STRATIGRAPHY, SEDIMENTATION AND BASIN EVOLUTION OF THE PICTOU GROUP (PENNSYLVANIAN), OROMOCTO SUB-BASIN, NEW BRUNSWICK, CANADA

by

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ABSTRACT

The stratigraphy of the Upper Pennsylvanian (Westphalian C-D, Stephanian) Pictou Group, in a study area at the southwest end of the Central Carboniferous Basin, New Brunswick, records the development of large scale megacyclic units 150 to 400 meters thick and smaller scale cycles 25 to 75 meters thick. The bases of the cycles are dominated by a succession of grey coarse-grained sandstones and conglomerates while the upper portions are dominated by a succession of red fine-grained sandstones, siltstones and shales. These two major lithofacies assemblages record coexisting fluvial channel and flood plain depositional systems. A study of the detailed vertical facies sequences in drill cores indicates that the fluvial channel systems were characterized by the channel deposits of large river belts with a high sediment charge and probably of braided pattern. The flood plain system developed as a wide flat-lying alluvial plain subject to seasonal flooding and drying with pedogenesis. The cyclic stratigraphy developed as a product of dynamic interaction between the two juxtaposed depositional systems. Actual causes and mechanisms of the cyclicity were probably multivariate. Allocyclic controls, such as tectonics and source area climate, likely triggered changes in the distribution pattern of the major fluvial belts. Seasonal flooding of the fluvial belts controlled the more detailed facies patterns and sequence within each depositional system.

RESUME

La stratigraphie du groupe de Pictou (Pennsylvanien Supérieur: Westphalien C-D, Stéphanien) tel qu'étudiée dans l'extrémité sud-ouest du Bassin Carbonifère Central du Nouveau-Brunswick a enregistré la formation de grands mégacycles de 150 à 400 mètres d'épaisseur et de cycles plus petits, épais de 25 à 75 mètres. Les bases de ces cycles sont dominées par une succession de grès grossiers et conglomérats gris alors que les sommets comprennent surtout des grès fins, siltstones et shales rouges. Ces deux principales lithologies démontrent la coexistence de systèmes sédimentaires de type chenal fluviatile et de type plaine d'épandage. L'étude détaillée des séquences verticales de faciès en carottes de forage indique que les systèmes de type chenal fluviatile sont caractérisés par les dépôts de chenal de grands ensembles fluviatiles à forte charge détritique, probablement à chenaux en tresses. Les systèmes de type plaine d'épandage se formaient sur une large plaine alluviale sujette à des inondations saisonnières suivies d'assèchement avec pédogenèse. La stratigraphie cyclique est un produit de l'interaction dynamique de ces deux systèmes sédimentaires juxtaposés. Les causes et mécanismes de cette cyclicité étaient probablement multivariés. Des contrôles allocycliques tels que la tectonique ou le climat de la région-source déclenchaient sans doute des variations dans la distribution de ces grands ensembles fluviatiles. Les inondations saisonnières de ces plaines contrôlaient le détail des séquences et de la distribution des faciès dans chaque système sédimentaire.

ANNOTATION

The author of this thesis has taken advantage of an option provided by regulations of the Faculty of Graduate Studies and Research which allows, for the inclusion as a part of a thesis, the text of an original paper suitable for the submission to learned journals for publication.

Chapter III in its entirety is in the process of being submitted for publication under the main thesis title. A separate abstract, introduction, conclusion and reference list are included in this chapter. A full introduction with connecting text, and a joint abstract, summary, conclusions and references are provided in the main text of the thesis.

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Equal appreciation is extended to all my colleagues and peers at SERU, and assistants on the New Brunswick Project 1979, including A. Cournut, K. Schimann, R. (Fraser) Cournut, and D. Walsh, without whose help the quality and quantity of core logging accomplished in 1979 would not have been possible. I thank Cominco Ltd. and E & B Explorations (Canada) Ltd. for access to drill cores from their French Lake and Oro Properties. I also thank the Department of Natural Resources, New Brunswick, for access to core and drill chip materials, and for supporting the spore analysis palynology.

I wish to thank my supervisors Dr. R. Hesse and Dr. C.W. Stearn whose doors were always open for consultations, suggestions and encouragement.

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Dr. H.W. Van de Poll, at the University of New Brunswick, for the many creative and helpful discussions, and who pioneered the present understanding of the Pictou Group more than ten years ago; Dr. P. Hacquebard and Dr. S. Barss, at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia, for data on coal maturation levels and palynological spore analysis; Mr. D. Ball for the interesting and helpful discussions about the Pictou Group during 1979, 1981/82; Mrs. M. Moysan (SERU) for the typing of the manuscript, and Mr. Y. Girouard (SERU) for the draughting of part of the preliminary maps and figures.

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(in envelope)

CHAPTER I : GENERAL INTRODUCTION

1.1 LOCATION, ACCESS AND PREVIOUS WORK

The sediments of this study are Westphalian C-D and Stephanian (Pennsylvanian) in age (Barss and Hacquebard, 1967; Hacquebard, 1971; Ball et al, 1981). They belong to the Pictou Group which underlies more than one quarter of the province of New Brunswick (Figure 1.1) and dominates the sedimentary fill of the Central Carboniferous Basin (New Brunswick Platform). Carboniferous strata in the Central Basin were deposited unconformably on Silurian and earlier basement rocks deformed and metamorphosed by the Late Devonian Acadian orogeny (Poole, 1967).

The study area is located in southwestern New Brunswick within a 2000 square kilometer area extending from a short distance north of the city of Fredericton, southwest to the Oromocto Lake area, and east as far as the Oromocto River and the Camp Gagetown boundary (Figure 1.2). Road access is provided by Highway 2 along the St. John River and highways 7, 3, 101 as well as numerous public and private side roads. The land in the area is principally used for farming, wood lots and residential purposes.

Here the Pictou Group generally unconformably overlies clastic sediments of the Riversdale Group (Westphalian A),

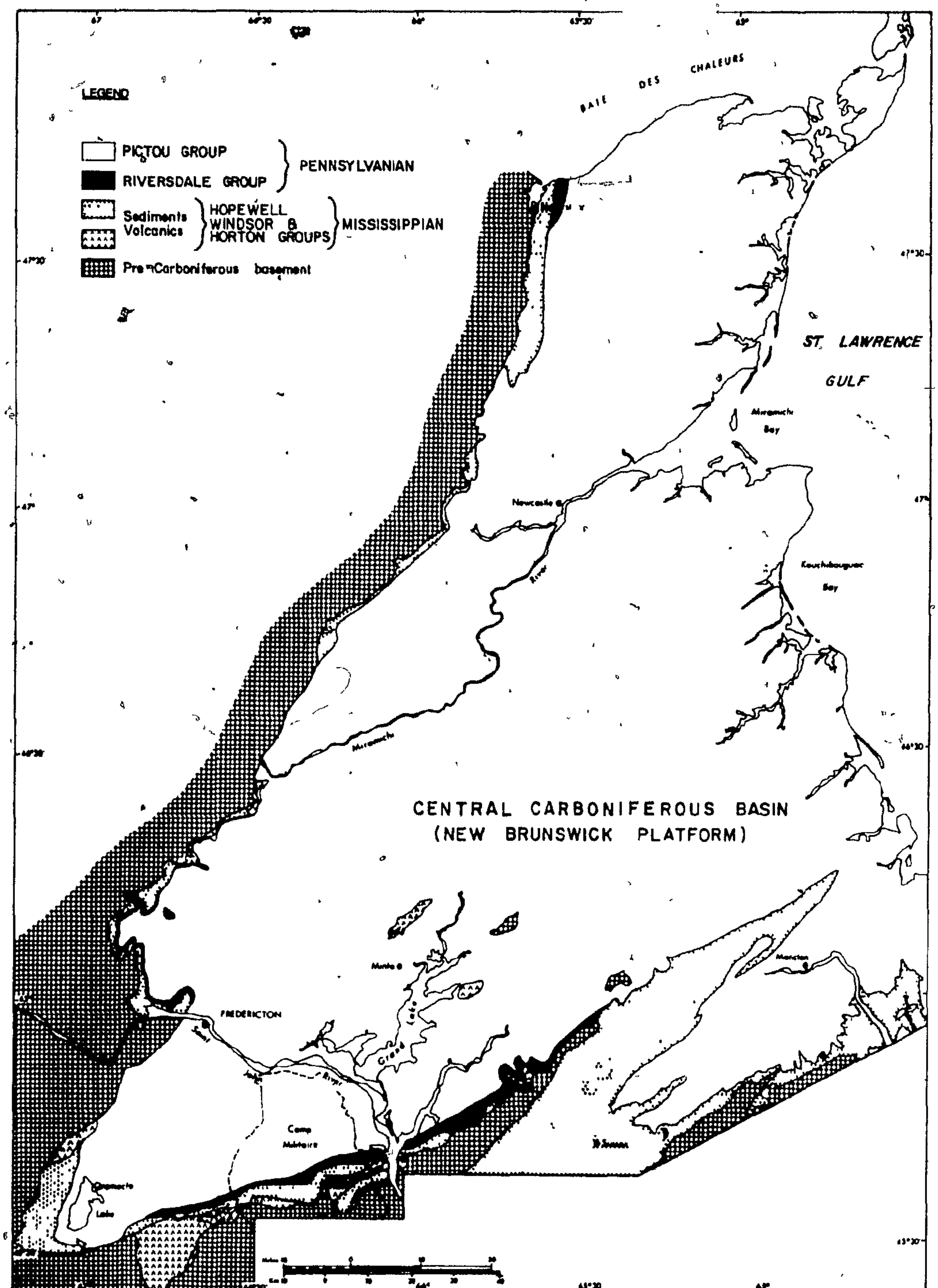


Figure 1.1. General Geology of the Central Carboniferous Basin, New Brunswick (adapted in part from Ball et al., 1981)

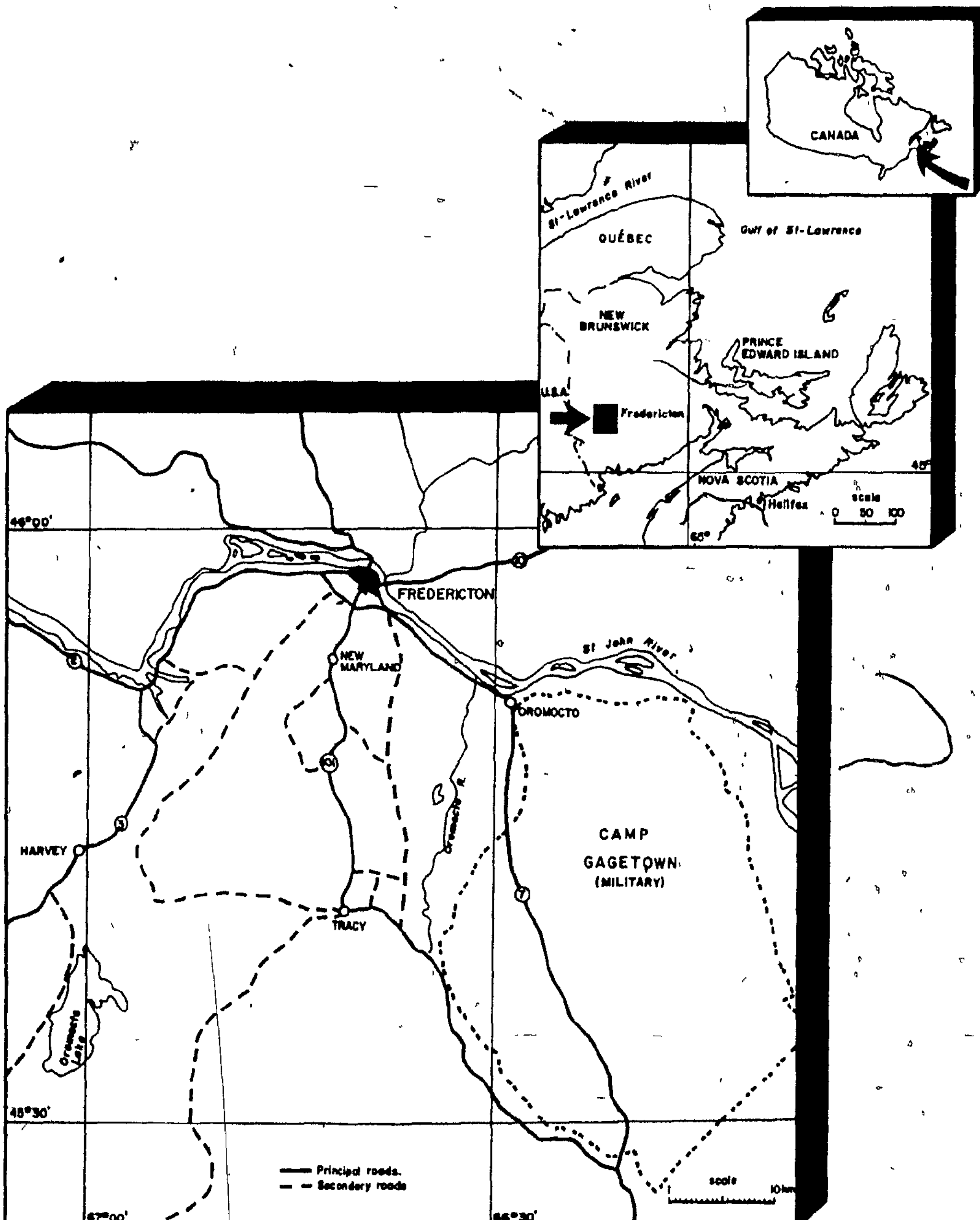


Figure: I.2 Location of study area in New Brunswick showing principal access routes and centres of habitation.

and Mississippian sedimentary and volcanic rocks of the Hopewell, Windsor and Horton Groups (Van de Poll, 1970). Pictou strata are faulted against Silurian metasediments of the Kingsclear Series, just to the west of the city of Fredericton (Van de Poll, 1973b).

Relief in the study area is slight. The highest topographic relief occurs in the city of Fredericton where the land rises from near sea level on the St.John River to some 250 meters along the south limits of the city. Cuesta style ridges formed by basal units of resistant sandstone occur along the western margin of the basin, southwest of Fredericton. These produce a subtle relief of 50 to 125 meters which is not readily apparent on the ground but easily visible on air photos and topographic maps. Relief diminishes towards the south and southeast. The centre of the basin is virtually flat and principally underlain by less resistant red shales and siltstones. Outcrops within the area are limited to small, horizontal to sub-horizontal exposures along constructed roads, excavated foundations, ditches and river banks. Nowhere do they exceed 4 meters in stratigraphic section or 20 meters in lateral extent.

This lack of outcrop has precluded any previous detailed study of the stratigraphy and sedimentation of the Pictou Group in this area of the province. Up to the present time, speculations on the stratigraphy of the area were largely based on comparison with more regional and detailed studies in better exposed areas. Van de Poll (1973b) summarized the geology of the southwestern

Central Basin from the limited drill hole information which existed at the time. He recognized the essentially flat to gently dipping geometry of the Pictou strata and documented the presence of a structural trough (graben), formed by major northeast trending fault structures in the Fredericton area. He proposed that a significantly thicker succession of Pictou sediments was preserved in this trough structure.

The data base that has recently become available consists of over 15,000 meters of core, drill cuttings and electric logs. It is the basis for the present study and provides new and significant information for the understanding of the Pictou Group. Most of the drill holes were undertaken by the following mineral exploration companies: Cominco Canada Limited (Kipling, 1980 and 1981); Imperial Oil Canada Limited (Hasan, 1977, 1978); Killarny Oil and Gas Limited (unreferenced data file, Government of New Brunswick, Mineral Branch); and SERU Nucléaire (Canada) Limited (Le Gallais, 1980 and 1982).

General ideas on the sedimentology of the Pictou Group within the Central Basin previously proposed have encompassed the following models. Kelly (1967) in a study of the Carboniferous throughout the Atlantic provinces suggested a model of lateral infilling by deltaic sedimentation from the east for the Pictou strata of the Central Basin. Modifications of this relatively simple model did not occur until the work of Van de Poll (1970). In a comprehensive study throughout the entire Central Basin, he divided the Pictou Group into three major 'fluvial cyclothems', each made up of several hundred meters of strata consisting of a grey relatively coarse-grained facies sequence at the base and an overlying finer-grained red facies sequence at the top. Climate and tectonics were seen as the major controls on the development and distribution of these cyclothems. Van de Poll suggested that the Pictou succession at the southwestern end of the Central Basin comprised three such cyclothems or megacycles (Figure 1.3). Van de Poll (1973a), in a further refinement of his cyclothemic model, suggested that the various sandstone and shale lithologies making up the Pictou Group are not laterally persistent but instead represent changing facies of recurring first and second order fluvial cycles.

Ball et al. (1981), in a New Brunswick Government-sponsored regional scale investigation mapping, spore dating and drilling, have added a great deal of new subsurface data on the Pictou Group throughout New Brunswick. The program included the rotary drilling of some 294 test holes in the Central Basin averaging 122 meters in depth. Several deeper holes (averaging 305 meters in depth) were also drilled. Ball et al. (1981) discounted the existence of Van de Poll's cyclothems and suggested instead a model of mixed meandering, braided and paludal environments which defy any attempts at lateral correlation on local or regional scales.

