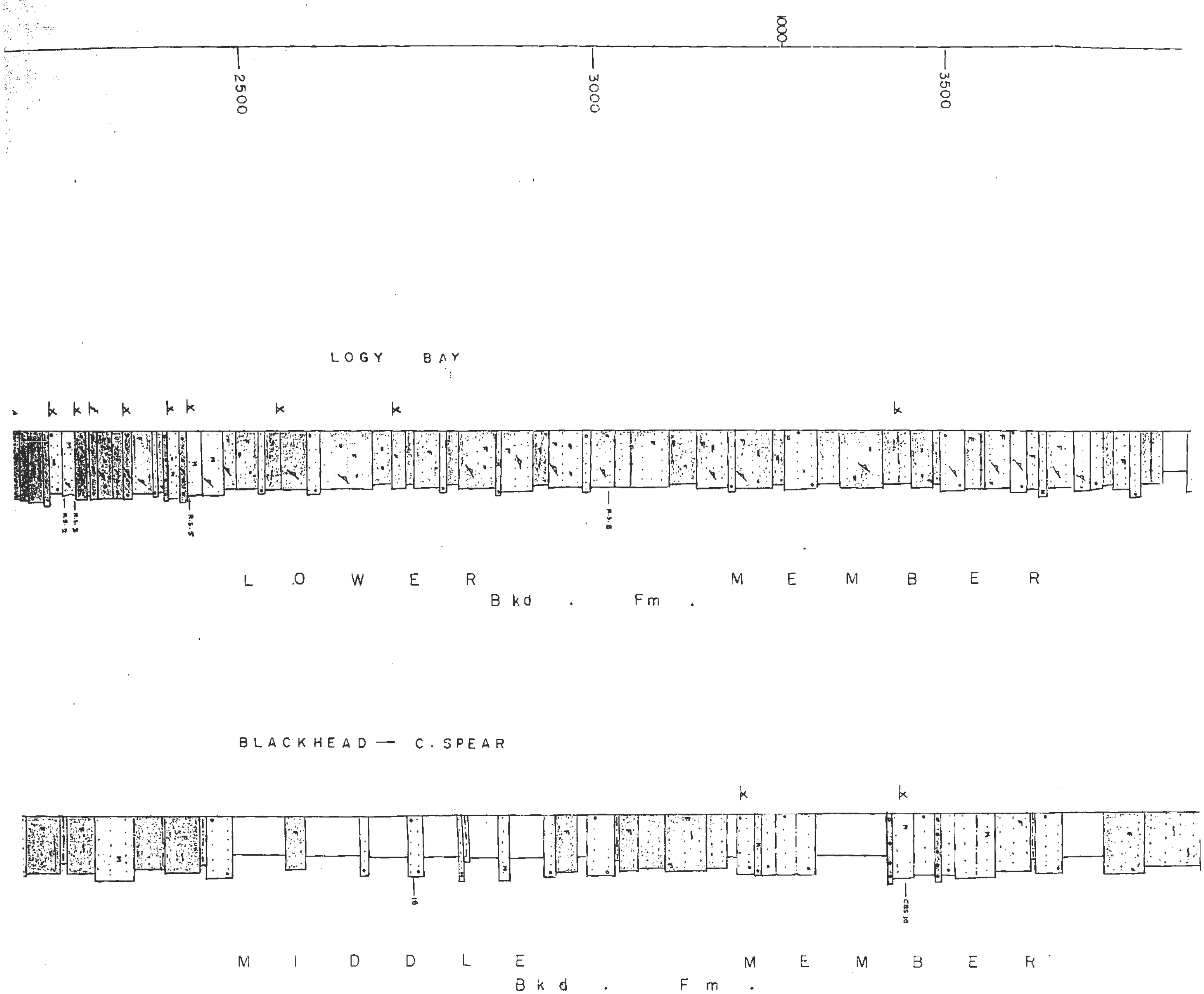

3
LOWER MEMBER
Sig . Hl . Fm .
MIDDLE MEMBER
Sig . Hl . Fm .
Up . Member.
Sig . Hl . Fm.
QUIDI VIDI
4
LOWER MEMBER
Sig . Hl . Fm.
MIDDLE MEMBER
UPPER
Sig . H
SIGNAL HILL
5
LOWER MEMBER.
Sig . Hl . Fm.
MIDDLE
MEM

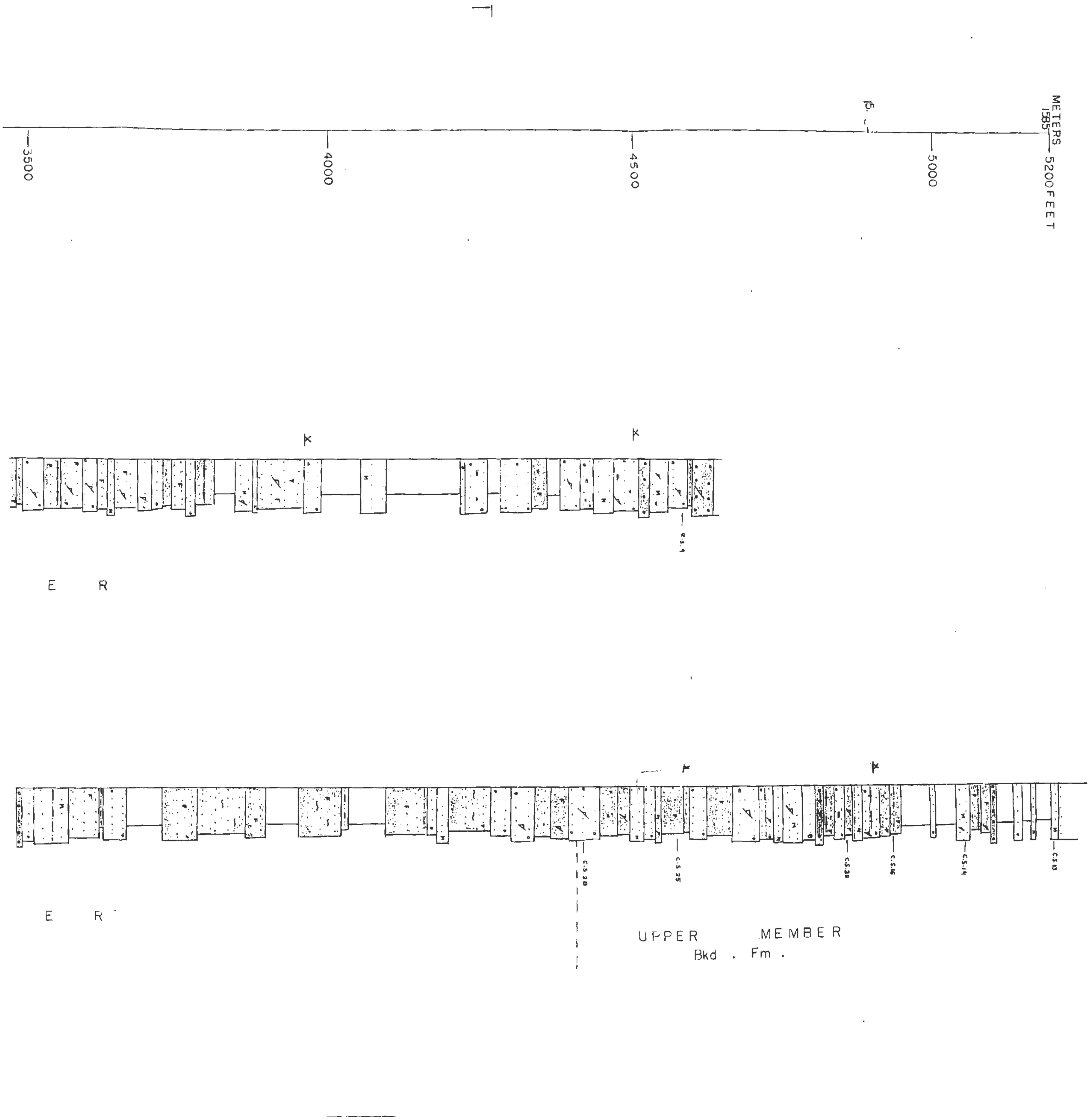
PLATE 2-2


0
500
1000
1500
1 of
2
MIDDLE MEMBER
Sig.Hl.Fm.
U P P E R M E M B E R
Sig. H l. Fm.
6
UPPER MEMBER
Sig.Hl.Fm.
L O W E R M E M B E R
B k d . Fm.

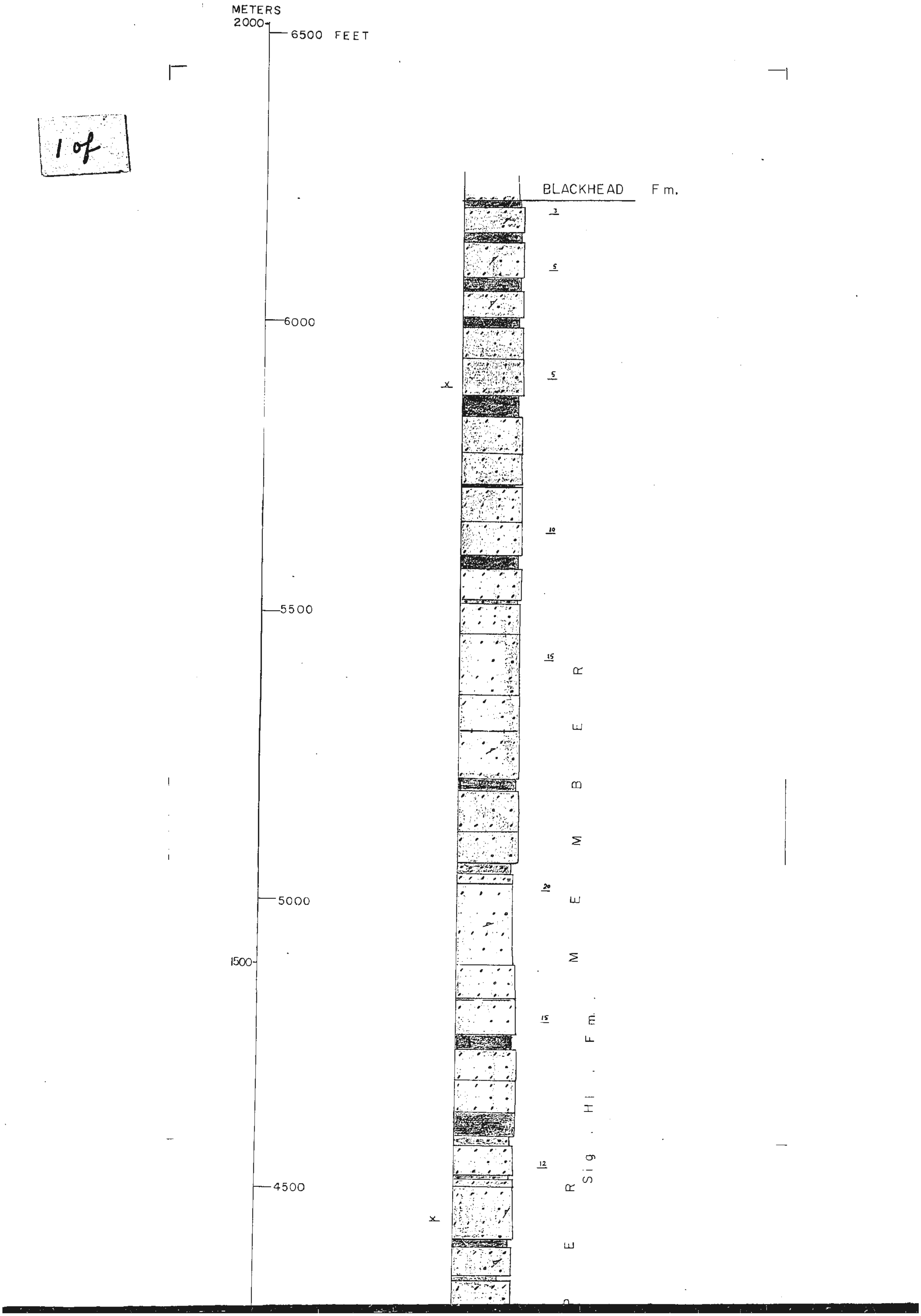
PLATE 2-3


500
1500
2000
2500
3000
LOGY BAY
MBER
LOWER
Bkd.
BLACKHEAD — C. SPEAR
MIDDLE
Bkd.