Legun (1980) conducted the first detailed sedimentologic study of Pictou strata occurring in sea cliff exposures at the extreme northeast end of the Central Basin. Here the vertical

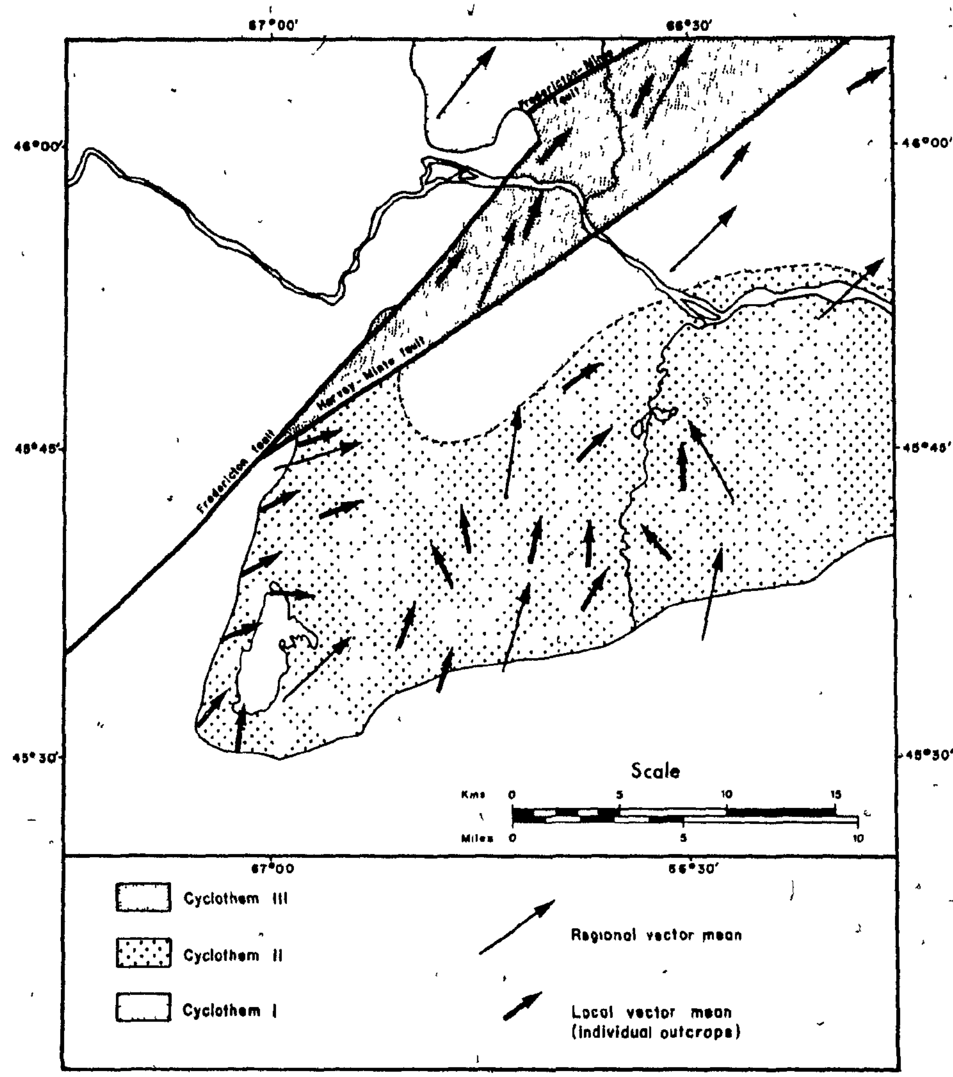


Figure 1.3: Fluvial Cyclothems of Van de Poll (1970) and Sediment Dispersal Vectors in the Pictou Group, Central Carboniferous Basin, New Brunswick (the figure is a redraughted and slightly modified combined version of figures 20, 21 and 22, from Van de Poll, 1970)

section straddles the transition from a lower member of a shale dominated succession overlain by an upper member of a sandstone dominated succession. Legun (1980) and Legun and Rust (1981;1982) attributed the lower shale succession to deposition on a semi-arid alluvial plain with thin sand bodies representing isolated fluvial channels. The upper sandstone succession was tentatively attributed to braided river deposition prograding over the alluvial plain environment.

A miospore and megafloral correlation of the Pictou Group throughout New Brunswick is shown in Table 1.1 compiled from data appearing in Ball et al. (1981), and spore dating accomplished in the present study (Barss, 1982).

1.2 STUDY METHODS: DATA BASE, WORK OUTLINE AND OBJECTIVES

Sixty-four separate holes drilled into the Pictou Group and representing a total of 15,749 meters are the principal sample material on which this study is based. The drill hole numbers, depth, type of drilling (i.e. sample material available), available well logs and drill hole location are summarized in Figure 1.4 and Table 1.2. Most of the core, drill chips and well logs are from holes drilled by the New Brunswick Government or by private companies, and are currently or will be available for examination at the Government of New Brunswick core storage facilities on York Street and College Hill Road, Fredericton. The drill core belonging to

Table 1.1: Stratigraphic Correlation of the Pennsylvanian Pictou Group throughout the Central Carboniferous Basin, New Brunswick, based on Miospora and Megaflora Data (after Hamilton, 1962; Barss and Hacquebard, 1967; Legun, 1980; Ball et al., 1981; and the present study)

AGE		GROUP	MEGAFLORA ZONE	MIOSPORE ZONE	NORTHERN N.B.		CENTRAL N.B.	EASTERN N.B.	OROMOCTO SUB-BASIN
Permian				*Vittatina* Spore Zone F	Clifton Fm.	C	//////	//////	//////
Pennsylvanian	Stephanian	Pictou Group		*Potonieisporites* Spore Zone D			Richibucto Fm	Tourmentine Fm. / Richibucto Fm.	Megacycle III
	Westphalian D		*Ptychocarpus Unitas*	*Thymospora* Spore Zone C		B / -?-	Scoudouc Fm.	Scoudouc Fm.	Megacycles I & II
	Westphalian C		*Linopteris Obliqua*	*Torispora* Spore Zone B		A	Sunbury Creek Fm. / Hurley Cr Fm.	Salisbury Fm.	
			Lonchopteris	*Vestispora* Spore Zone A			Minto Fm. (Upper / Lower)		
	Westphalian B	Cumberland Group							
	Westphalian A	Riversdale Group		Spore Zone E	Bathurst Fm.		Newcastle Creek Fm.	Boss Pt. Fm.	Boss Point Fm.
	Namurian C			Spore Zone D					
	Namurian B			Spore Zone C	? //////		? ?	Enrage Fm.	undifferentiated Hopewell Group
	Namurian A	Canso Group		Spore Zone B	//////				

Cominco Canada Ltd. will probably be released sometime in the near future (personal communication, R.W. Kipling, Cominco Ltd.). Much of the drill information represents either recently acquired data or previously confidential material, which the author was given permission to examine, and has never before been comprehensively studied in detail.

The author personally logged more than 2000 meters at a scale of 1:100 of the cored holes drilled by SERU Nucléaire (Canada) Ltd. in 1979 and was involved in the supervision of the logging of the remaining SERU core by other employees of SERU Nucléaire Ltée. The author logged all additional drill cores in the study region at 1:500 scale and examined well logs and chip samples from the rotary holes. The Cominco holes were logged in early 1982. Outcrop exposures along roads and rivers were examined in 1979.

A detailed study of the facies in representative stratigraphic intervals from the best drill cores of the SERU, Imperial Oil Ltd. and Cominco holes was undertaken in 1982. This latter study represents a detailed examination of over 6500 meters of cored sections.

Palynological spore analysis was undertaken by Dr. S. Barss, Bedford Institute, Dartmouth, Nova Scotia, from samples provided by the author from SERU core in 1979 and Cominco core in 1982.

Table 1.2 : Summary of Drill Hole Data in the Study Area, Oromocto Sub-basin in New Brunswick

DRILL NO,	TOTAL DEPTH (meters)	SOURCE	AVAILABLE DRILL MATERIAL			AVAILABLE WELL LOGS			
			Core	Cuttings	O	Gamma-ray	Neutron	Resistivity	Spontaneous potential
C-225	122	G N.B.		X		X	X	X	X
C-248	122	G.N.B.		X		X	X		
C-249	122	G.N.B.		X		X	X		
C-268	122	G.N.B.		X		X	X	X	
C-270	117	G.N B.		X		X	X	X	
C-284	122.2	G.N.B.		X		X	X		
C-285	122	G.N.B.		X		X	X		
C-286	122	G.N.B.		X		X	X		
C-287	122	G.N B.		X		X	X	X	
C-296	122.2	G.N B.		X		X	X	X	X
C-297	114 3	G N.B.		X		X	X		
C-298	123	G.N.B		X		X	X	X	X
C-299	122	G.N.B.		X		X	X	X	
C-300	122.2	G.N.B.		X		X	X		
C-303	122.2	G.N.B.		X		X	X	X	X
C-305	122.2	G.N.B.		X		X	X	X	X
C-306	113.4	G.N B.		X		X	X	X	X
C-307	122.2	G.N B.		X		X	X		
C-308	105.2	G.N.B.		X		X	X		
C-309	93.3	G.N B.		X		X		X	X
C-1269	305	G.N.B.		X		X	X		
C-1304	294 1	G N.B.		X		X	X	X	X
67	150.9	I.O.	X			X		X	X
68	154.5	I.O.	X			X		X	X
69	213	I O.	X			X		X	X
70	114	I.O.	X			X		X	X
71	160.5	I O.	X			X		X	X
72	155	I O.	X			X		X	X
73	146	I.O.	X			X		X	X
32	1050	K.O G.		X					
32a	350	K.O G			X				
32b	354.9	K.O.G.			X				
32c	377.4	K.O.G			X				
45	641	K.O G.	X						
O-1	82 9	C.O.	X			X	X	X	X
O-2	64 0	C.O	X			X	X	X	X
O-4	65.8	C.O.	X			X	X	X	X
O-12	79.8	C.O.	X			X	X	X	X
O-13	63.1	C.O.	X			X	X	X	X
RF-1	238.1	C.O.	X			X			
RF-2	300 0	C.O.	X			X			
RF-3	313 8	C.O.	X			X		X	
RF-4	302.5	C.O	X			X			
RF-5	302 6	C.O	X			X			
RF-6	300.8	C.O.	X			X	X	X	
F-1	846.5	SNCL	X			X	X	X	X
F-2	1102	SNCL	X			X	X	X	X
F-3	365	SNCL	X				X	X	X
F-4	273.5	SNCL	X				X	X	X
F-5	307.2	SNCL	X			X	X	X	X
F-6	285	SNCL	X				X		
F-7	304.8	SNCL	X			X	X	X	X
F-8	350.5	SNCL	X	X		X	X	X	X
F-9	320.4	SNCL	X	X		X	X		
F-10	304.2	SNCL	X			X	X	X	X
F-11	367 6	SNCL	X			X	X	X	X
F-12	243.2	SNCL	X			X	X	X	X
F-13	365.2	SNCL	X			X	X	X	X
F-14	257.9	SNCL	X			X	X	X	X
F-15	336.5	SNCL	X			X	X	X	X
F-16	118.3	SNCL	X						
F-17	296.9	SNCL	X			X	X	X	X
F-18	139.6	SNCL	X			X	X		
F-19	209.7	SNCL	X			X	X		
TOTAL	15,749.1								

G.N.B. : Government of New Brunswick Carboniferous Drilling Program
I.O. : Imperial Oil
K.O.G. : Killarney Oil and Gas
SNCL : SERU Nucléaire (Canada) Limitée
C.O. : Cominco Canada Ltd.

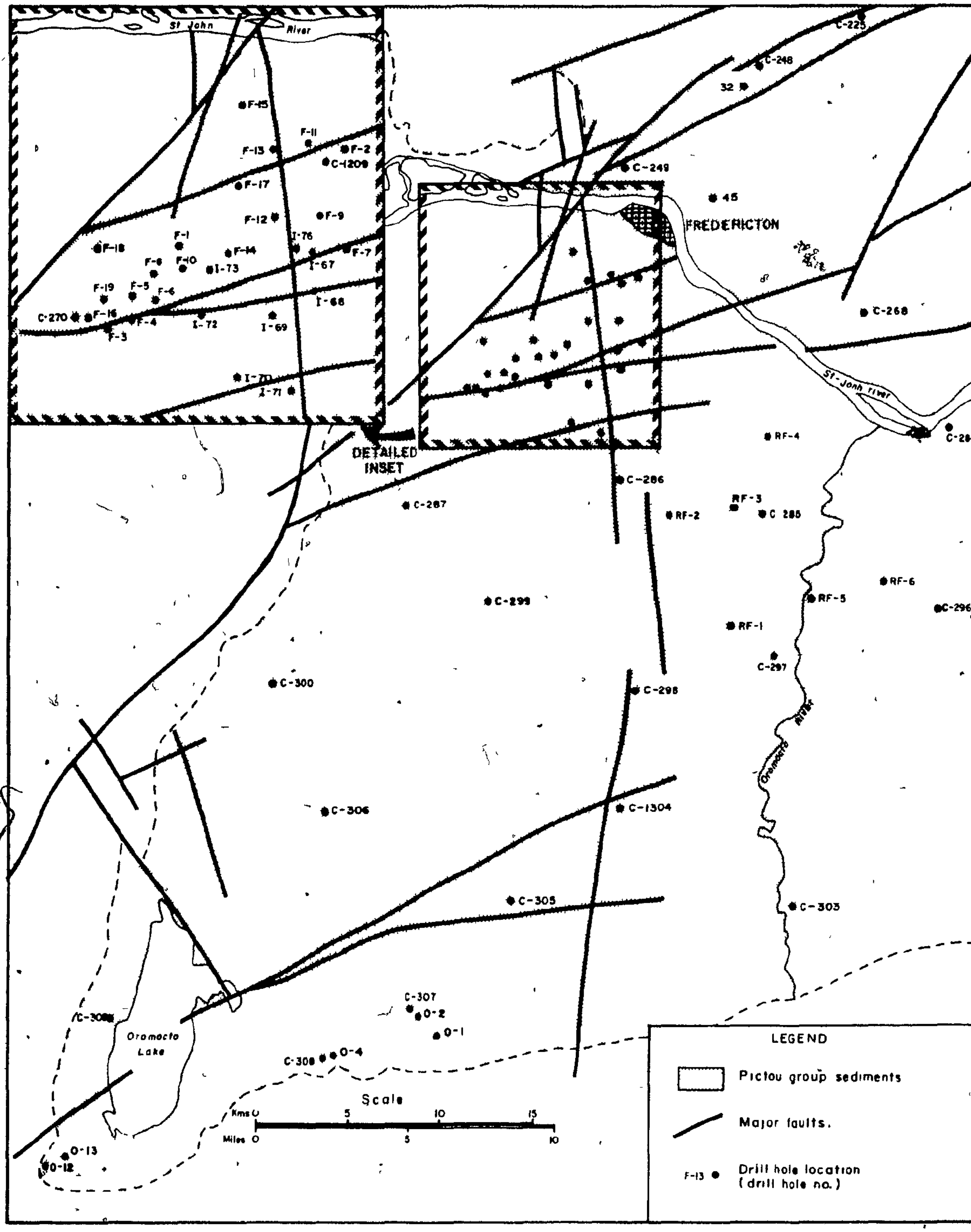


Figure 1 4 Drill hole location and density in the study area, southwestern Central Basin, New-Brunswick.

All drill hole data have been compiled to 1:500, 1:5,000 and 1:10,000 scales for the purpose of convenient and practical representation in this thesis. For greater detail, the reader is referred to 1:500 scale graphic logs and 1:100 scale descriptive logs provided by the author to the Government of New Brunswick and available on open file (Le Gallais, 1982).

The objectives of this study were:

1) To present a new body of subsurface data on the Pictou Group in a portion of the Central Basin of New Brunswick.

2) To document the cyclic nature of the vertical stratigraphy in the Pictou Group. Note that although the cyclic concept is not new, corroboratory evidence has been previously lacking in many areas of the Central Basin.

3) To present a regional depositional model which links the vertical stratigraphy to the dynamic evolution of the sedimentary basin.

It is hoped that the suggested model(s) can serve as a basis for expanded research and depositional facies study of the Pictou Group throughout the Central Basin as a whole.

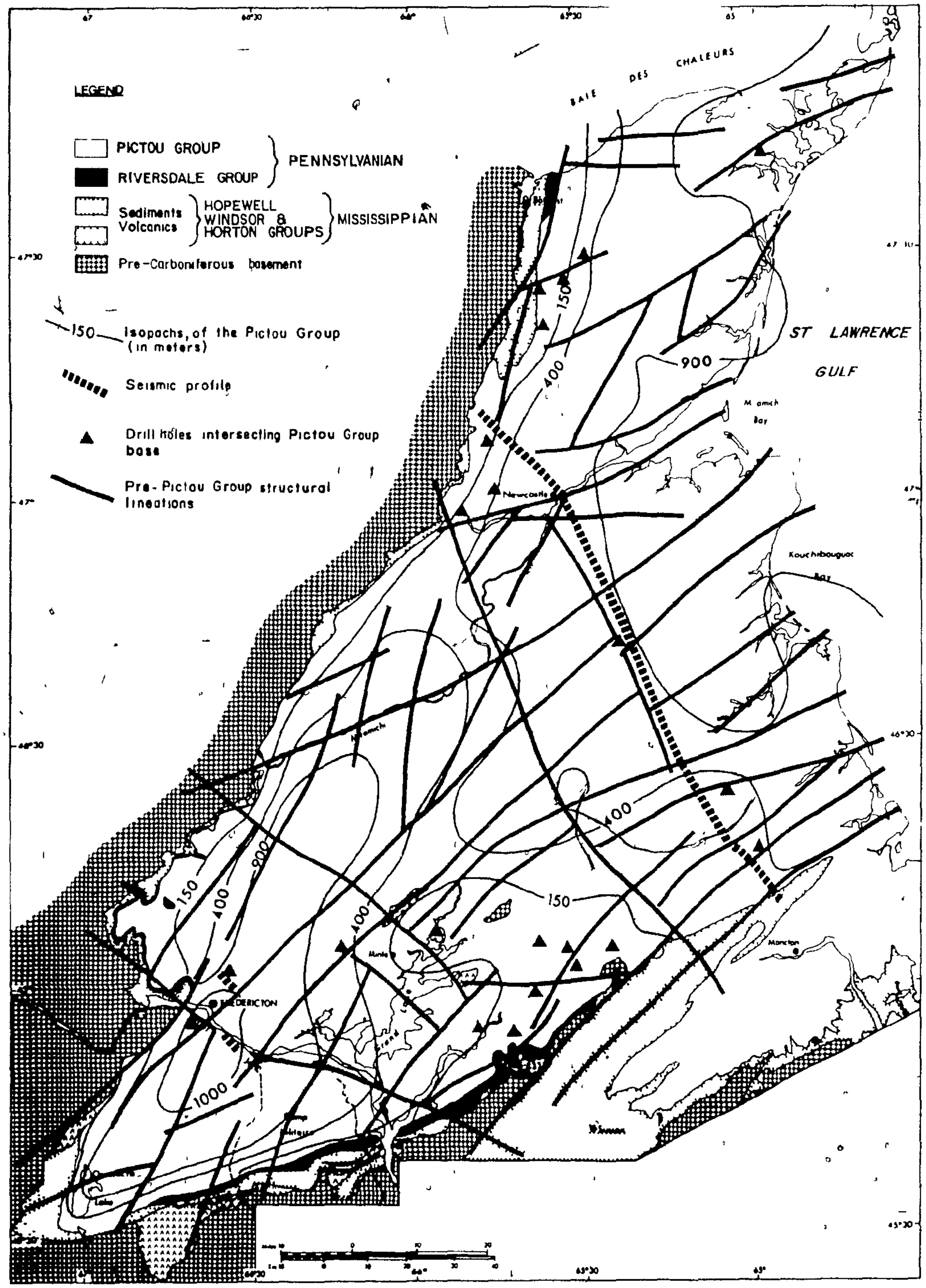
In the ensuing text, Chapter II will deal primarily with a description of the stratigraphy and correlation problems. Emphasis will be placed on the area around Fredericton where the greatest density of drill holes occurs. Other areas will be mentioned briefly. An attempt at facies subdivision will be undertaken in Chapter III.