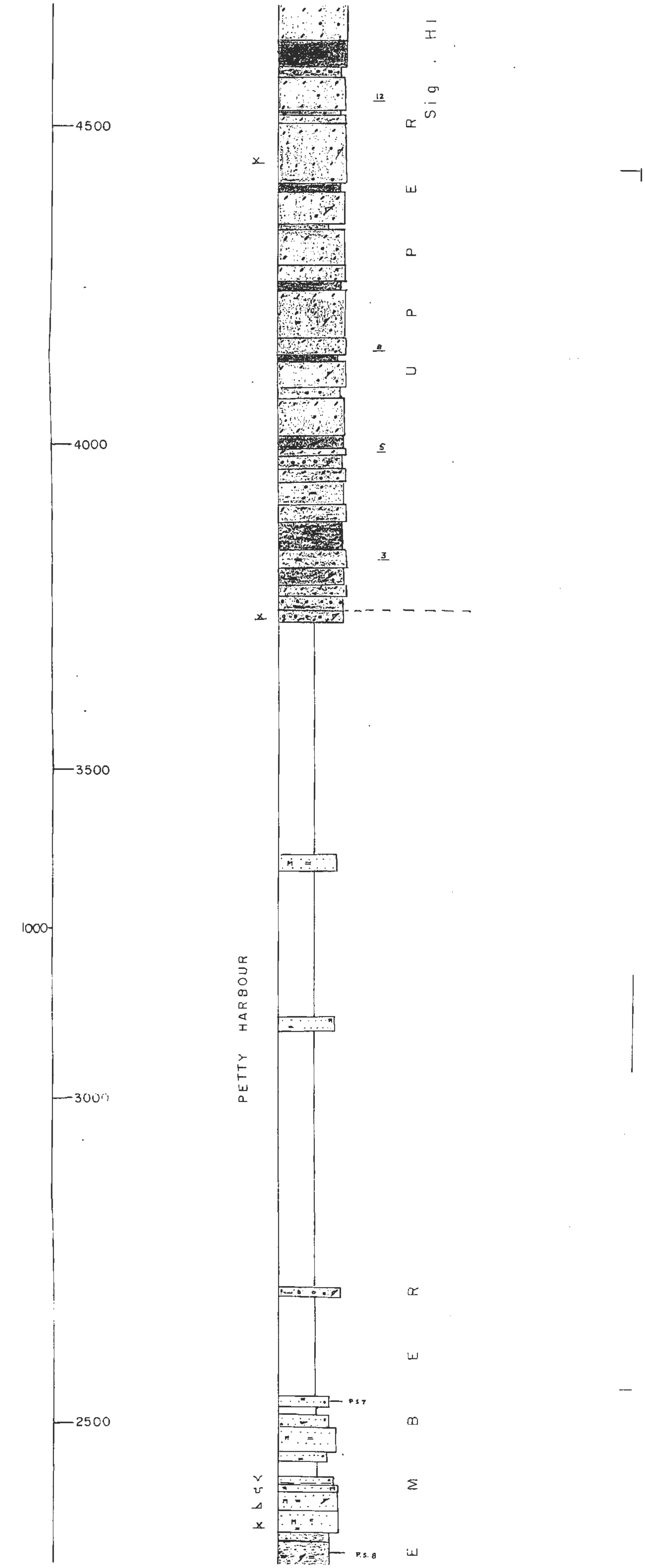

1000
2500
3000
3500
LOGY BAY
LOWER MEMBER
Bkd. Fm.
BLACKHEAD — C. SPEAR
MIDDLE MEMBER
Bkd. Fm.


3500
4000
4500
5000
5200 FEET
METERS
1585
E R
E R
UPPER MEMBER
Bkd. Fm.

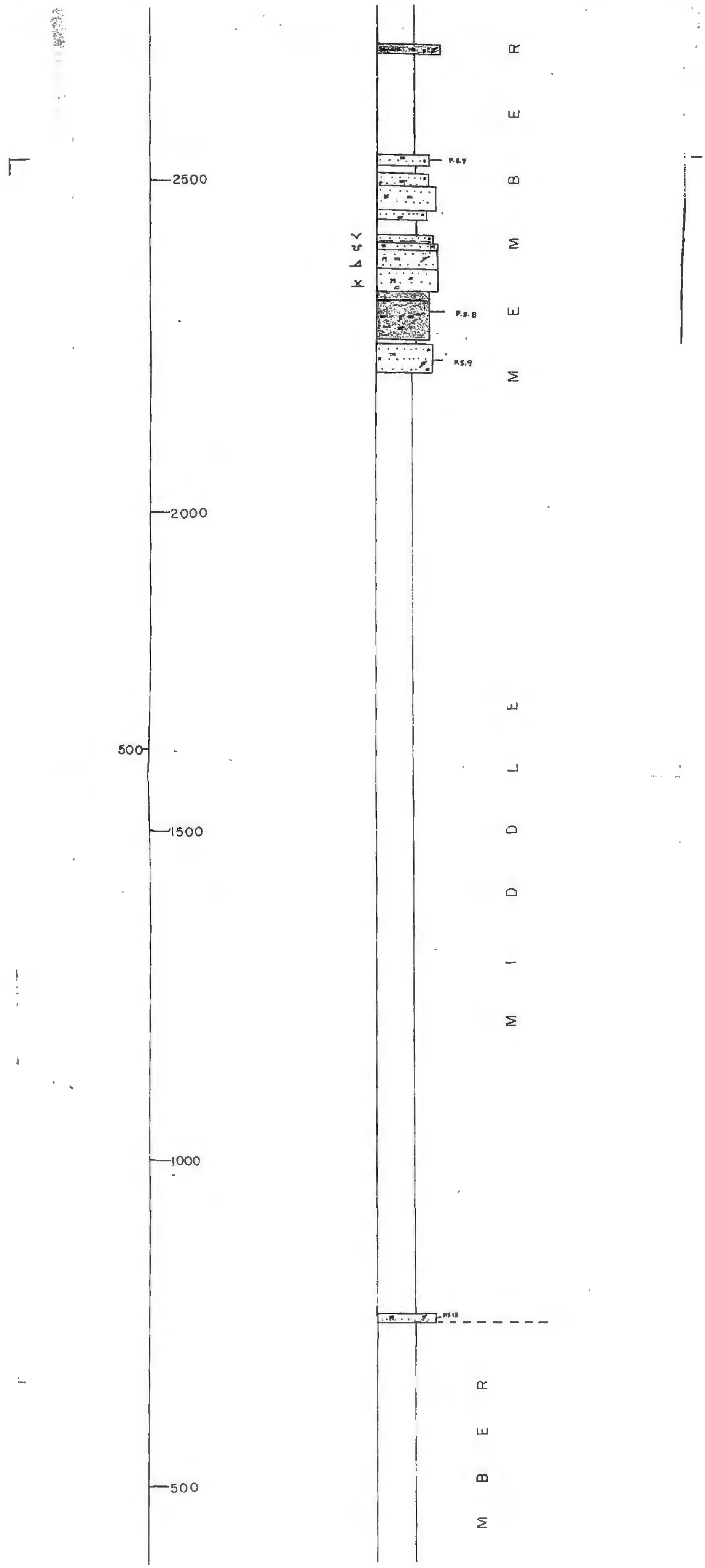
1 of


METERS
2000
6500 FEET
6000
5500
5000
1500
4500
BLACKHEAD Fm.
3
5
5
10
15
20
15
12
MEMBER
Sig. Hl. Fm.

2 of


4500
4000
3500
1000
3000
2500
12
8
5
3
PETTY HARBOUR
UPPER
MEMBER
Sig. Hi
PS7
P.S.8

4 of.



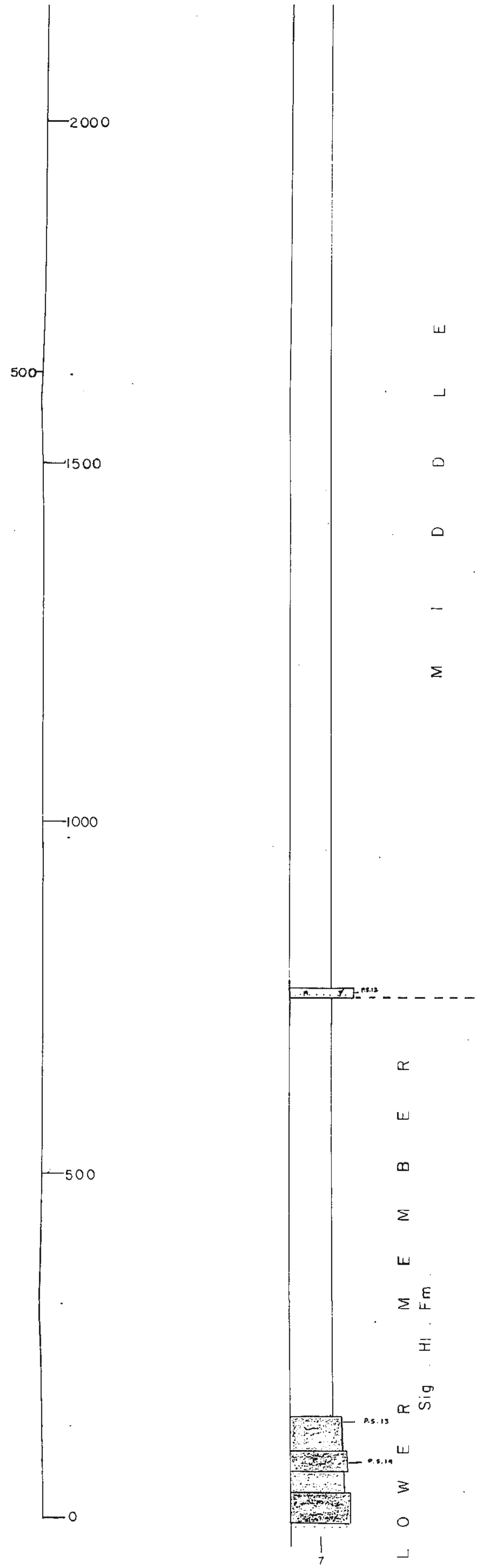

2000
1500
1500
1000
500
0
MIDDLE
LOWER MEMBER
Sig Hl. Fm
P.S.13
P.S.13
P.S.14
7

PLATE 2-4

1 of 1

LEGEND

SIGNAL HILL AND BLACKHEAD FORMATIOI

(Singh, M.Sc, thesis)

Breccia ... conglomerate.

Conglomerate with lenses and thin beds of sandstone

Very coarse - grained to pebbly sandstone

Coarse - to very coarse - grained sandstone

Medium - to coarse - grained sandstone

Medium - grained sandstone

Fine - to medium - grained sandstone

Fine - grained sandstone

Very fine - to fine - grained sandstone

Siltstone

Argillite with sandstone partings

Argillite

Red argillite bands

Tuff

Ripple marks

Cross bedding (undifferentiated)

Ripple lamination

Ripple - drift cross - lamination

Soft sediment deformation structures

Overturned flame structure

5 Average pebble size in millimeters.

Red argillite fragments

Hematitic clay partings

Greenish grey argillite - partings.

LEGEND

SIGNAL HILL AND BLACKHEAD FORMATIONS

(Singh, M.Sc, thesis)

- Ripple marks
- Cross bedding (undifferentiated)
- Ripple lamination
- Ripple_ drift cross_ lamination
- Soft sediment deformation structures
- Overturned flame structure
- 5 Average pebble size in millimeters.
- Red argillite fragments
- Hematitic clay partings
- Greenish grey argillite-partings.