CHAPTER II : BASIN GEOMETRY AND STRATIGRAPHY

2.1 GENERAL BASIN GEOMETRY

The southwestern end of the Central Carboniferous Basin forms a bowl-shaped sub-basin bounded by faulting along the northwest and northern margins (Figure 2.1). This area has been informally named the Oromocto Sub-basin by the author for convenient discussion in this text. Up to 1000 meters of Pennsylvanian shales, sandstones and conglomerates of the Pictou Group were deposited in the sub-basin (Figure 2.1). Suboutcropping strata trends which are clearly visible on airphotos and bedding dips measured from surface exposures, define the sub-basin geometry (Figure 2.2). Along the margins of the basin, Pictou strata dip from 5^{0} to 8^{0} towards the centre where bedding becomes essentially horizontal. Large scale very broad open fold warping of the strata near Fredericton is clearly visible on airphotos of the region (Figure 2.2). The warping of the strata is likely formed in response to the major northeast trending faults forming the Fredericton graben structure (Figure 2.2). The relative fault displacement, sense of movement and structural patterns of the strata are also confirmed in structural contours measured on stratigraphic marker horizons in drill holes (discussed in Chapter III). The indicated fault displacement estimated from structural sections (refer to map 1), taking into consideration broad scale deformation of the strata and assuming subvertical fault orientation, ranges from 50 to 60 meters along the New Maryland, Rusagonis and Hanwell faults, and from 20 to 40 meters along the Tracy fault (Figure 2.2).

Figure 2.1: General Geology of the Central Carboniferous Basin showing the outline of the Pictou Group and the major Basin Structure. Structural lineaments are taken from published maps and from studies by Chandra et al. (1982). Isopachs of the Pennsylvanian sediments are compiled and extrapolated from holes drilled to the basement (Ball et al., 1981); seismic profiles (Steeves and Kingston, 1981); estimates of other authors (Gussow, 1953); new drill data (presented here); and regional geological considerations.


LEGEND
PICTOU GROUP
RIVERSDALE GROUP
PENNSYLVANIAN
Sediments
Volcanics
HOPEWELL
WINDSOR &
HORTON GROUPS
MISSISSIPPIAN
Pre-Carboniferous basement
150 Isopachs of the Pictou Group (in meters)
Seismic profile
Drill holes intersecting Pictou Group base
Pre-Pictou Group structural lineations
BAIE DES CHALEURS
ST LAWRENCE
GULF
FREDERICTON
150
400
900
1000

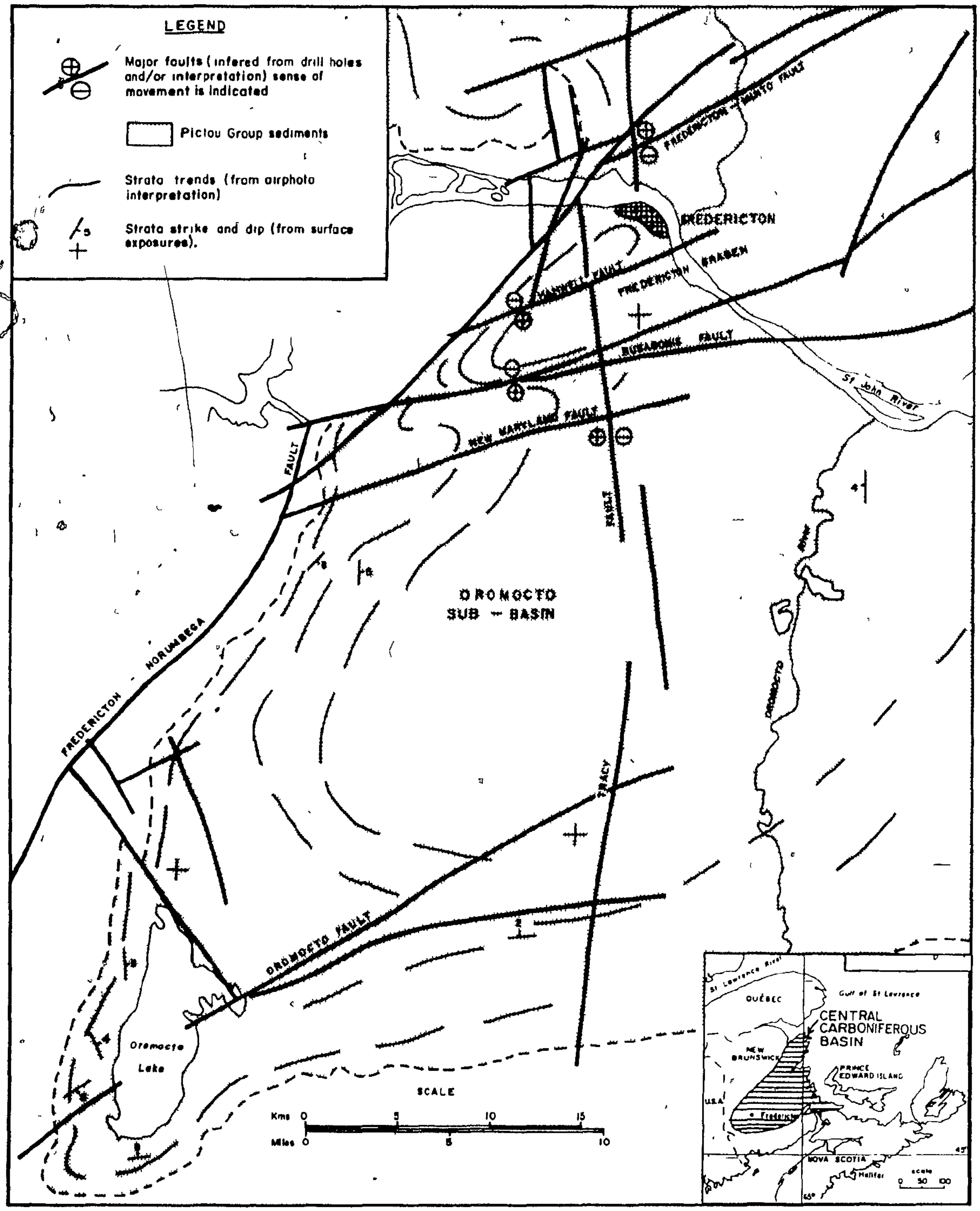


Figure 2.2· Major Structural Elements and Geometry of the Oromocto Sub-basin, Southwestern Central Carboniferous Basin, New Brunswick General strata trends, structural faults, folding and regional dip of the Pictou Group strata are shown.

2.2 GENERAL STRATIGRAPHY, PETROLOGY AND STRUCTURE

2.2.1 Introduction

Van de Poll (1970) suggested a vertical sequence of 3 megacyclic units or 'cyclothems'(1) from inspection of the 640 meter deep drill hole No.45 (Marysville #2) at a time when the true thickness of the Pictou Group in the Oromocto Sub-basin was unknown. Three megacyclic stratigraphic units are redefined in this study using the more complete and deeper drilling data which now exist. These megacycles can be correlated over a large area of the Oromocto Sub-basin, although significant lateral variations occur.

The vertical stratigraphy can be defined best in the Fredericton area where the deepest drill holes and greatest density of drilling information exist (Figure 1.4 and Table 1.2). The reconstructed subsurface stratigraphy can then be traced towards the south and southwest, and finally regionally throughout the sub-basin. Stratigraphic correlation is facilitated by the widespread development of small and large scale cycles and the presence of a number of laterally persistent marker horizons in drill holes near Fredericton. The cycles are also characterized by a distinctive geophysical well log signature.

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(1) I have referred to the term cyclothem here since it has been used extensively throughout the work of Van de Poll (1970, 1973a). However, I would suggest that it be dropped and replaced by the term megacycle to prevent confusion with the quite different stratigraphic profile making up the 'classic Pennsylvanian cyclothem' as defined by Duff et al. (1967) and others.

2.2.2 Fredericton Area

Figure 2.3 shows the stratigraphy of the Pictou Group in the Fredericton area in terms of sandstone and shale distribution. Two drill holes, Nos. 32 (Killarney Oil and Gas) and F-2 (SERU), intercept the base of the Pictou Group at a depth of 737 meters and 1005 meters respectively (Figure 2.3). In hole No.32, the Pictou Group lies directly on Mississippian volcanics (Van de Poll, 1973b). Sediments from beneath the volcanics are the pre-Pictou Canso-Riversdale Group of Late Visean-Early Namurian age (Barss et al., 1979). A continuous 1102 meter cored section is available for drill hole F-2. The hole is collared at approximately the same stratigraphic level as drill hole No.32 but intercepts strata of the Boss Point Formation (Riversdale Group, Figure 2.3) at 1005 meters. Boss Point strata in hole F-2 are composed largely of quartzites and quartz pebble conglomerates (Plate 2.1) which are easily distinguishable from the overlying litharenite dominated Pictou Group sediments and are characteristic of the Boss Point Formation throughout New Brunswick (Van de Poll, 1970; personal observation). A spore analysis from 1045 meter depth gave a poorly defined Late Namurian/Early Westphalian age which correlates these beds with the Riversdale Group (Barss, personal communication).

Additional holes drilled within and south of the Fredericton Graben range from 116 to 645 meters in depth and

Plate 2.1

Quartz pebble conglomerate of the Boss Point Formation. Drill hole F-2, 1100 m. depth.

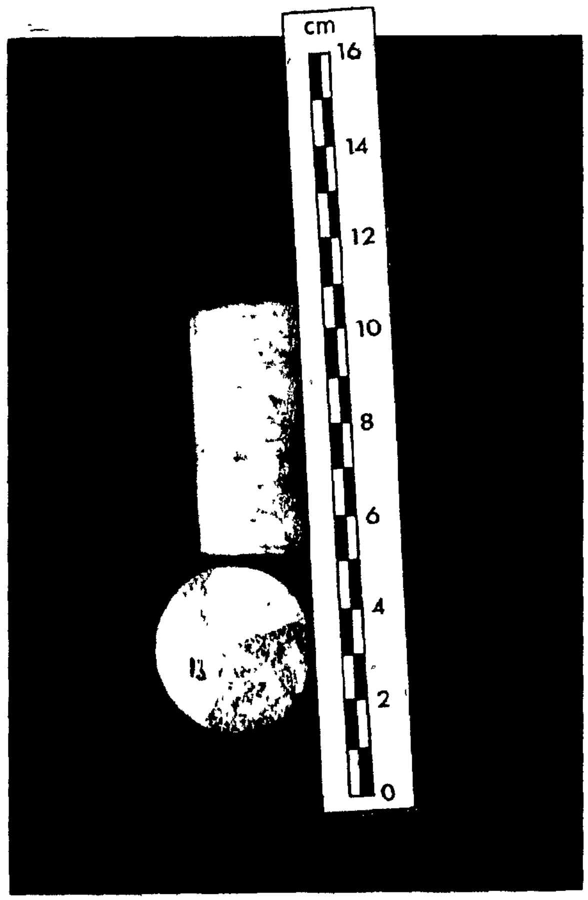

cm
16
14
12
10
8
6
4
2
0

Figure 2.3: Definition of Stratigraphic Intervals and Correlation between Drill Holes in the Fredericton Area. The drill holes are hung on datum lines PH-1 and PH-3 marker horizons. The variation in collared stratigraphic level of the drill holes is mainly produced by faulting and topographic variation in the Fredericton area. See Figure 1.4 for location of drill holes. The stratigraphic sections presented in this figure represent drill holes from a given area. No particular scale between drill holes is intended.

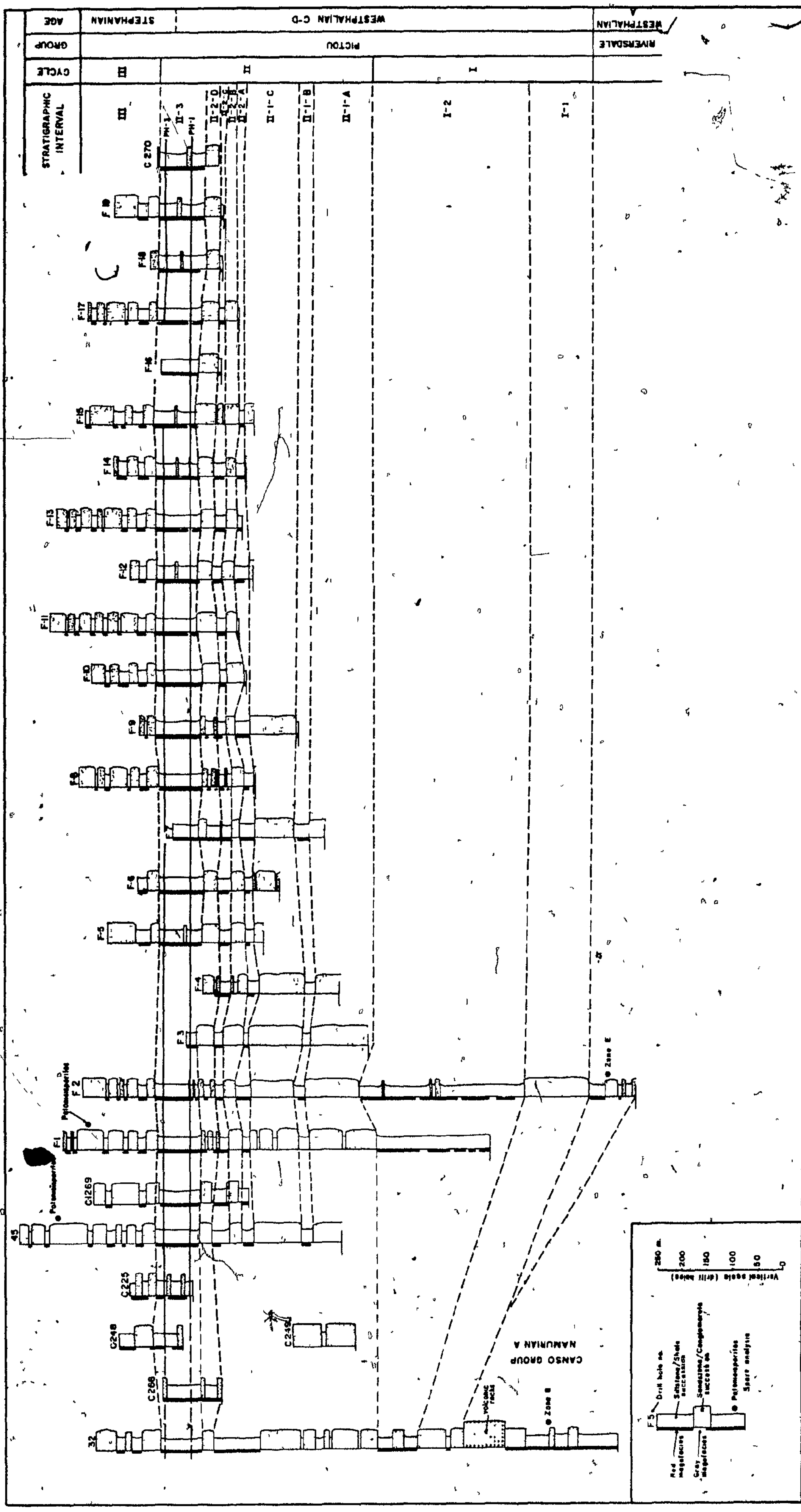
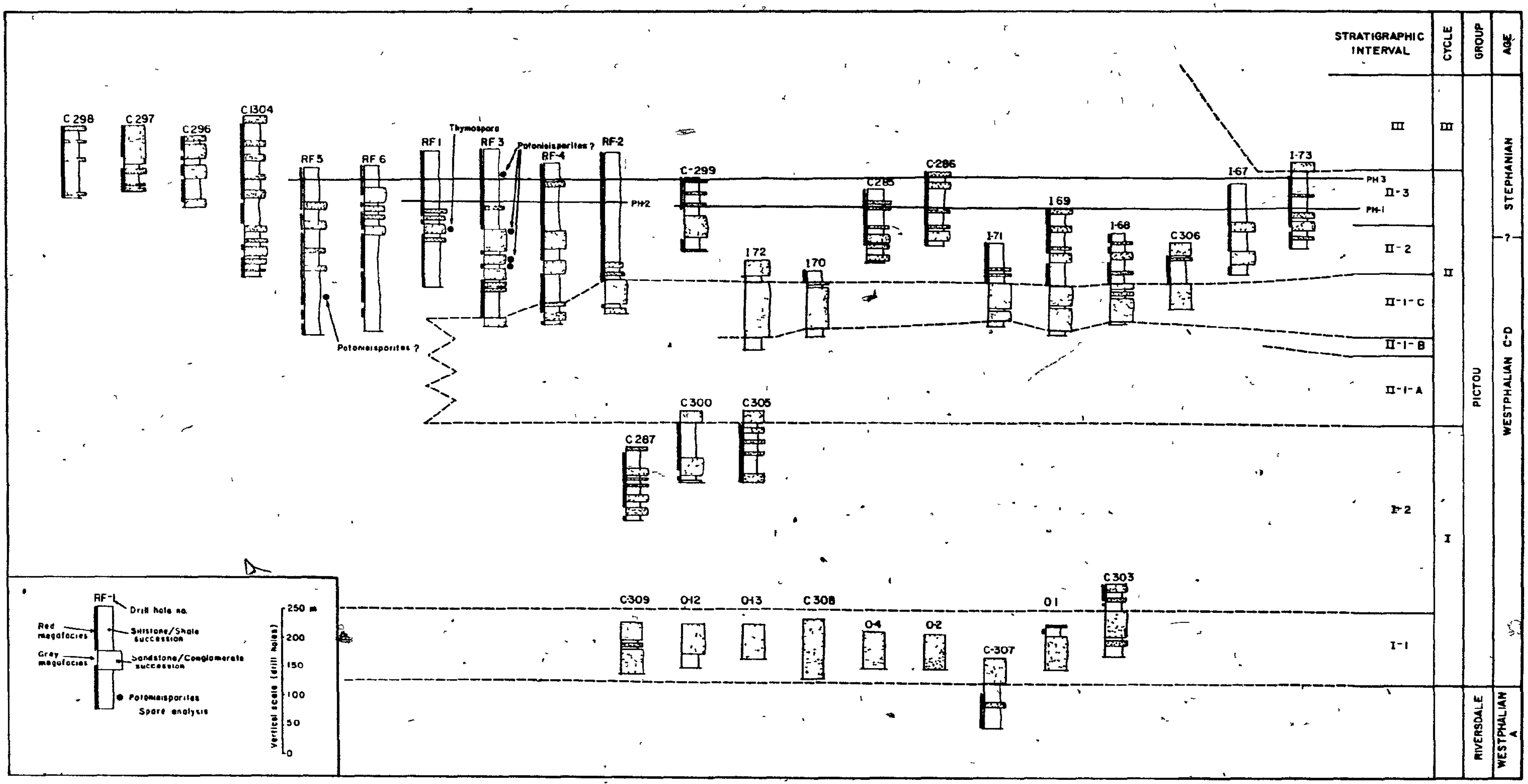

AGE
STEPHANIAN
WESTPHALIAN C-D
WESTPHALIAN B
GROUP
PICTOU
RIVERSDALE
CYCLE
III
II
I
STRATIGRAPHIC INTERVAL
I-2
I-1
CANSO GROUP
NAMURIAN A
Zone E
Zone B
Volcanic rocks
Red megafacies
Gray megafacies
Drill hole no.
Siltstone/Shale succession
Sandstone/Conglomerate succession
Spore analysis
Vertical scale (drill holes)
250 m
200
150
100
50
0

Figure 2.4: Definition of Stratigraphic Intervals and Correlation between Drill Holes in the Fredericton Area and Southwest toward French Lake and Oromocto River. The variation in the collared stratigraphic level of the drill holes is mainly produced by the basin geometry. See Figure 1.4 for location of drill holes. The stratigraphic sections presented in this figure represent drill holes from a given area. No particular scale between drill holes is intended.


STRATIGRAPHIC INTERVAL
CYCLE
GROUP
AGE
C 298
C 297
C 296
C1304
RF 5
RF 6
RF 1
Thymospora
RF 3
Potonieisporites ?
RF-4
RF-2
C-299
C 285
C 286
I 69
I-71
I-68
C 306
I-67
I-73
I 72
I 70
Potonieisporites ?
C 300
C 305
C 287
C 309
O12
O13
C 308
O4
O2
C-307
O1
C 303
PH 3
PH 2
PH-1
III
II - 3
II - 2
II - I - C
II - I - B
II - I - A
I - 2
I - I
I
II
STEPHANIAN
WESTPHALIAN C-D
WESTPHALIAN A
PICTOU
RIVERSDALE
RF-1
Drill hole no.
Red megafacies
Siltstone/Shale succession
Grey megafacies
Sandstone/Conglomerate succession
Potonieisporites
Spore analysis
Vertical scale (drill holes)
250 m
200
150
100
50
0

all bottom within the Pictou Group (Figure 2.3). The uppermost stratum within the Fredericton Graben (Figure 2.3) is dated as Stephanian in age from miospores (Van de Poll, 1973b; Barss et al., 1979; and personal communication). Unfortunately, high maturation levels preclude age determinations at intermediate stratigraphic levels in the immediate vicinity of Fredericton (Hacquebard and Avery, 1982; Barss, personal communication). However, the intermediate levels can be correlated by lithostratigraphy with drill holes in the Oromocto River area to the southeast, which have produced tentative miospore ages of mixed Thynospora/Potonieisporites zones (Figure 2.4; Barss, 1982). The entire uninterrupted Westphalian C-D, Stephanian section of the Pictou Group appears to be preserved in the Oromocto Sub-basin (Table 1.1).

Three megacycles are defined in this study by the deepest drill holes near Fredericton. The thickness of the megacycles ranges from 150 to 400 meters and forms a basis for consistent lateral lithostratigraphic correlation throughout the Oromocto Sub-basin (Figures 2.3 and 2.4).

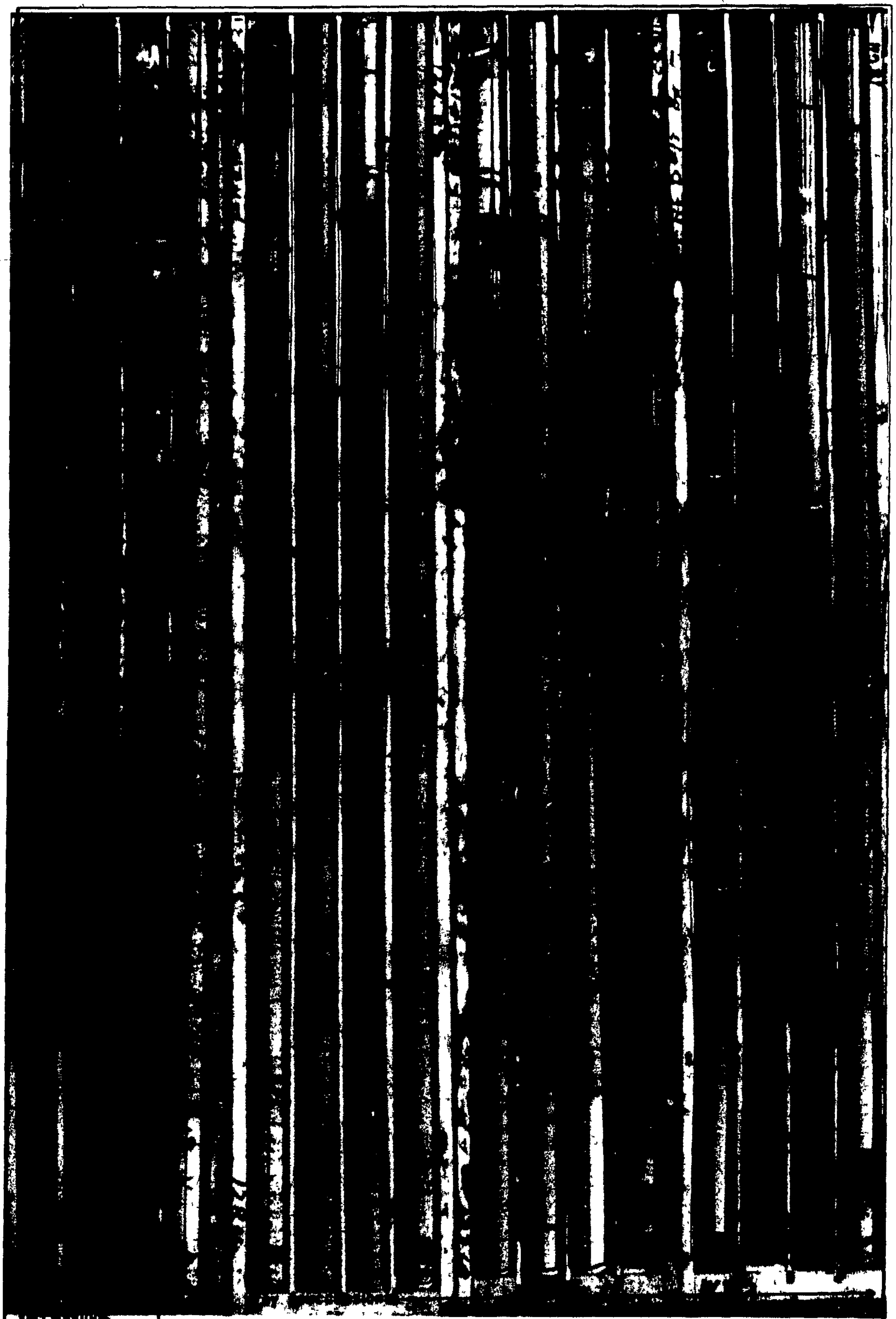
The megacycles and some of the smaller scale cycles appear to be sufficiently distinct and extensive to merit member status. I prefer not to impose any of the constraints of formal unit stratigraphy on the Pictou Group and accordingly refer to the megacycles with Roman numerals: I, II, and III.

Lithostratigraphic subdivision within the megacycles into appropriate stratigraphic intervals are designated by Arabic numbers 1, 2, ... etc. and letters A, B, C,...etc. where a third level of division is warranted (Figures 2.3 and 2.4). Marker horizons of laterally persistent coaly laminae are referred to by letters PH-1, PH-2, etc. Three such horizons useful for stratigraphic correlations have been recognized in this study. Megacycles I and II are characterized by a thick lower succession dominated by grey, coarse-grained sandstones and conglomerates overlain by an upper succession of red shales and siltstones. Megacycle III consists of repeated smaller scale cycles (10-75 meters thick) of similar character, and megacycle II has a prominent transitional zone of small scale cycles (i.e. interval II-2, Figure 2.3) between its lower and upper successions.

In more detail, the lower grey successions of the cycles consist predominantly of coarse-grained sandstone and conglomerate with minor shale. The sandstones contain abundant coaly spar and fine plant debris, and are characterized by large scale cross-bedding structures. Layers of fine-grained sand and shale (generally dark-coloured with abundant fine coaly plant debris) occur in intervals up to 20 meters thick but these are rare. Some of these intervals (i.e. interval II-1-B, Figures 2.3, 2.4) can be correlated over a considerable lateral distance. The upper red successions, on the other hand, are dominated by massive mudstones, siltstones and very fine-grained sandstones with small scale current and bedding structures. Mottled root zones, ferricrete and calcrete nodules are common in these successions. Coarser sandstones occur only as isolated bodies 0.5 to 5 meters thick.

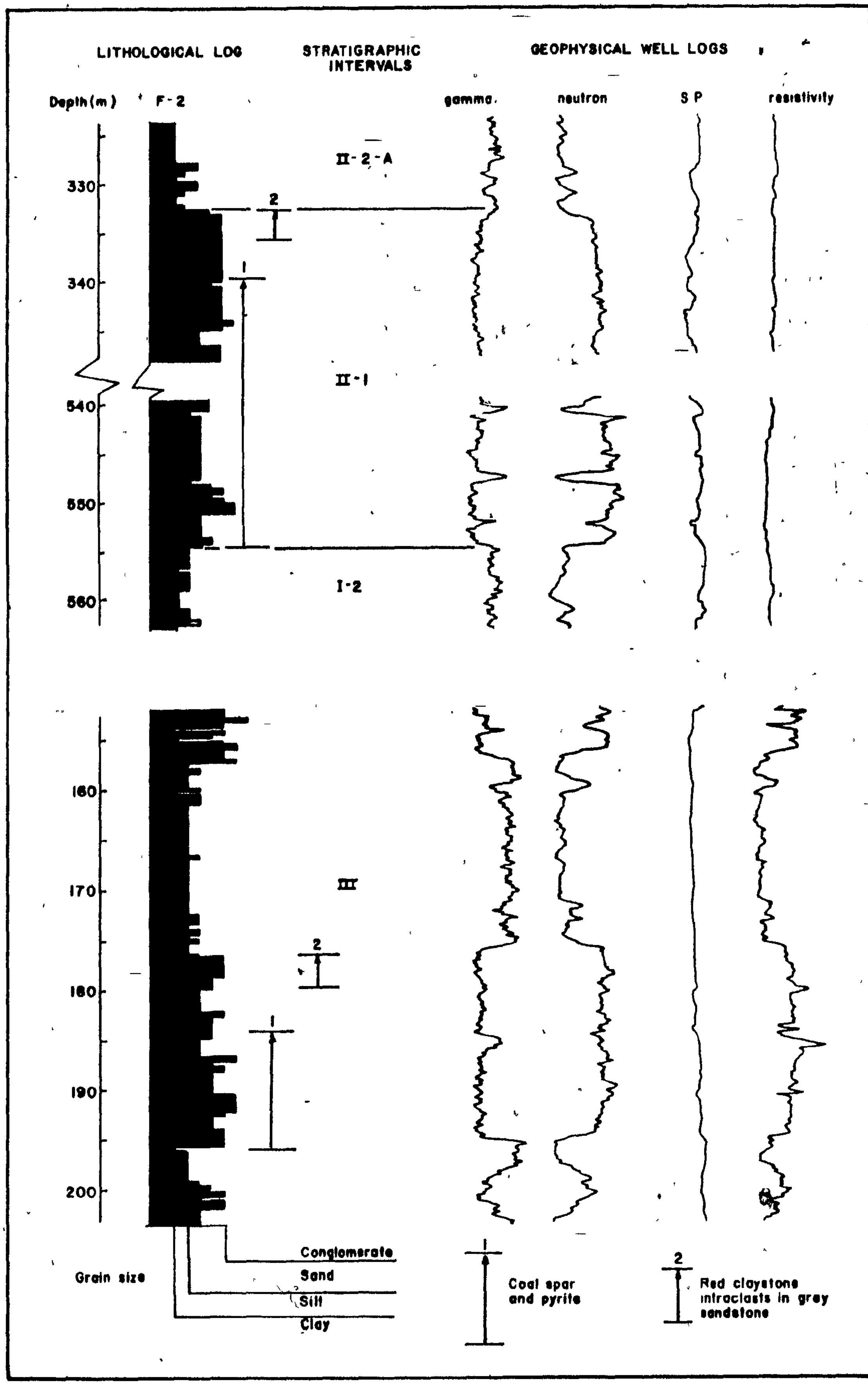
The lower, grey, coarse-grained successions at the base of the cycles always display a very sharp colour, well log, and lithologic contact with underlying fine red successions (Plate 2.2). The upward transition from grey to red successions in contrast is generally more gradational, characterized by a decrease in coal spar and pyrite, appearance of red claystone intraclasts in the grey sandstones and a gradational colour change (Figure 2.5). No evidence for an upward coarsening in the thick red successions indicating facies progradation of overlying coarse sands and conglomerates was observed in detailed logging of the core. This contrasts somewhat with reported observations in chip sample holes of similar cycles in other areas of the Central Basin (Legun, 1980; Ball et al., 1981; Legun and Rust, 1982). The lithologic and sedimentary character of the cycles suggests that the upper and lower successions can be better defined in terms of "megafacies sequences" rather than simply coarse grey and fine red successions. In addition, the grey versus red colour of the assemblages is viewed as only a general, large scale guide to

Plate 2.2: Photographs of core showing cycle transition and facies types. Typical sharp transition from the fine red succession (left), to the overlying grey coarse-grained succession (right). Lithofacies described in chapter III are identified on the transparent overleaf. Drill hole F-13, stratigraphic interval III, 110.8 to 134.7 meter depth. Depth in meters is marked on the core.




Se
Fm
Se
Se
Fm
FLOOD PLAIN SYSTEM (Facies Fl and Fm)
St
FLUVIAL CHANNEL SYSTEM
St
Sr
Sh
Se
Fsc
Sr
Sr
Sr
Fsc
Sr
St
Fine, red successions
grey successions

Figure 2.5: Typical Colour Transition Characteristics of the Red Shale Dominated and Grey Sandstone Dominated Successions in Large and Small Scale Cycles of Drill Hole F-2. The observed colour of the sediments is shown in this figure with reduced grey and green colours displayed as green, oxidized red colours displayed as red and transitional colours as purple.



LITHOLOGICAL LOG
STRATIGRAPHIC INTERVALS
GEOPHYSICAL WELL LOGS
Depth (m)
F-2
gamma
neutron
S P
resistivity
330
340
540
550
560
160
170
180
190
200
II-2-A
II-1
I-2
III
Grain size
Conglomerate
Sand
Silt
Clay
Coal spar and pyrite
Red claystone intraclasts in grey sandstone

the lithostratigraphy, which in detail breaks down. There are many thin horizons of grey coaly material in the thick red shale successions and likewise thick grey sand successions locally contain red horizons.

The colour of both of the successions is mainly a reflection of the colour of their clay fraction. The colour of clays in sediments is commonly independent of total iron content but is instead dependent on the Fe^{3+}/Fe^{2+} ratio or oxidation state of the sediment (Tomlinson, 1916; Berner, 1971). The oxidation state of most sediments is ultimately controlled by the amount of organic matter present (Potter et al., 1980, pages 55, 56). Van Houten (1961) in a major study of red beds concluded that the colour of sediments is almost always depositional or diagenetic in origin. No evidence of any major diagenetic colour changes such as secondary colour alterations along fractures or claystone intraclast margins was observed in detailed examination of drill core from the Oromocto Sub-basin. This suggests that the colour signature of the successions is largely a depositional or early diagenetic characteristic but it may be only of significant stratigraphic value in relatively small areas of the Central Basin such as the Oromocto Sub-basin. The megacycles and stratigraphic elements presented in Figures 2.3 and 2.4 can therefore be best understood in terms of the varying dominance of lithologies within the successions (Appendix A) and facies sequences which will be discussed in detail in Chapter III. The degree of lithostratigraphic correlation in the Oromocto Sub-basin indicates the continuity of the sedimentary processes within the cycles.

Thin millimeter to centimeter thick coaly laminae occur in the thick upper successions of intervals I-2 and II-3. Two such layers in stratigraphic interval II-3 (PH-1 and PH-3, Figures 2.3, 2.4) can be traced as thin marker horizons in all the holes drilled within a 12 km radius of Fredericton. An additional horizon (PH-2) is observed in the Cominco drill holes RF-4 to RF-6, southeast of Fredericton (Figure 2.4). These particular marker horizons often display a sharp gamma-ray peak on geophysical well logs.

2.2.3 Geophysical Well Log Signature

Analysis of geophysical well logs on the basis of curve shapes and patterns have been used for many years in the oil and mineral exploration industries for lithological interpretation, facies analysis and lateral correlation (Itenberg, 1971; Hallenburg, 1979; Pirson, 1963, 1977). Well logging is undertaken by lowering a narrow wire line probe down a drill hole and measuring various geophysical properties of the surrounding rock. Discussion of the numerous types of well logging will be limited here to a brief description of resistivity (Res.), self potential (S.P.), natural gamma-ray, and neutron logs which are available for most of the drill holes used in this study.

Resistivity and self potential logs are both geophysical electrical well logging techniques which measure various physical properties of a rock (Telford et al., 1976). The resistivity probe measures the electric resistance of a portion of the sediments adjacent to the drill hole and between the electrodes by which the current is introduced and measured. The actual measurement is dependent on the direct resistance of the rock, its porosity and the resistivity of formation waters contained in the rock. Contrasting sedimentary lithologies display different electrical resistances, and the resistivity curve can indicate approximate lithology and contact relationships in a drill hole (Figure 2.5). Generally speaking, shales are less resistant than sandstone. Self potential (S.P.) logging is a measure of the distribution of unbalanced ions caused by various lithologically induced mechanisms which are particularly sensitive and useful in distinguishing sand and shale contacts. Unfortunately, S.P. measurements are difficult to undertake and the logs are often subject to technical problems (Skipper, 1976; Hallenburg, 1979; p.59).

Gamma and neutron logging are radioactivity methods. The natural gamma probe measures the total radiation of natural gamma-rays emitted from the rock. The natural gamma curve also serves as an effective lithologic indicator. It is particularly useful in distinguishing sand and shale sequences and their contacts since shale generally has a higher natural radioactivity than sandstone (Figure 2.5). Neutron logging measures the response of the rock formation adjacent to the drill hole to the bombardment by a source of neutrons in the probe. The amount of hydrogen and therefore the amount of fluid filling pore spaces in the rock can be measured from this probe response (Telford et al., 1976). In clastic sequences the neutron method produces a good lithology curve because sandstone is generally more porous than shale (Figure 2.5).