Sample number

BLACKHEAD FORMATION

- Upper member
- Middle member
- Lower member

SIGNAL HILL FORMATION

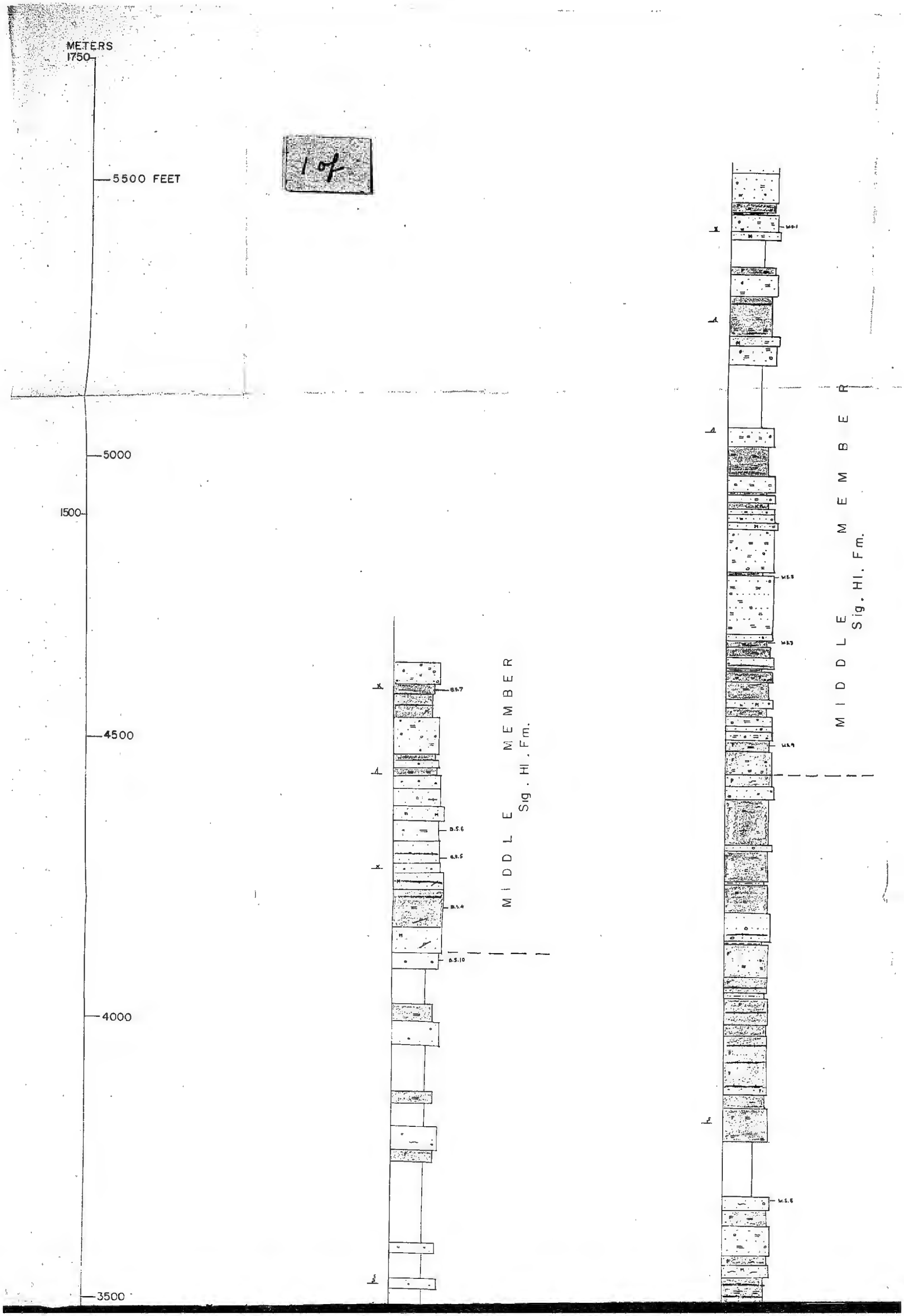
- Upper member
- Middle member
- Lower member