In addition to their use in identifying lithology (particularly shale-sand sequences), geophysical well logs can be used in lateral correlation of layered sequences. Shales generally form the reference or base line in lateral correlation of electric and radioactivity well logs of clastic sections (Allen, 1975). Radioactive shales are particularly useful. Lateral correlation using these criteria can define the large scale geometry of clastic sequences. Well logs can also be used to identify depositional processes and environments in sedimentary basins (Busch, 1974; Allen, 1975). This information is generally furnished by the identification of characteristic curve shapes and patterns reflecting the texture, fabric and geometry of sand and shale bodies. Electric and radioactivity well logs measure the 'degree of shaliness' in a typical sand-shale sequence. An examination of the patterns produced by these logs can therefore indicate internal contact and vertical profile relationships in layered sequences which may be related to depositional environments. Skipper (1976) cautions that no general panacea for the identification of depositional processes is to be found in well logs but that processes may be inferred by analyzing log patterns and relating them to known sand bodies or vertical facies sequence.

In the Pictou Group of the study area, the cycles, individual lithologies and megafacies assemblages display a characteristic well log signature. They form a particularly useful and essential tool in interpreting the rotary drill holes. Unfortunately, S.P. and resistivity logs generally display inconsistent or flattened profiles in many of the holes (Figure 2.5) due to technical problems related to the lack of conductivity between the probe and rock (personal communication, Mike Fowler, SERU Nucléaire Ltée). In many of the holes, the S.P. and resistivity logs could not be run because measurements were made through the drill rods. Both the neutron and gamma logging provide well defined lithologic contacts and can be interpreted in terms of the distinctive facies patterns of

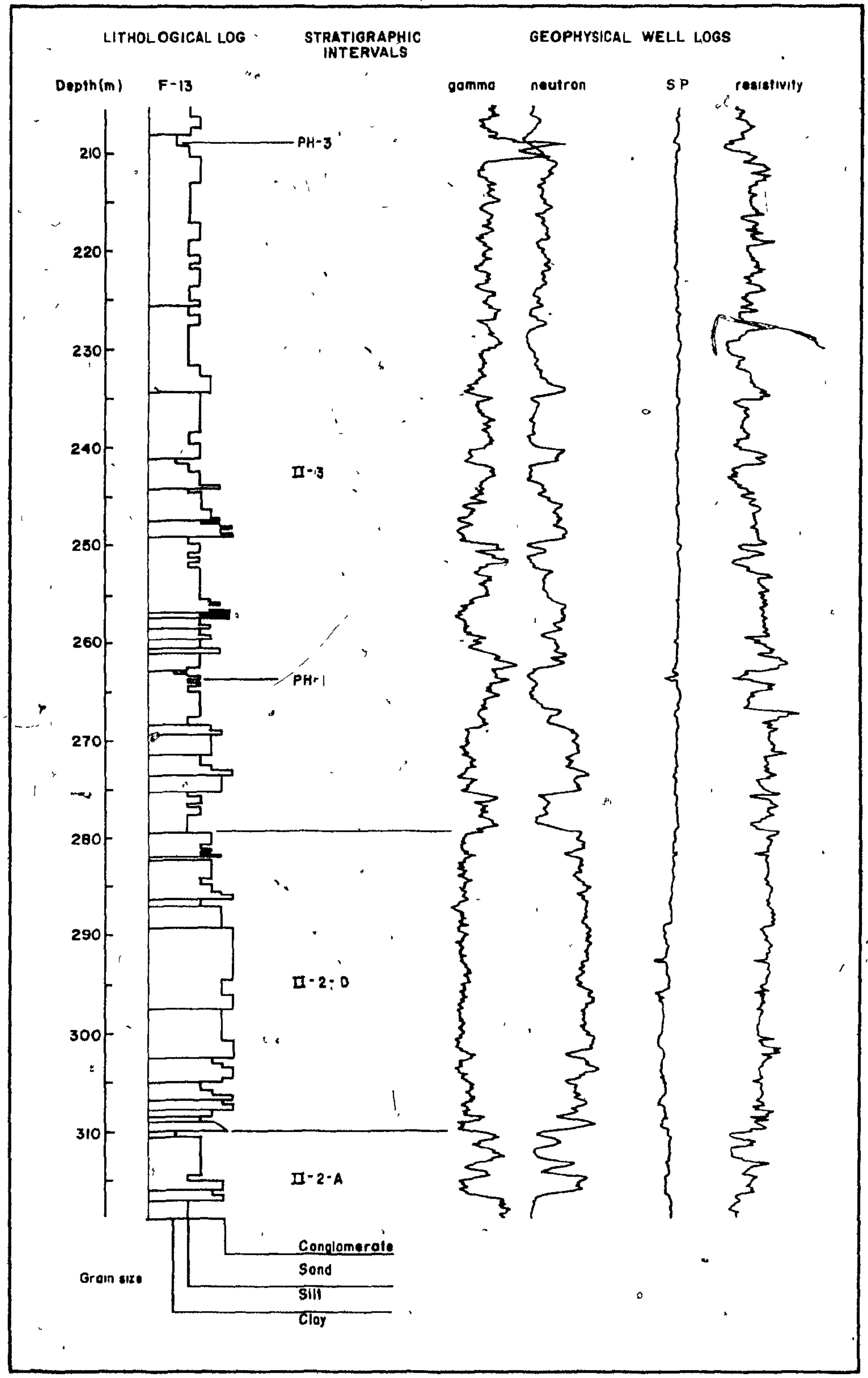


Figure 2.6: Geophysical Well Log Signature and Patterns of Stratigraphic Intervals, Pictou Group, Oromocto Sub-basin.

the Pictou Group (Figure 2.6). Sandstones in the fine red successions are generally isolated and fine upward which produces a characteristic "christmas tree" shape (Figure 2.7A). In comparison, the coarse grey successions forming the base of cycles are dominated by sandstone and conglomerate which display overall homogeneous porosity and a vertically uniform gamma response. Shale intervals show relatively sharp lower and upper contacts. This produces a characteristic "box-shaped" pattern (Figure 2.7B). The resistivity curves, when available and of good quality, can also be used to define fining upward and coarsening upward sequences. S.P. curves in the coarse grey successions sometimes display sharp inflexion due to contrasting sand and shale contacts. Thin horizons of coaly laminae in the fine red successions commonly display a sharp gamma peak. The characteristic curve patterns and coaly laminae with gamma peaks can be used to correlate large and small scale cycles between drill holes throughout the basin.

2.2.4 Sandstone Composition and Provenance

Table 2.1 documents examples of representative samples from different drill holes and stratigraphic levels of the Pictou Group in the Fredericton area. No significant stratigraphically controlled compositional variation could be identified in this study from sandstone samples taken from the drill holes. Samples from different stratigraphic intervals, cycles and contrasting facies all have a lithic arenite

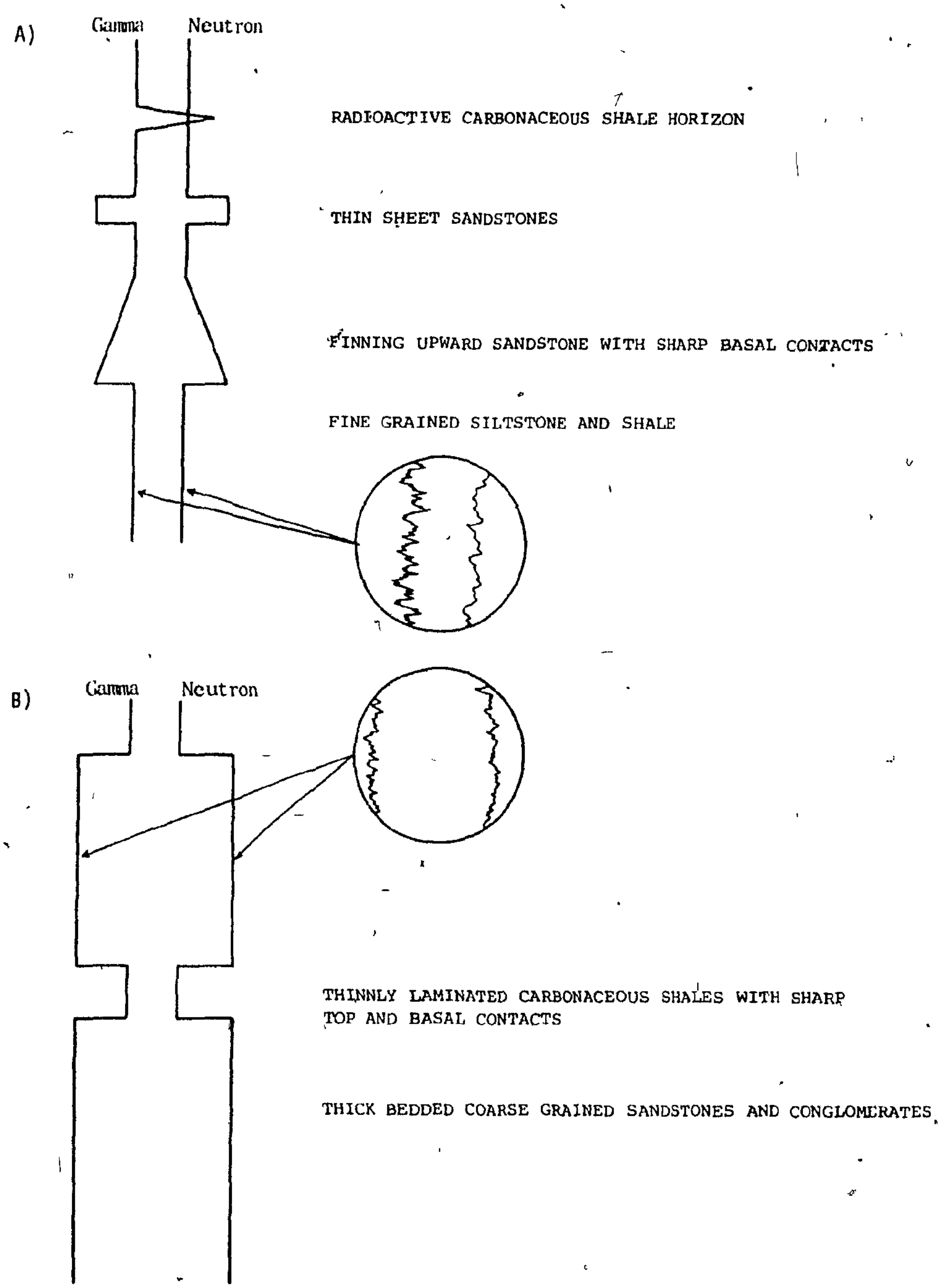


Figure 2.7: Ideal Patterns in Gamma and Neutron Geophysical Well Logs of the Pictou Group, Oromocto Sub-basin:

A) Red Fine-Grained Successions, "Christmas Tree" Pattern
B) Grey Coarse-Grained Successions, "Box Shape" Pattern

composition characteristic of the Pictou Group in general (Van de Poll, 1970; Ball et al., 1981).

The framework mineralogy of the Pictou Group lithic arenites consists of various types of rock fragments (mostly volcanic or volcaniclastic and metamorphic with some plutonic), quartz (mainly undulose varieties), feldspar (both potassium feldspar and plagioclase), and accessory chert, muscovite and various heavy minerals such as tourmaline, sphene and zircon.

Volcanic and metasedimentary rock fragments are common constituents of the Pictou Group (Table 2.1). The meta-sedimentary fragments are dominantly a quartzite rock (poly-crystalline quartz grains) containing some metamorphic minerals such as muscovite. The individual quartz crystals within these composite grains show strong undulose extinction and preferred orientation characteristic of metamorphic quartz. The volcanic rock fragments consist of both composite quartz rich volcani-clastic rocks and quartz-feldspar porphyry. The volcaniclastic fragments can be distinguished from the metasedimentary grains by their characteristic non-undulose extinction and broken shard outlines of the composite quartz grains (Plate 2.3).

Quartz grains in the samples were all of a common type characterized by an irregular outline, silica cement over-growths, small fluid inclusions (with vapour bubbles), and moderate to strongly undulose extinction. These characteristics

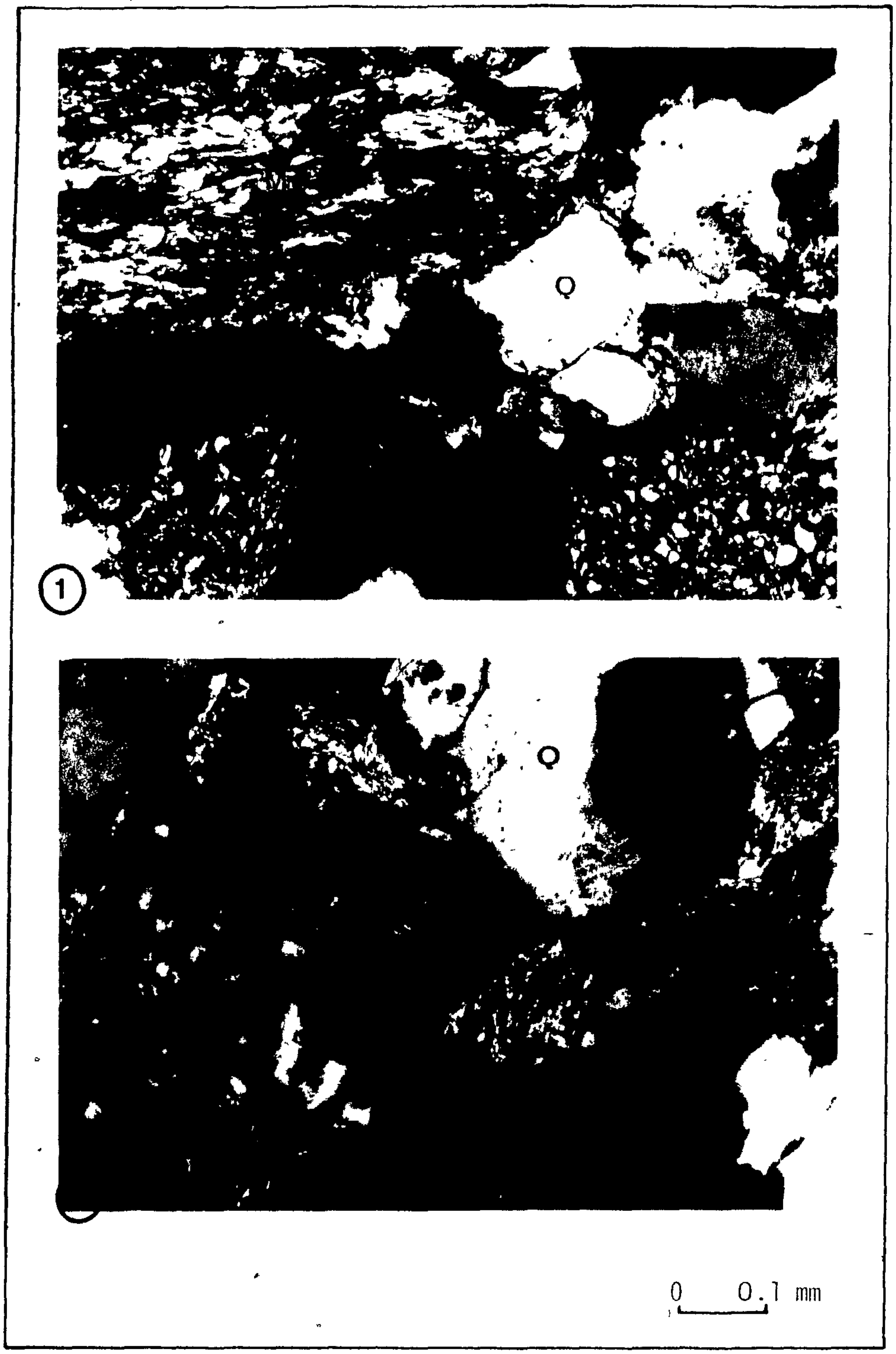


Plate 2.3: Photomicrographs of Pictou Group Sandstones.

Figure 1: Lithic arenite, stratigraphic interval III, 40.6 meter depth, drill hole F-2. Note presence of metamorphic rock fragments (M), volcanic rock fragments (V), and quartz (Q). Crossed nicols.

Figure 2: Lithic arenite, stratigraphic interval II-1-B, 436.5 meter depth, drill hole F-2. Note presence of quartz (Q), feldspar (F), metamorphic rock fragments (M), and the tuffaceous and porphyritic types of volcanic rock fragments (V). Crossed nicols.

Table 2.1: Point Counted Sandstone from Different Stratigraphic Intervals of the Pictou Group and Boss Point Formation (Riversdale Group), Fredericton Area. All percentages relate to total point counts (over 1000) of all famework grains, recalculated to 100%. Rock classifications are after Pettijohn, 1975, page 212.

DRILL HOLE NO.	STRATIGRAPHIC INTERVAL	DEPTH (m)	% QUARTZ	% FELDSPAR	% CHERT	% CALCITE (REPLACEMENT)	% VOLCANIC ROCK FRAGMENTS	% METASEDIMENTARY ROCK FRAGMENTS	CLASSIFICATION
F-2	PICTOU III	140 5	43.7	15.5	1.3	1.3	12.7	25.5	LITHIC ARENITE
F-15	PICTOU III	40.6	33.5	12.3	1.2	4.4	18.0	30.6	LITHIC ARENITE
F-2	PICTOU II-3	184.3	27.7	11.7	0.6	1.2	24.8	34.0	LITHIC ARENITE
F-2	PICTOU II-2-D	240.8	27.9	15.9	0.6	0.4	17.8	37.4	LITHIC ARENITE
F-5	PICTOU II-2-B	245.4	34.8	18.1	1.0	0.9	19.6	25.6	LITHIC ARENITE
F-2	PICTOU II-1-C	365.7	32.9	19.2	0.7	1.9	16.2	29.1	LITHIC ARENITE
F-2	PICTOU II-1-B	436.5	26.3	17.6	1.2	14.0	15.2	25.7	LITHIC ARENITE
F-2	PICTOU II-1-A	500.1	28.1	12.2	3.1	0.9	9.6	46.1	LITHIC ARENITE
F-2	PICTOU I-2	664.4	33.5	11.1	0.8	0.1	23 7	30.8	LITHIC ARENITE
F-2	PICTOU I-2	808.5	29.3	13.1	4.6	1.3	14.4	37.3	LITHIC ARENITE
F-2	PICTOU I-1	862.3	37.4	14.0	1.5	0.3	12.6	34.2	LITHIC ARENITE
F-2	RIVERSDALE GROUP	1080.2	53.3	17.9	1.7	0.8	14 1	12.2	LITHIC ARENITE
F-2	"	1099.1	62.4	5 7	6.3	0.1	4.5	21.0	LITHIC ARENITE

are suggestive of plutonic, vein or metamorphic origin (Folk, 1959). Feldspars in the samples consist of both potassic and plagioclase varieties. Both are commonly moderately altered in appearance. Feldspar replacement by calcite is a common feature in many samples.

A predominance of metamorphic rock fragments and undulose quartz grains suggests that the Pictou Group sandstones were derived mainly from the surrounding pre-Carboniferous metamorphic terrain underlying most of New Brunswick (Van de Poll, 1970). The volcanic fragments observed in samples from the Fredericton area are similar in texture and composition to the acidic tuffs and porphyry of the Mississippian Harvey succession which underlies the Pictou Group to the southwest of Fredericton (Kuan, 1970).

The composition of two samples taken from the base of drill hole F-2 in the Boss Point Formation (Table 2.1) indicates that Boss Point sandstones can be distinguished from the Pictou Group on the basis of their increased quartz content, as suggested by Van de Poll (1970).

2.2.5 French Lake-Oromocto River Area

Six drill core holes (RF-1 to RF-6 inclusive) occur in an area 12 to 25 km southeast of Fredericton, in the French Lake-Oromocto River area (Figure 2.4). They are all collared in lateral equivalents to stratigraphic interval II-3. The marker horizons PH-1 and PH-3 do not occur except in the hole closest to Fredericton (RF-4). An intermediate marker horizon (PH-2) is observed in most of these drill holes. The most important stratigraphic aspect of these holes is the apparent lateral variation and change in stratigraphic intervals II-1 and II-2. No difference between the facies assemblages of these drill holes and those in the Fredericton area was observed. Well logs, although incomplete and of poorer quality, display the same characteristic patterns seen in adjacent holes, and can be used in regional lithostratigraphic correlation.

2.2.6 Regional Oromocto Sub-basin

The remaining holes drilled throughout the basin average only 122 meters in depth and are much more widely spaced (Figures 1.6, 2.4). Topographic expression of megacycles I and II as cuesta ridges is well developed along the western margin of the Oromocto Sub-basin but becomes less so to more poorly developed to the east and southeast. Correlation in these areas becomes uncertain, but nevertheless the general pattern of the megacycles can be outlined (Map No.1). Two aspects of the stratigraphy appear to be indicated:

1) The overall megacyclic stratigraphy is laterally continuous along the western margin of the Oromocto Sub-basin.

2) The basal strata of megacycle II become thin and probably pinch out completely to the east and south-east. The basal strata of megacycle I, however, are largely continuous and correlate with outcrop samples dated as Westphalian C, Vestispora Zone (Ball et al., 1981).

A synthesis of all geological and structural information with the generalized patterns of megacycle distribution in the Oromocto Sub-basin is presented on Map 1.

CHAPTER III : FACIES ANALYSIS AND BASIN EVOLUTION

ABSTRACT

The Pictou Group of Upper Pennsylvanian age is a non-marine assemblage of clastic rocks which dominate the sedimentary fill of the Central Carboniferous Basin of New Brunswick. Stratigraphy in the southwest portion of the Central Basin records the development of large scale megacycles 150 to 400 meters thick and smaller scale cycles 25 to 75 meters thick. Lateral facies continuity in the cycles varies. The bases of the cycles are dominated by a succession of grey coarse-grained sandstones and conglomerates while the upper portions of the cycles are dominated by a succession of red fine-grained sandstones, siltstones and shales. The cycles are largely the product of dynamic sedimentary interplay between coexisting fluvial channel and flood plain depositional systems. The fluvial channel system is characterized by a sequence of repeated conglomerate-sandstone channel facies. Deposition of sediments rich in plant debris occurred in abandoned channels. The fluvial channel systems probably represented the deposits of major rivers of a braided pattern and high sediment charge. The flood plain system is dominated by a facies sequence of fine-grained sediments deposited distally on a flood plain. Pedogenic features are common and thin isolated sandstone beds record minor channel deposits. Seasonal flooding of the major fluvial channels controlled the detailed lithostratigraphy and facies sequence within each depositional system. Allocyclic controls such as tectonics and source area climate likely triggered changes in the distribution patterns of the unstable, highly sediment-charged fluvial belts.

3.1 INTRODUCTION

This report documents the evolution of continental clastic sediments of the Pennsylvanian Pictou Group (Westphalian C-D, Stephanian in age) in a portion of the Central Carboniferous Basin, New Brunswick (Figure 3.1). Studies of the lithology and sedimentology of the Pictou Group in New Brunswick have been previously carried out (Kelley, 1967; Van de Poll, 1970, 1973a, 1973b; Legun, 1980; Ball et al., 1981; Legun and Rust, 1982) but no examples of regional basin evolution have been documented. Lack of consistent exposure throughout the Central Basin makes lateral comparison and correlation difficult (Ball et al., 1981). The interpretation of the depositional facies of the Pictou Group is also hampered by a poverty of lithologic variations and expression of depositional environment. As a result, previous studies have ignored or have been unable to determine sedimentary mechanisms by which the basin has been filled.

Recent core and rotary drilling information from the south-western portion of the Central Basin now make it possible to reconstruct the facies distribution. Across most of this area, two distinctive alluvial depositional systems are recognized and are observed in large and small scale cycles. The recognition of the cyclic nature of the Pictou Group is not new in itself. Van de Poll (1970), in an analysis of the entire Central Basin, divided the Pictou Group into major 'fluvial cyclothems', each 100 to 300

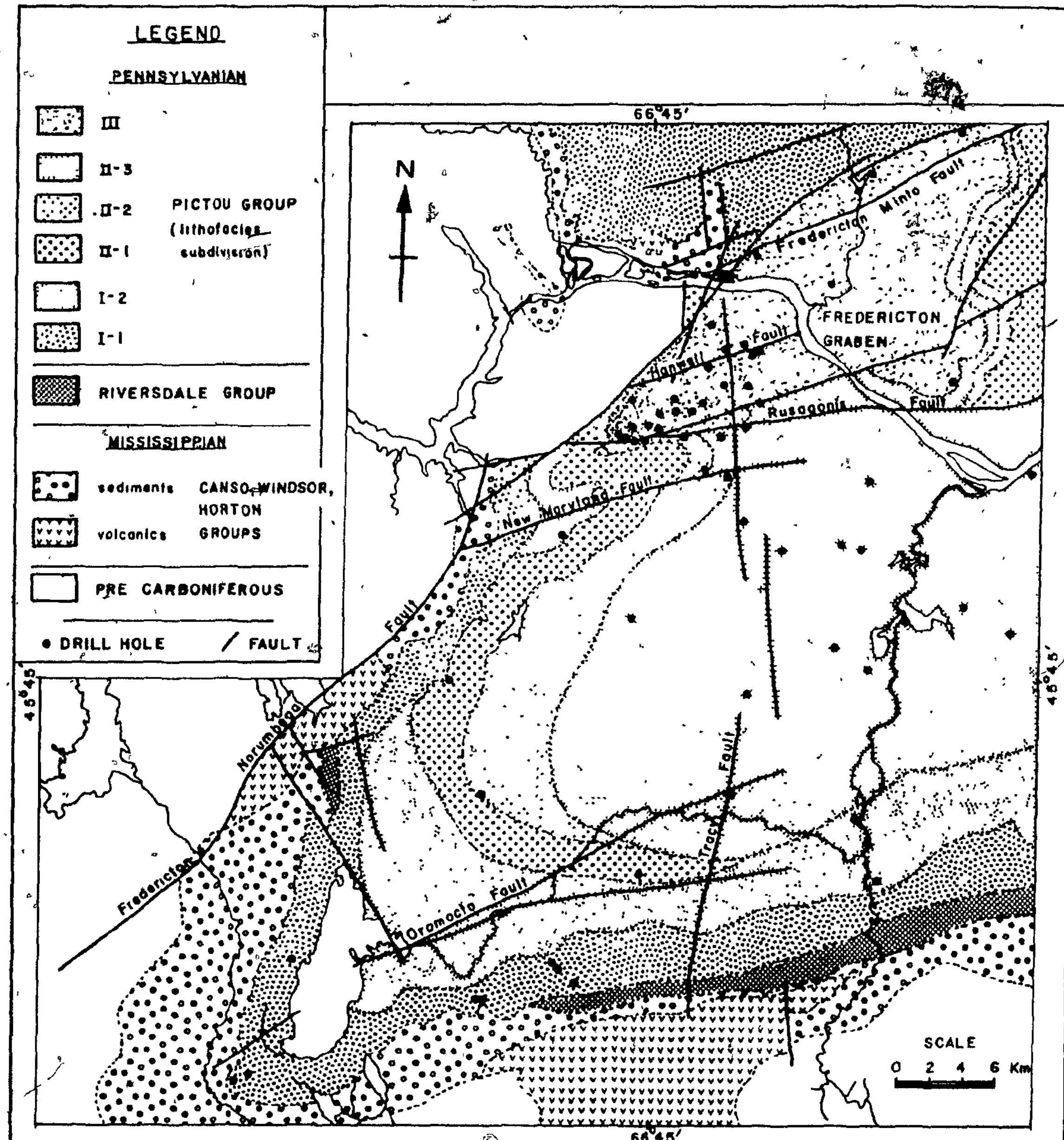


Figure 3.1: Regional Geology, Structure, Location of Study Area, and Drill Holes in the Oromocto Sub-basin, Fredericton Area, New Brunswick.

meters thick, consisting of a coarse-grained, grey-coloured megafacies at the base and a finer-grained, red-coloured megafacies at the top. Van de Poll (1973a) further suggested that vertical and lateral stratigraphy in the basin could be explained in terms of recurring cyclothems at different scales. In my own study, a comparison of the cyclic stratigraphy shows that the development, relative position and migration of large and small scale cycles were strongly dependent on extrabasinal controls or allocyclic mechanisms as defined by Beerbower (1964) such as tectonics, source area climate, and the supply and transport of the clastic sediment into the basin. Smaller scale internal facies patterns within the cycles were largely produced by intrabasinal energy distribution or autocyclic mechanisms (Beerbower, 1964), resulting in individual channel migration and avulsion.

The object of this report is to develop a regional model for the evolution of the Pictou Group. To accomplish this goal requires an identification of the major depositional systems and a discussion of their interrelation and impact on basin evolution. More than 15,000 meters of drill core, drill chips and geophysical well logs in 64 separate holes served as the data base from which this report was prepared. For an area measuring approximately 2,000 km^2, this represents only a moderate density of drill holes but the majority of the holes have continuously cored sections which were examined in great detail. In addition, almost half of the holes were drilled in and around the city of Fredericton which permits a more detailed subsurface picture to be assembled in this area. Numerous stratigraphic cross-sections were constructed to determine the framework of the facies distribution. Integration of chip samples and core logs with geophysical well logs aided the interpretation of stratigraphy and construction of facies maps.

3.2 REGIONAL BASIN GEOMETRY

The southwestern end of the Central Carboniferous Basin forms a bowl-shaped sub-basin up to 1000 meters thick and bounded by faults and the Fredericton graben structure along the northwest and northern margins (Figure 3.1). For convenience, the author has named this area the Oromocto Sub-basin. Suboutcropping strata trends which are clearly visible as topographic variations on airphotos, and bedding dips measured from surface exposures define the sub-basin structure. Pictou strata along the margins of the sub-basin dip from 5^{o} to 8^{o} towards the centre where bedding becomes essentially horizontal. Large scale broad open warp folds within and on the south edge of the Fredericton graben are likely formed in response to the major northeast trending faults. The relative fault displacement and fold pattern is confirmed in structural contours measured from marker horizons identified in drill holes. Strata in the Fredericton graben have been down-faulted approximately 50 to 150 meters in Post-Pennsylvanian time, as revealed by the displacement of marker horizons.

AGE (Ma)			STAGES		GROUP	MIOSPORE ZONE	
280–	CARBONIFEROUS	PENNSYLVANIAN	Stephanian		Pictou	D	*Potonieisporites*
290–			Westphalian	D	Pictou	C	*Tymospora*
				C		B A	*Torispora* *Vestispora*
				B			
				A	Riversdale		
310–		MISSISSIPPIAN	Namurian		Hopewell		
325–			Visean		Windsor		
335–			Tournaisian		? Horton		
345–	DEVONIAN/ SILURIAN		undifferentiated metasediments and intrusive rocks				

Table 3.1: Schematic Stratigraphic Chart of the Oromocto Sub-basin area, New Brunswick (in part after Ball et al., 1981)

The Oromocto Sub-basin is filled mostly with clastic sediments of the Pictou Group of Westphalian C-D and Stephanian age (Table 3.1). Stephanian strata are preserved only in the upper stratigraphic succession within the Fredericton graben. Pre-Pictou (mostly Mississippian) clastic and volcanic rocks of the Riversdale, Hopewell and Windsor groups occur along the margins of the basin (Figure 3.1).

3.3 PICTOU GROUP DEPOSITIONAL SYSTEMS

The Pictou Group has hitherto not been satisfactorily subdivided into regional lithostratigraphic units. Stratigraphic units and nomenclature previously suggested by various authors (Alcock, 1935; Muller, 1952; Gussow, 1953; Carr, 1964) are only of local value (Van de Poll, 1973a). I will make no attempt here to establish formal stratigraphic nomenclature, although various stratigraphic intervals defined by the examination and correlation of drill hole logs appear to be sufficiently distinct and extensive to merit member status. The major stratigraphic intervals have been assigned numerals with letter subscripts for reference (Figures 2.3 and 2.4). Coaly laminae which are used as marker horizons are identified by labels PH-1, PH-2, etc.

The basin fill will be discussed and reviewed in terms of genetically-related depositional systems. A depositional system is made up of an association of genetically linked depositional environments inferred from an assemblage of lithofacies (Fisher and McGowen, 1967).

Two major depositional systems are recognized in the Pennsylvanian Pictou strata of the Oromocto Sub-basin. They are: 1) a fluvial channel system, and 2) a flood plain system. Each of these depositional systems is characterized by a distinctive assemblage and sequence of facies, spatial and lateral distribution within the basin, and geophysical well log signature (Figure 3.2). In addition, the depositional systems occur in repetitive 150 to 450 meter thick megacycles and smaller scale, 25 to 75 meter thick cycles. The fluvial channel system forms the base of the cycles while the flood plain system occurs at the top. In the study area, the fluvial channel system is dominated by grey, coarse-grained sandstones and organic matter-rich mudstones. The flood plain system is dominated by very fine-grained sandstones, siltstones and mudstones with thin isolated beds of coarser sandstone. Stratigraphic and facies cross-sections indicate that the two depositional systems co-existed in time within the basin and that the fluvial channel systems developed in major belts up to 15 kilometers wide.

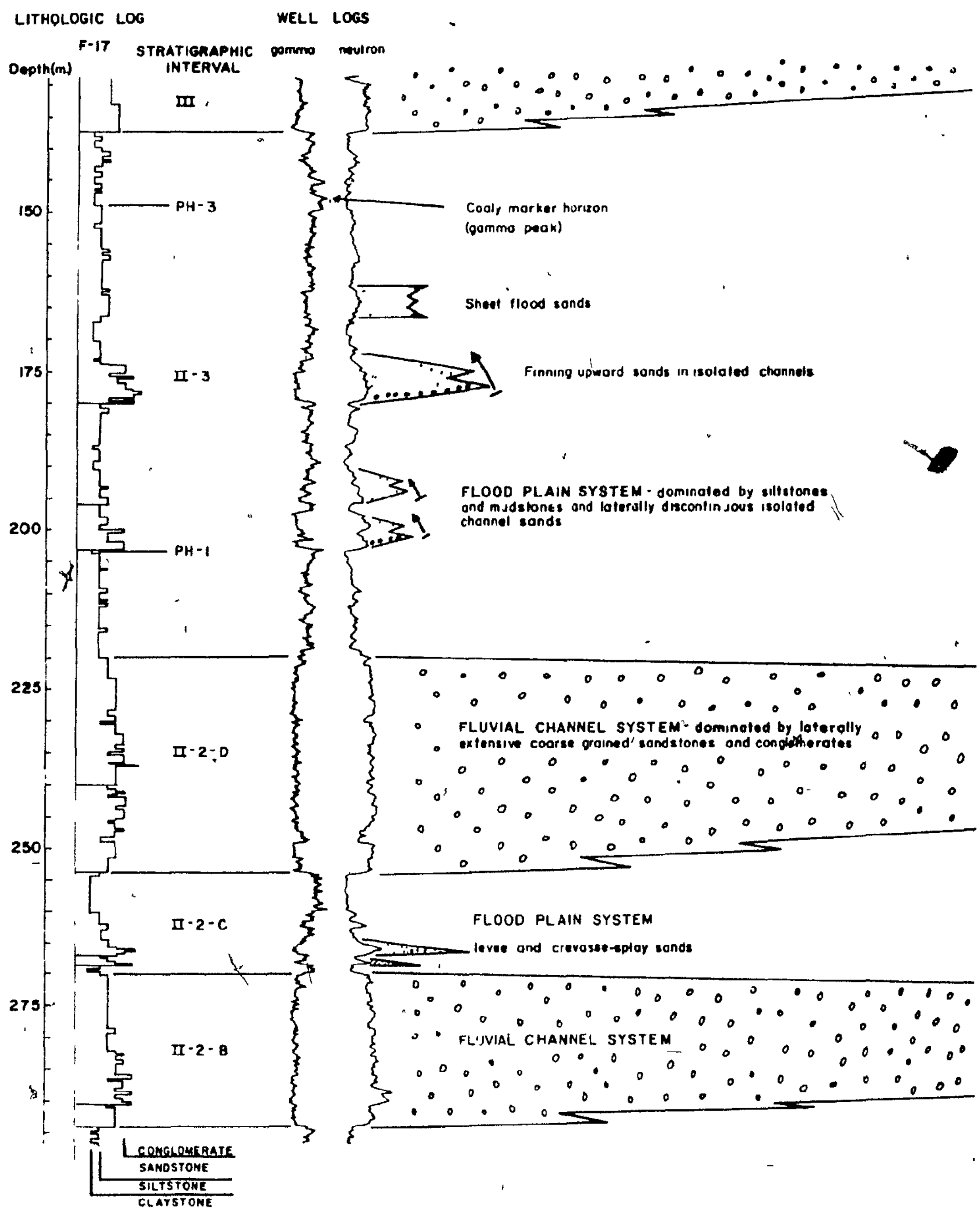


Figure 3.2: Typical Geophysical Well Log Signature and Patterns of Natural Gamma and Neutron Curves of Facies making up the Flood Plain and Fluvial Channel Depositional Systems.

3.4 FLUVIAL CHANNEL SYSTEM

3.4.1 Facies Description

Seven distinctive facies were recognized in the fluvial channel system from detailed studies of core sections (symbols after Miall, 1978a, with some modifications):

Gm : pebble and granule conglomerates

Se : intraformational clay chip conglomerate

St : medium to very coarse-grained cross-bedded sandstone

Sr : very fine to medium-grained ripple cross-laminated sandstone

Sh : fine to coarse-grained sandstone, either massive or horizontally layered

Fsc : thinly laminated siltstone and mudstone

Fm : massive mudstone.