- Boundaries of formation
- Boundaries of member

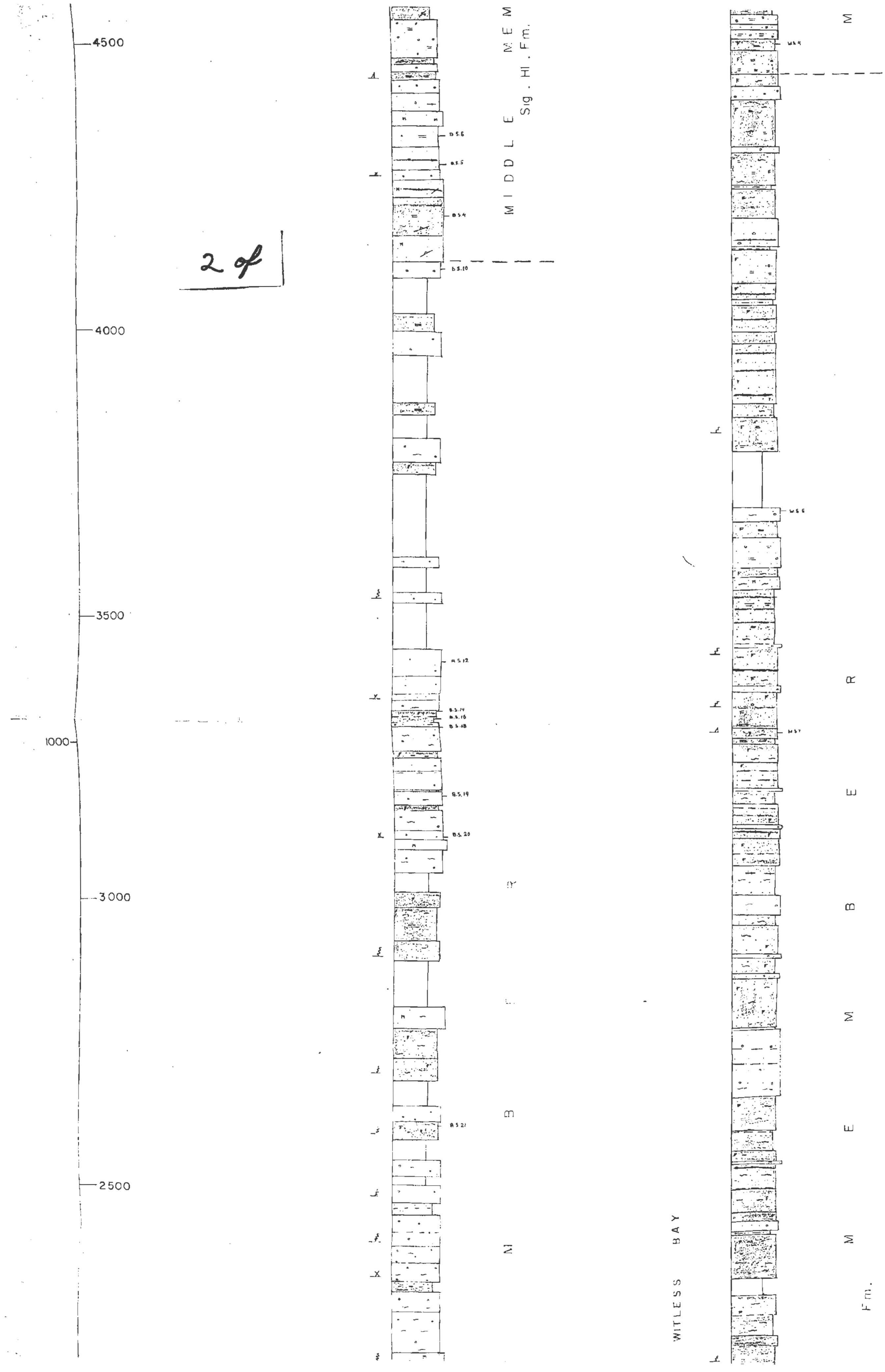
STRATIGRAPHIC THICKNESS

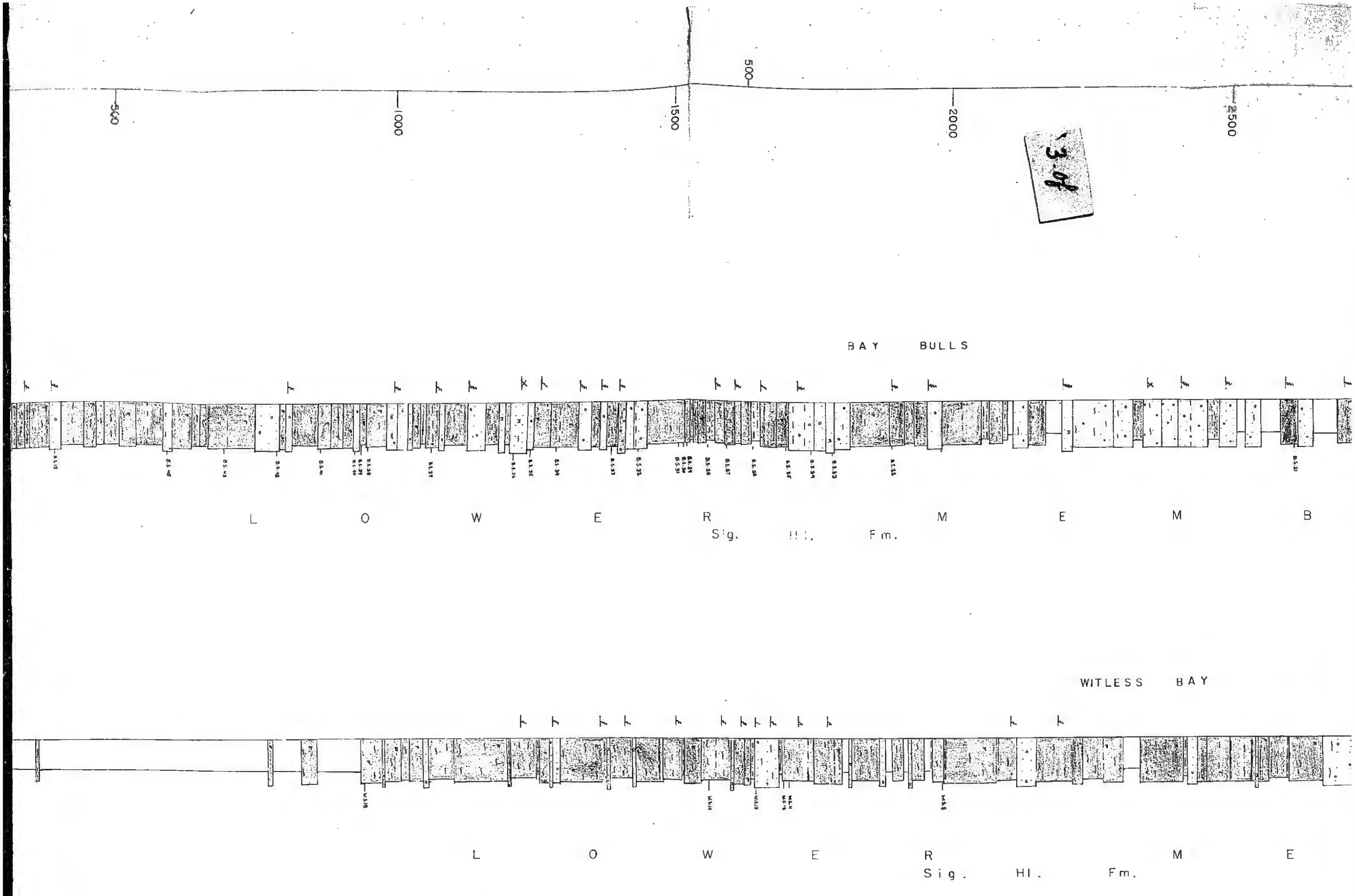
- Thickness estimated
- Thickness inferred (no exposure)