Conglomerate Facies (Gm)

Facies Gm consists of massive to poorly-bedded, clast-supported conglomerates (Plate 3.1, Figure 1). They range from granule microconglomerates to pebble conglomerates with

Plate 3.1

Figure 1: Typical massive pebble conglomerate (facies Gm) in fluvial channel system. Stratigraphic interval III, drill hole F-13, 91.3 m. depth.

Figure 2: Intraformational conglomerate (facies Se) truncating laminated black mudstone (facies Fsc). Stratigraphic interval II-2-D, drill hole F-11, 303.6 m. depth.

Figure 3: Flattened mudstone intraclasts in facies Se of fluvial channel system. Stratigraphic interval II-2-D, drill hole F-12, 150.5 m. depth.

Figure 4: Typical cross-bedded sandstone (facies St) of fluvial channel system, stratigraphic interval II-1-A, drill hole F-1, 492.7 m. depth.

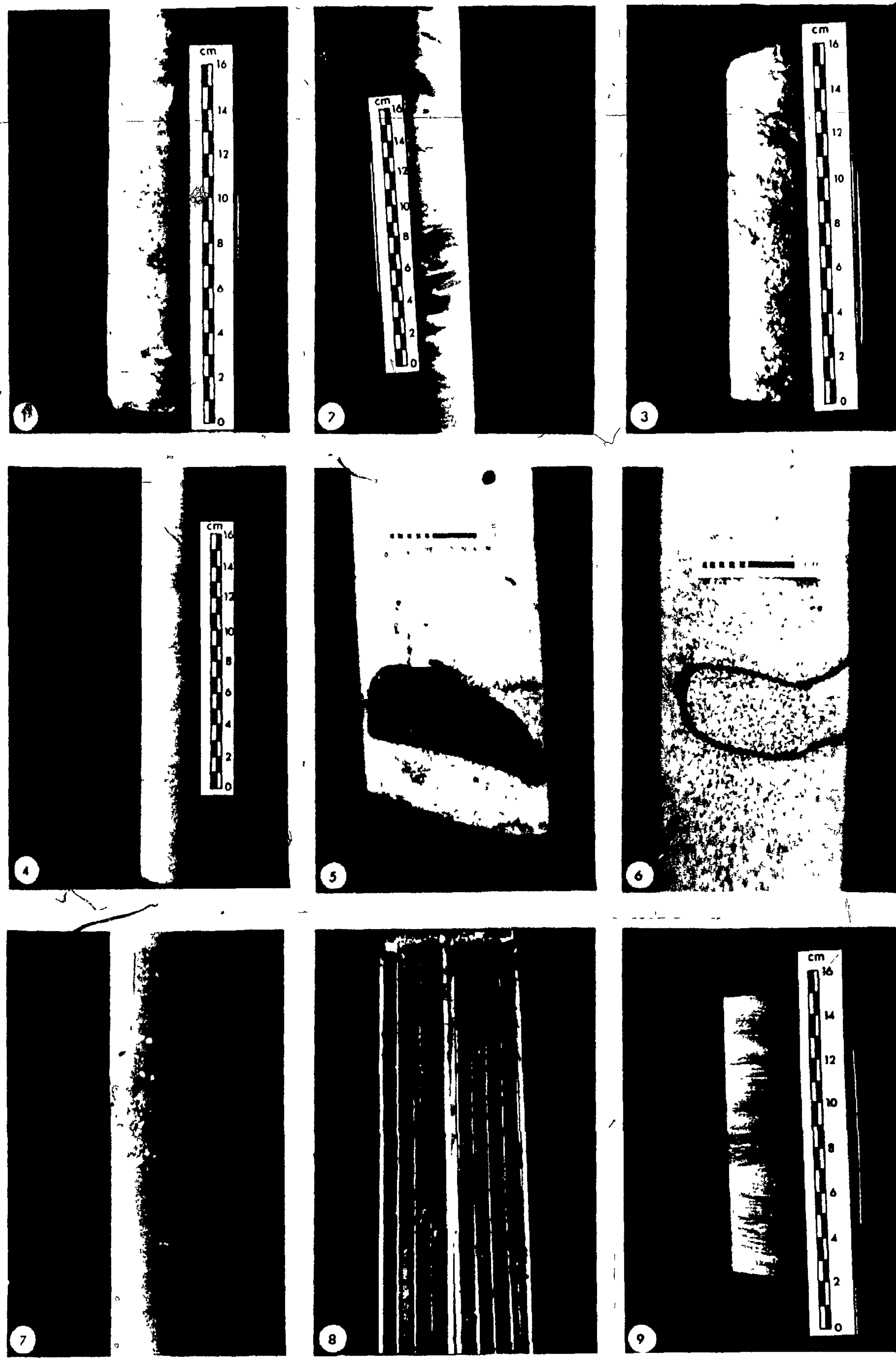
Figure 5: Large coal spar fragment in course sandstone of facies St, fluvial channel system. Stratigraphic interval II-1-C, drill hole F-4, 199 m. depth.

Figure 6: Coalified plant stem filled with sand, in coarse channel sands of the fluvial channel system. Stratigraphic interval II-2-B, drill hole F-3, 86.5 m. depth.

Figure 7: Pebble conglomerate lag at base of a cross-bed set. Bedding is outlined with chalk marks in photo. Stratigraphic interval III, drill hole F-1, 75 m. depth.

Figure 8: Typical conglomerate - sandstone cycles in the fluvial channel depositional system. The cycles are fining upward sequences of / Gm → St → Sr facies. Stratigraphic interval II-2-C, 172-184 m. depth, hole F-7. Box length in photo is 1.5 m.

Figure 9: Ripple cross-laminations, climbing ripples in bar top sands (facies Sr) of the fluvial channel system. Stratigraphic interval II-2-D, drill hole F-18, 109 m. depth.


1
2
3
4
5
6
7
8
9
cm

an interstitial matrix of coarse sand. Cement is silica with rare calcite. Conglomerate beds generally range in thickness from 5 cm to 2 to 3 meters. Beds up to 6 meters thick are rare. The basal contacts are sharp and erosive. Coalspar and coalified plant debris are abundant and clay chip intraclasts are common. The conglomerates generally grade upwards into sequences of cross-bedded sandstone beds (facies St).

Intraformational Conglomerate Facies (Se)

Facies Se consists of intraformational conglomerates occurring with sharp erosional bases. Clasts are predominantly green to black mudstone chips which often show syndepositional deformation (Plate 3.1, Figure 2), slump features, and flattening of clasts by compaction (Plate 3.1, Figure 3). The intraclasts generally float with coalspar in a matrix of mixed coarse sand and pebbly conglomerate. Shale intraclasts can exceed the thickness of the core (i.e. >5.7 cm). Facies Se generally occurs at the base of thick conglomerate-sandstone sequences or overlying thick sections of Fsc facies. The presence of the intraformational clasts indicates that the Se facies developed scour channels which eroded finer grained deposits, or incorporated clay drapes formed in previous flood events.

Cross-Bedded Sandstone Facies (*St*)

Facies St consists of medium to very coarse-grained cross-bedded sandstone (Plate 3.1, Figure 4). A distinction between types of cross-bedding could not be made in the thin core samples. This facies is generally grey to green in colour. The matrix is generally clayey, calcite cement is rare. Coalspar and plant litter (Plate 3.1, Figures 5 and 6) with associated pyrite are common. Individual cross-bed sets range in thickness from 10 centimeters to a maximum of 2 or 3 meters. Pebble lenses (lag deposits) can occur at the base of cross-bedded sets (Plate 3.1, Figure 7). Stacked sequences of facies St, 2 to 40 meters in thickness, often display an overall fining upward trend in grain size along with a decrease in the thickness of individual cross-bed sets. Along with the conglomerate facies Gm and Se, the St facies comprises 80% or more of the vertical sections that characterize the fluvial channel system. The current oriented structures, coarse grained nature and fining upward conglomerate-sandstone sequences (Plate 3.1, Figure 8) suggest relatively high energy bed load deposits of channel deposition.

Ripple Cross-Laminated Sand Facies (*Sr*)

Facies Sr consists of very fine to medium-grained sandstone, coloured generally dark green to grey/green. These sandstones contain very fine-grained plant debris which outlines bedding surface. Normal asymmetric ripples as well as climbing ripples and complex ripple cross-lamination structures are prominent (Plate 3.1, Figure 9). This facies generally occurs in 10 centimeter to 3 meter thick sequences associated with facies Sh at the top of fining upward St sandstone successions. The fine grained ripple laminations and vertical sequence indicates lateral accretion under lower flow regime conditions.

Laminated to Massive Sandstone Facies (*Sh*)

Facies Sh consists of fine to coarse grained sandstone, similar in appearance to the sandstones of St except that lamination is either absent or horizontal. It is often rich in very fine organic debris and is generally thinly laminated on a millimeter to centimeter scale and fissile. Fine grained, horizontally bedded sandstones occur as 0.5 to 3 meter thick sequences associated with Sr sandstones at the top of fining upward St sequences (Plate 3.2, Figure 1). Massive coarser grained sandstones in 1 to 4 meter thick beds occur throughout stacked St sequences.

Laminated Siltstone and Mudstone Facies (*Fsc*)

Facies Fsc consists of black to green coloured, thinly laminated siltstone, mudstone and very fine grained sandstone. Lamination is typically on a millimeter scale. Leaf and plant stem imprints are present on fissile bed partings (Plate 3.2, Figures 2 and 3). This fine grained facies commonly occurs at the top of fining upward sandstone sequences, and sharp lower

Plate 3.2

Figure 1: Typical horizontally laminated medium to fine grained sandstone of bar top facies (Sh) in the fluvial channel system. Stratigraphic interval II-2-B, drill hole F-2, 278.6 m. depth.

Figure 2: Leaf imprint, probably of Neuropteris genus (identified after Bell, 1962) in laminated black mudstone (facies Fsc). Stratigraphic interval II-1-C, drill hole F-1, 468.2 m. depth.

Figure 3: Laminated black mudstone (facies Fsc) with thin rhythmites of sand. Abundant plant fragments on bed partings (top) in fine laminated layers. Stratigraphic level II-2-D, drill hole F-9, 140 m. depth.

Figure 4: Scoured channel of facies (Se) overlain by black mudstone of facies Fsc in a thick interval of cross-bedded sandstone (facies St). Note the sharp basal and top truncations. Stratigraphic interval II-1-C, 208-214 m. depth, hole F-7. Box length in photo is 1.5 m.

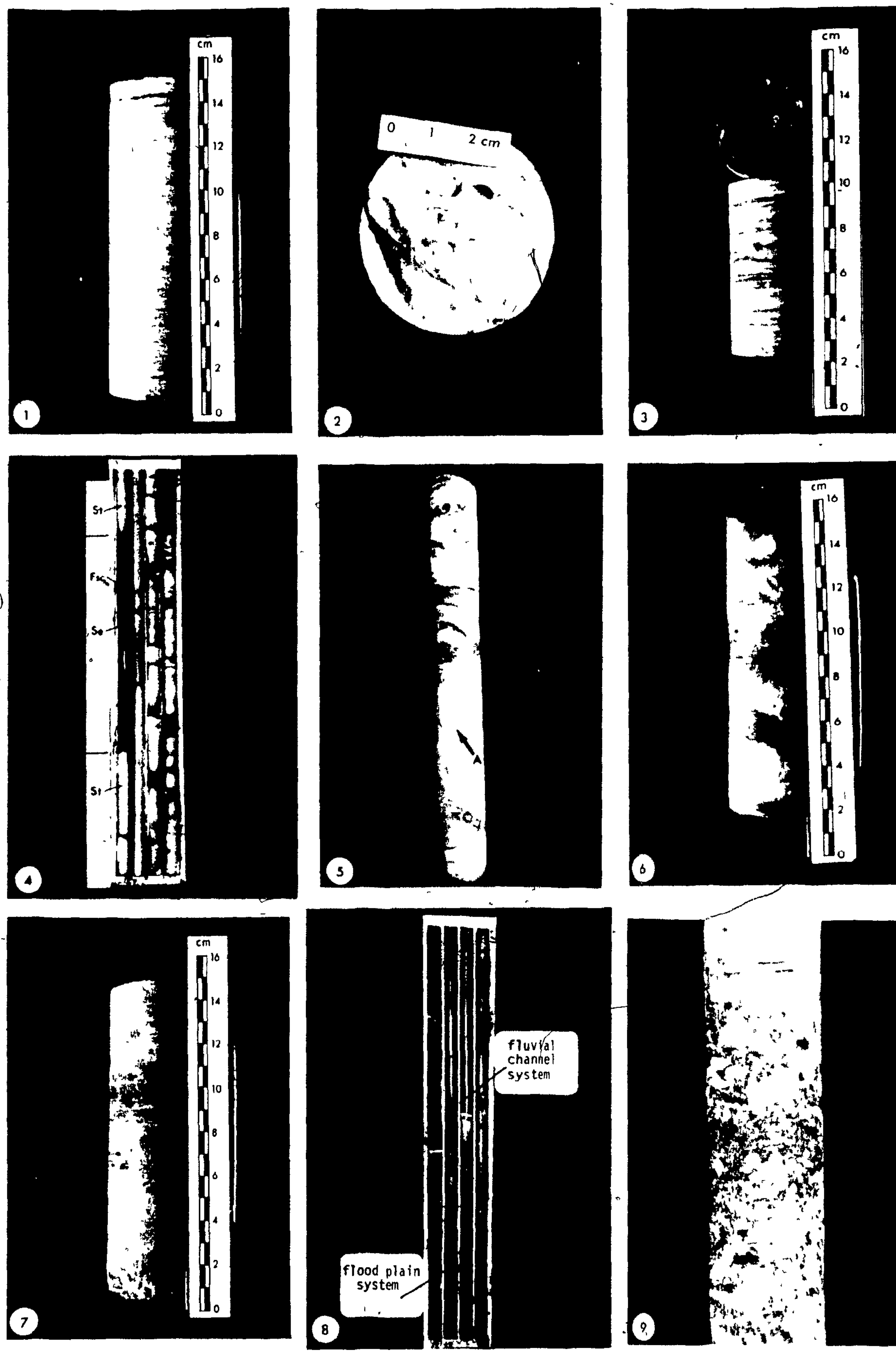
Figure 5: Loading feature of sand (A) in laminated mudstone (facies Fsc). Banding on the core is from scotch tape. Stratigraphic interval II-1-A, drill hole F-3, 269.5 m. depth.

Figure 6: Black finely laminated mudstone (facies Fsc) with pebble horizons. Stratigraphic level II-2-B, drill hole F-10, 289 m. depth.

Figure 7: Dark green coloured massive claystone with some calcareous nodules, facies Fm in fluvial channel system. Base of stratigraphic interval II-1-A, drill hole F-1, 626.5 m. depth.

Figure 8: Typical transition from flood plain system facies Fl, Fm (left) to fluvial channel system facies St (right). Base of stratigraphic interval II-2-B, 296-301 m. depth, drill hole F-10. Box length in photo is 1.5 m.

Figure 9: Crudely bedded conglomerate (facies Gm) in flood plain system. Stratigraphic interval II-3, drill hole F-15, 180.4 m. depth.


1
2
0 1 2 cm
3
4
St
Fsc
Se
St
5
A
6
7
8
fluvial channel system
flood plain system
9
cm

and upper contacts are common (Plate 3.2, Figure 4). Loading features from overlying truncating sands or conglomerates are also common (Plate 3.2, Figure 5). In thicker bedded (1-10 m) sequences, centimeter thick sandstone horizons or laminae display well developed graded bedding profiles. The Fsc facies generally comprises less than 10% of the vertical sequence in the fluvial belt system. The fine grained laminated bedding structure with well preserved plant stems and leaves along bed partings indicates low energy deposition in restricted, ponded water. Thin horizons of sandstone and conglomerate indicate frequent flood incursions of coarser material deposited as possible small overbank flows (Plate 3.2, Figure 6). The presence of Fsc material as intraclasts in Se facies suggests frequent erosion of these very low energy deposits by migrating channels.

Massive Mudstone Facies (Fm)

Facies Fm consists of a massive, green to grey coloured mudstone. No current generated sedimentary structures are present. Calcareous nodules ranging from 2 to 10 mm in size, carbonaceous films, and slikenslide surfaces are common (Plate 3.2, Figure 7). The Fm facies occurs only as 10 centimeter to 2 meter thick beds at the transition between the two contrasting depositional systems (Plate 3.2, Figure 8).

3.4.2 Facies Sequence

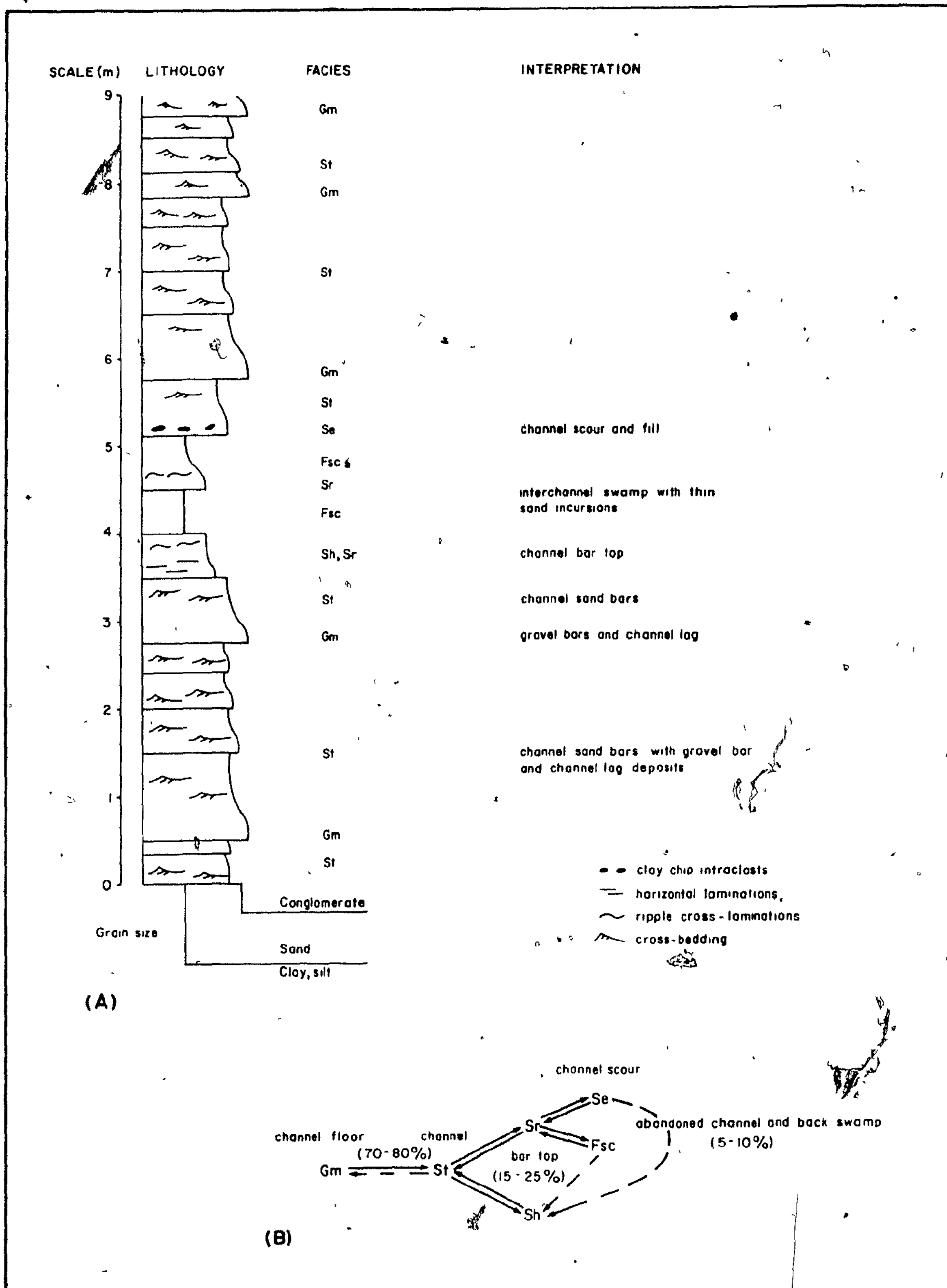
Facies transitions were defined with Markov chain analysis (Appendix A) using methods suggested by Miall (1977a). No distinction could be made between the vertical facies patterns of the fluvial channel system in the megacyclic sequences from those in smaller cycles. These results indicate the continuity of the sedimentary processes operating in the system through time. An ideal synthetic profile (Figure 3.3) constructed from the facies pathway, measured bed thicknesses, and contact relationships, compares favourably with actual observed sequences in the bore holes.