PLATE 2-6

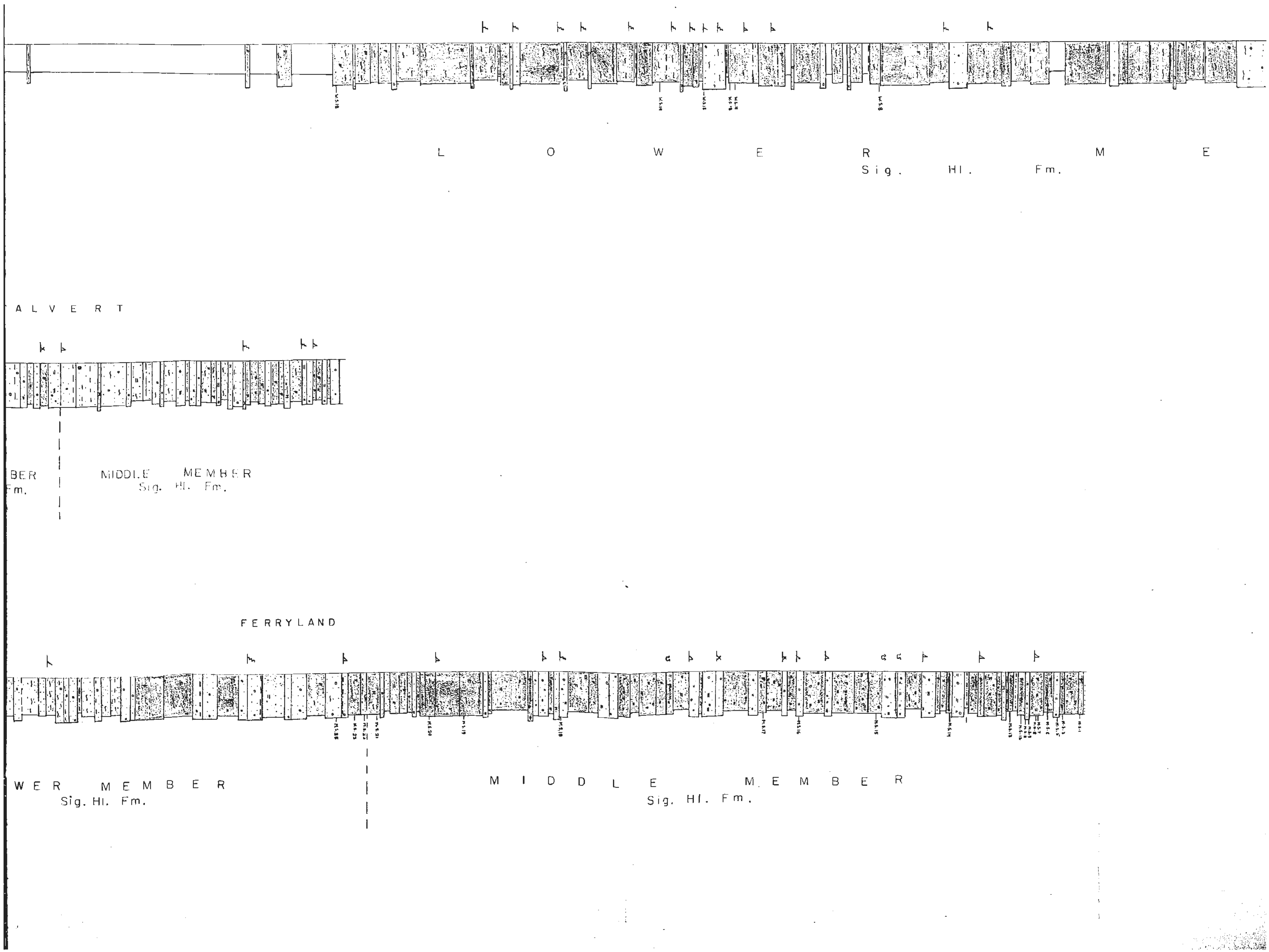

1 of
METERS
1750
5500 FEET
5000
1500
4500
4000
3500
B.S.7
B.S.6
B.S.5
B.S.4
B.S.10
MIDDLE MEMBER
Sig. Hl. Fm.
MIDDLE MEMBER
Sig. Hl. Fm.

2 of

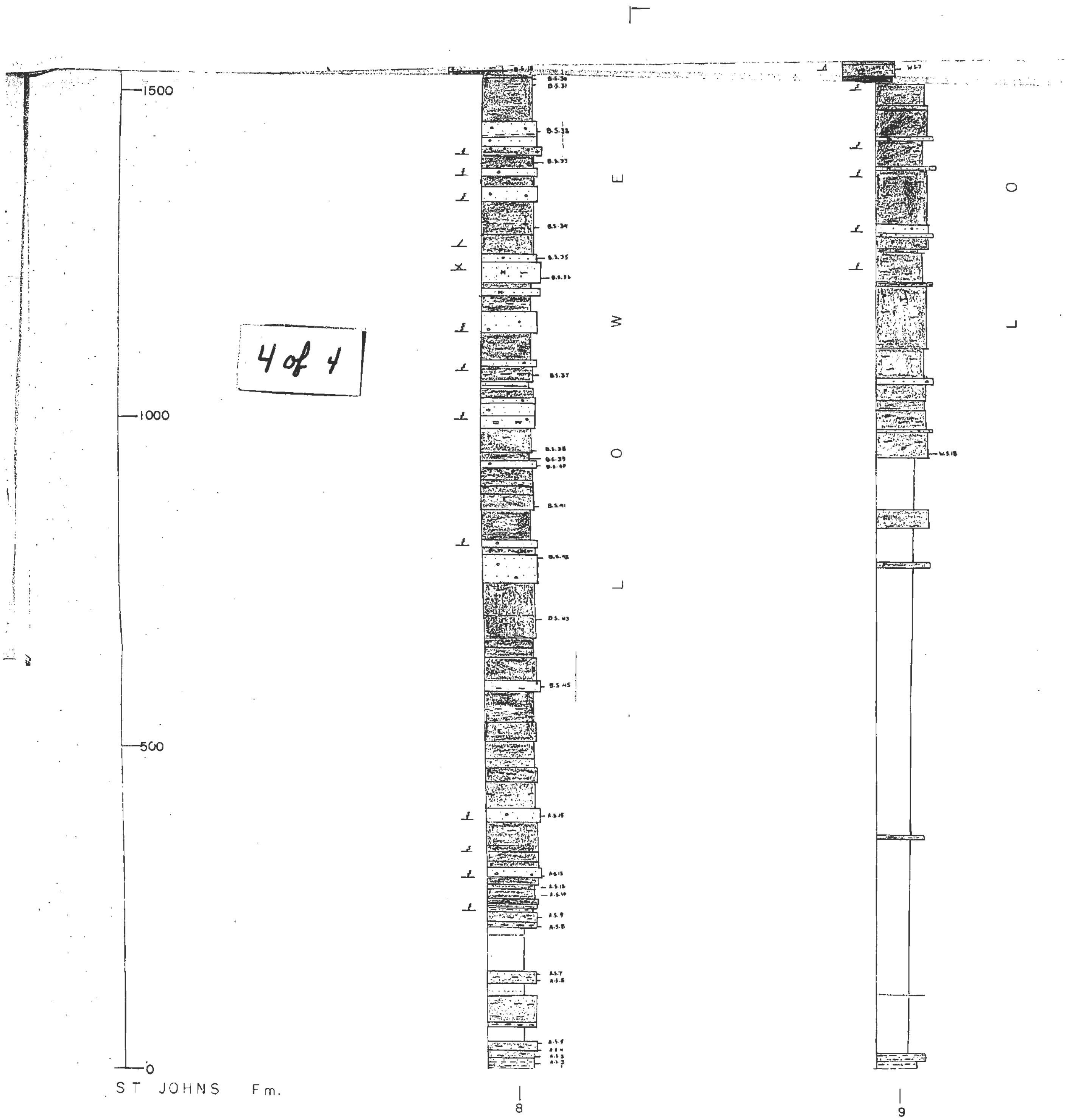

4500
4000
3500
1000
3000
2500
MIDDLE MEM
Sig. Hl. Fm.
B.S.6
B.S.5
B.S.4
B.S.10
B.S.12
B.S.14
B.S.16
B.S.18
B.S.19
B.S.20
B.S.21
W.S.6
W.S.7
MEMBER
WITLESS BAY Fm.



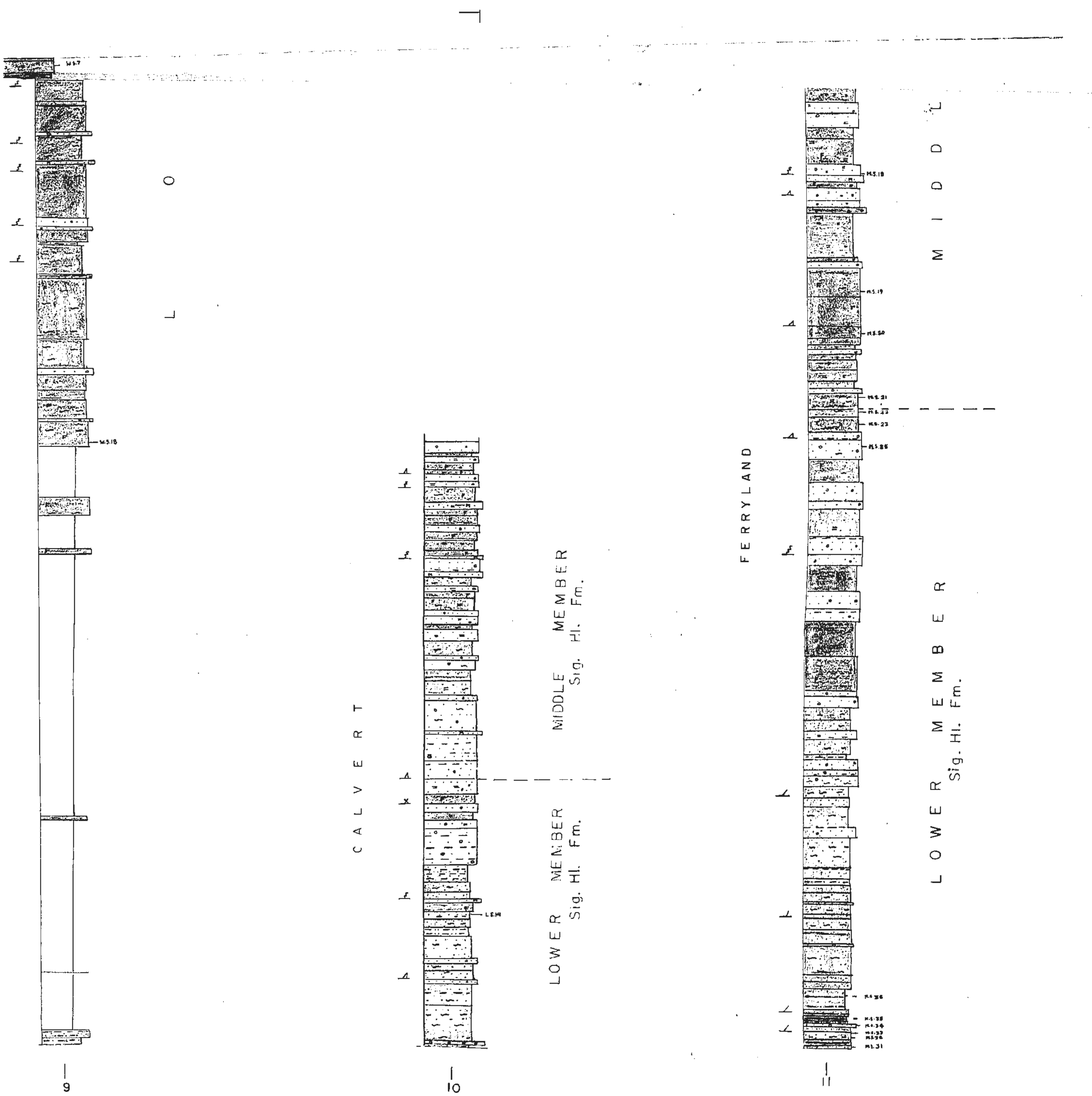
500
1000
1500
500
2000
2500
3 of
BAY BULLS
B.S.15
B.S.21
B.S.22
B.S.23
B.S.24
B.S.25
B.S.26
B.S.27
B.S.28
B.S.29
B.S.30
B.S.31
B.S.32
B.S.33
B.S.34
B.S.35
B.S.36
B.S.37
B.S.38
B.S.39
B.S.40
B.S.41
B.S.42
B.S.43
B.S.45
LOWER MEMB
Sig. Hl. Fm.
WITLESS BAY
W.S.8
W.S.11
W.S.12
W.S.13
W.S.14
W.S.15
LOWER MEME
Sig. Hl. Fm.



LOWER MEMBER
Sig. Hl. Fm.
W.S.8
W.S.18
ALVERT
BER
Fm.
MIDDLE MEMBER
Sig. Hl. Fm.
FERRYLAND
WER MEMBER
Sig. Hl. Fm.
MIDDLE MEMBER
Sig. Hl. Fm.
M.S.14
M.S.15
M.S.16
M.S.17
M.S.18
M.S.19
M.S.20



1500
1000
500
0
ST JOHNS Fm.
4 of 4
8
9



L O
M I D D L
CALVERT
FERRYLAND
MIDDLE MEMBER Sig. Hl. Fm.
LOWER MEMBER Sig. Hl. Fm.
LOWER MEMBER Sig. Hl. Fm.
9
10
11

PLATE 2-5

1 of

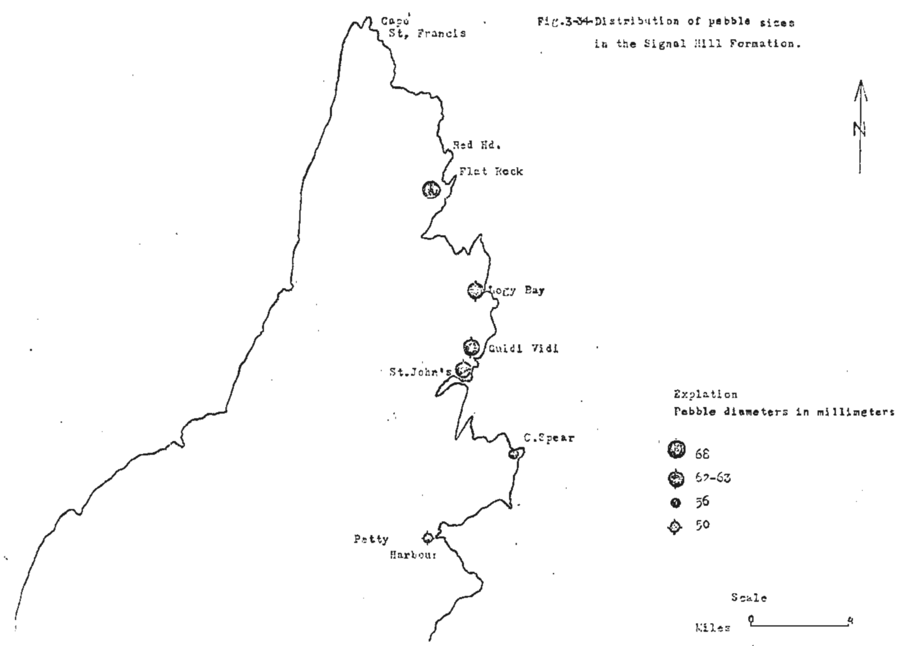


Fig.3-34-Distribution of pebble sizes in the Signal Hill Formation.