The coarser sandstones and conglomerates of facies Gm and St make up more than 80% of the vertical section in the fluvial channel system. These usually occur as overall fining upward sequences consisting of a basal conglomerate, followed by thick cross-bedded sandstone sets. The conglomerate-sandstone sequences vary in the range of 1 meter to over 20 meters in thickness. Rare coarsening upward sequences also occur. The fining upward sequences locally grade into finer grained sandstones of facies Sh and Sr or display a sharp transition to very fine grained organic matter-rich mudstones of facies Fsc.

Figure 3.3: Fluvial Channel Depositional System, Lower Succession of the Cycles:

A) Synthetic or ideal vertical facies sequence

B) Facies transition pathways dérived from Markov analysis. The percentage of each facies type in the typical vertical profile is marked.


SCALE (m)
LITHOLOGY
FACIES
INTERPRETATION
9
8
7
6
5
4
3
2
1
0
Gm
St
Gm
St
Gm
St
Se
Fsc &
Sr
Fsc
Sh, Sr
St
Gm
St
Gm
St
channel scour and fill
interchannel swamp with thin sand incursions
channel bar top
channel sand bars
gravel bars and channel lag
channel sand bars with gravel bar and channel lag deposits
clay chip intraclasts
horizontal laminations
ripple cross-laminations
cross-bedding
Conglomerate
Grain size
Sand
Clay, silt
(A)
channel scour
Se
Sr
Fsc
abandoned channel and back swamp
(5-10%)
channel floor
channel
(70-80%)
Gm
St
bar top
(15-25%)
Sh
(B)

The conglomerate-sandstone sequences and associated finer grained facies are interpreted as the deposits of braided rather than meandering rivers for the following reasons: the vertical stratigraphic profile in the fluvial channel system is characterized by thick intervals of cross-bedded sandstones with horizontally laminated sands and gravels distributed throughout, and the very high proportion of coarse sandstones and conglomerates compared to shale strongly suggests a braided rather than meandering fluvial environment (Miall, 1977a,b; Fisher, 1982). The fining upward sequences with conglomeratic basal units require initial high energy currents waning to lower energy regimes which are characteristic of braided rivers (Collinson, 1978; Fisher, 1982). The presence of thin finer grained silt and mudstone sediments with abrupt basal and upper facies contacts is also a characteristic feature of braided systems largely caused by flashy discharge in flow regime and a predominance of bedload deposition over suspension load (Fisher, 1982). Unfortunately, many distinguishing criteria of braided river systems, such as exact channel morphology, sand body geometry, the presence of tabular cross-bedding structures (impossible to distinguish from trough cross-bedding because of the thin core samples), and the degree of variation in paleocurrents vectors cannot be fully examined because of the lack of surface outcrops. Van de Poll (1970) found a very low variance in predominantly north to northeast trending paleocurrents throughout the sub-basin area (Figure 1.3).

However, his data are based on outcrop sampling in the basin which is severely biased in favour of certain areas and stratigraphic layers. The data derived from drill hole cores do not preclude a hybrid of both braided and coarse grained meandering models for the fluvial channel depositional system (Cant and Walker, 1976).

In braided rivers, sandstones and conglomerates are deposited mostly as longitudinal and transverse bars by the migration of large scale, foresetted or horizontal bedforms (Leopold and Wolman, 1957; Miall, 1977a). During the deposition of each succeeding bar, erosion of underlying sand occurs and may develop a basal scour filled with a conglomerate lag containing large plant fragments. Waning currents deposit finer grained sandstones with ripple laminations at the top of the conglomerate-sandstone bar sequences.

Much of the very fine grained mudstones and siltstones of facies Fsc appear to have been deposited in interchannel areas of ponded waters. Accumulations of very fine grained plant material and layers of leaves and small tree stems are common in facies Fsc. Deposition probably took place in abandoned channels although Williams and Rust (1969) show that silts can be also preserved as drapes at the top of bars in modern braided rivers. The sharp basal and upper truncations generally seen in the Fsc facies indicate that channel bar migration was rapid. Common incursions of coarser sandstone deposited as thin graded horizons in Fsc facies indicate that adjacent active channels flooded over bars through small crevasse-splays into the abandoned water filled channels. The quiet water sediments of facies Fsc are generally of limited extent and cannot be traced from one drill hole to the next. An exception to this occurs in the fluvial system making up the base of megacycle II where a 10 to 20 meter thick interval of carbonaceous mudstones can be traced between holes drilled throughout the Fredericton graben area of several tens of square kilometers. This probably indicates the development of a somewhat more laterally extensive interchannel backswamp environment which has been interpreted as occurring adjacent to channels of large fluvial systems in major coal basins (Horne et al., 1978).

The vertical facies sequence in the fluvial channel system is similar to that described by Willians and Rust (1969), and Miall (1978a), in the gravel- and sand-dominated Donjek River. In contrast to the Donjek example, however, the Pictou is characterized by the absence of evidence for exposure or vegetation of interchannel bars. On the other hand, frequent flooding and erosion of abandoned channel systems is evident and suggests seasonal water level fluctuations. This may indicate that water levels in the main channels never dropped to extremely low levels during interflood stages or it may indicate a low preservation potential for the exposed interchannel bars (Miall, 1980, p.72).

Braided channel patterns can occur in river systems having a relatively steep slope, an overabundance of bedload or a combination of the two (Coleman, 1969; Fisher, 1982). In small high gradient streams, slope is the dominant factor causing braiding but in large scale rivers characterized by extensive flood plains, bedload and seasonal discharge must be considered as the controlling factor. The scale of the fluvial belt systems considered for the Pictou Group in this study suggests the development of "big river" systems (Potter, 1978), with extensive flood plains. Physical constraints on such river systems suggest high bed and suspension load and extremely unstable hydrology caused by extreme seasonal discharge.

3.5 FLOOD PLAIN SYSTEM

3.5.1 Facies Description

Eight distinctive facies were recognized in the flood plain system and are described as follows, again using symbols with modifications after Miall (1978a). In addition to the facies listed in the discussion of the fluvial channel system, the following symbols are used:

- Fl : laminated mudstone, siltstone and very fine grained sandstone
- Fr : mottled seat earths
- C : carbonaceous organic matter laminae.

Massive Bedded Conglomerate Facies (*Gm*)

Facies Gm consists of a red to greyish red clast supported conglomerate made up of subrounded small pebbles and granule-sized clasts. Clasts are often imbricated or crudely bedded (Plate 3.2, Figure 9). Matrix and cement characteristics are similar to those describe in the fluvial channel system. This facies almost everywhere contains abundant red shale intraclasts. The basal contacts are generally sharp but the conglomerate occurs as thin (10 to 50 centimeter thick) beds grading within a few centimeters upwards into coarse cross-bedded sand of facies St. This facies is relatively uncommon in the flood plain system and nowhere accounts for more than several percent of the vertical sequence.

Cross-Bedded Sandstone Facies (*St*)

Facies St consists of medium to coarse grained silty sandstone with clay matric or calcareous cement. The colour is generally dark maroon. The facies is generally composed of stacked cross-bed sets from 10 to 20 centimeters (Plate 3.3, Figure 1). Outlines of large plant fragments preserved by hematite are common (Plate 3.3, Figure 2) and carbonaceous plant 'trash' is occasionally observed in some of the thicker sequences. Basal contacts are either sharp and erosive with abundant shale intraclasts or grade upwards from a basal pebble conglomerate. The sandstones generally occur in fining upward profiles 1 to 5 meters thick (Plate 3.3, Figure 3). These can be top truncated by soil profiles (Plate 3.3, Figure

Plate 3.3

Figure 1: Cross-bedded sandstone of facies St in the flood plain system, stratigraphic interval II-3, drill hole F-13, 236 m. depth.

Figure 2: Plant stem preserved as a hematized cast or halo in a thin sandstone bed in the flood plain system. Stratigraphic interval II-3, drill hole F-10, 174.8 m. depth.

Figure 3: Typical fining upward channel sequence / Gm → St → Fl, Fm in the flood plain system (to the left of photo). Stratigraphic interval II-3, 249-255 m. depth, drill hole F-11. Box length in photo is 1.5 m.

Figure 4: Top of fining upward cross-bedded sandstone sequence (facies St) in flood plain system. The sandstone is top truncated by a rootlet horizon (Fr). Stratigraphic interval II-3, drill hole F-14, 119 m. depth.

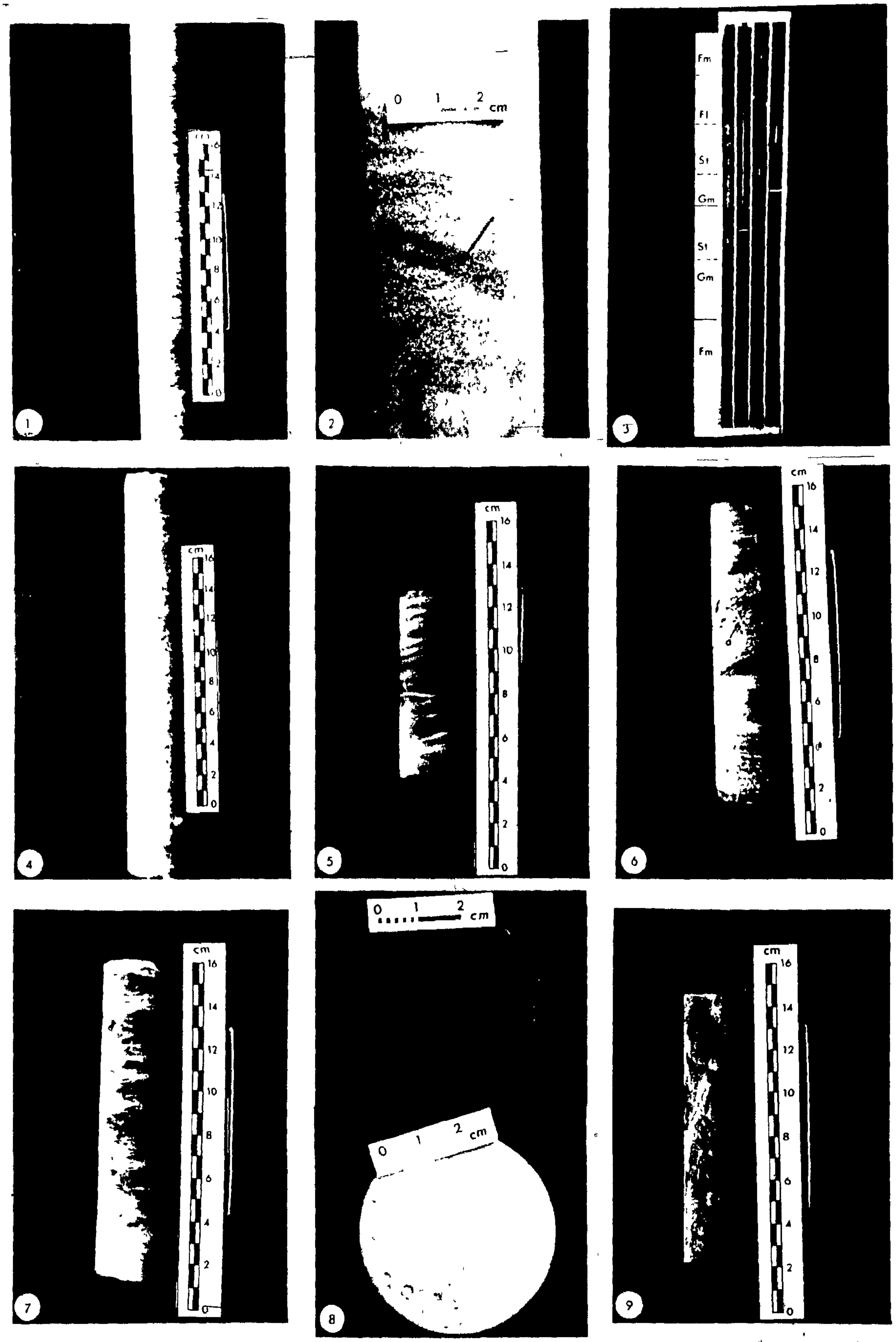
Figure 5: Climbing ripple lamination in fine sand of facies Fl, flood plain system. Stratigraphic interval II-3, drill hole F-18, 38.5 m. depth.

Figure 6: Calcrete (a) and claystone (b) intraclasts in distal flood sheet sands of facies Fl, flood plain system. Stratigraphic level II-3, drill hole F-13, 221 m. depth.

Figure 7: Typical sheet sand in the flood plain system with claystone intraclasts. Stratigraphic level II-3, drill hole F-12, 108.5 m. depth.

Figure 8: Rain drop imprints (bottom) and casts (top) in fine mudstone of the flood plain system. Stratigraphic interval II-3, drill hole F-13, 220 m. depth.

Figure 9: Typical massive mudstone (Fm) of the flood plain system. Some plant traces are visible and produce the "blocky texture". Stratigraphic interval II-2-C, drill hole F-11, 330 m. depth.


1
2
0 1 2 cm
3
Fm
Fl
St
Gm
St
Gm
Fm
4
5
6
7
8
0 1 2 cm
9
cm

4) or gradational with overlying fine rippled sandstone. Along with the other sand facies, they account for less than 15% (in vertical section) of the typical flood plain system, occurring as isolated bodies within a mud-dominated sequence. Sharp basal contacts, coarse grain size and fining upward sequences in the St facies suggest an isolated channel deposition although on alluvial plains actual fluvial channels may be difficult to distinguish from deposits formed from crevasse splay sheets (Reineck and Singh, 1980, p.291, 292).

Ripple Cross-Laminated Sandstone Facies (*Sr*)

Facies Sr consists of deep maroon coloured, fine to medium grained silty sandstone. Centimeter-scale asymmetric ripple laminations and climbing ripples are common (Plate 3.3, Figure 5). The Sr facies occurs at the top of thin fining upward sandstone sequences or as 0.5 to 1 meter thick isolated beds within the mud and silt-dominated sections.

Laminated Sandstone Facies (*Sh*)

Facies Sh consists of a fine to medium grained silty red sandstone. The facies contains both massive and horizontally laminated varieties, closely associated with rippled sandstones at the top of fining upward sequences.

Laminated Siltstone and Mudstone Facies (Fl)

The Fl facies consists of laminated mudstone, siltstone and very fine grained sandstone. Interbedding of sand, silt and mud on a millimeter to centimeter scale is common. Small scale ripple laminations and climbing ripples are observed in sandstone. Truncation surfaces at the base of thin sandy laminae are common and often contain rip-up mudstone intraclasts and/or calcrete clasts (Plate 3.3, Figures 6, 7). Plant debris preserved only as imprint casts along bed partings are very common. Desiccation features were not observed but these may be difficult to distinguish in the core. Well preserved rain drop imprints were observed in several horizons (Plate 3.3, Figure 8). The massive mudstone facies and the Fl facies accounts for 80 to 90% of the flood plain system. The thin laminated texture of interbedded claystone, siltstone and very fine grained sandstone indicates conditions fluctuating between lateral current transport and vertical accretion. Fine, small scale ripple lamination indicates lower energy waning currents. The currents were frequently strong enough to break up and transport calcrete crusts and shale chips as intraclasts. Redeposition of the intraclasts must have been rapid to preserve the delicate calcrete material. Organic material in the Fl facies was probably 'rafted' by the flood waters and subsequently destroyed by subaerial exposure and oxidation or by oxidizing groundwater after burial.

Massive Mudstone Facies (Fm)

The Fm facies consists of a massive mudstone (Plate 3.3, Figure 9). Current-oriented structures are not present. Plant traces are common as imprints or rare carbon films (Plate 3.4, Figure 1). Pedogenic calcrete (calcite identified from XRD pattern) and ferricrete structures are the most distinctive feature of this facies. Concentric or massive calcareous and ferricrete nodules or pisolites are commonly found in the same bed. The calcareous nodules have diameters of 1 to 10 millimeters. In section, calcite is mixed with clay and the nodules often show concentric rings (Plate 3.4, Figure 2). Calcretes also occur as honeycomb veinlet structures (Plate 3.4, Figure 3). The calcareous structures show characteristics commonly found in immature near surface calcrete horizons formed by the downward percolation of surface water under conditions of high PCO_2 and low pH (Leeder, 1975; Reeves, 1976). The presence of the calcretes as eroded and redeposited intraclasts in thin sandstones of the Fl facies also indicates that they were forming near the surface. Ferricretes occur as irregularly shaped nodules and coated pisolites 2 to 10 millimeters in diameter (Plate 3.4, Figure 4). They are composed of both yellow and red iron oxide minerals. The pisolites are made up of concentric layers around a massive ferricrete nodule. Rarely calcrete nodules or fragments form the nuclei of pisolites (Plate 3.4, Figure 5). The ferricretes are typical of pisolitic laterites and pedogenic iron nodules formed by a fluctuating groundwater table (McFarlane, 1976).

Plate 3.4

Figure 1: Plant fragment preserved as a carbon film on a bedding plane in massive mudstone (facies Fm) of the flood plain system. Stratigraphic interval II-2-A, drill hole F-1, 356.8 m. depth.

Figure 2: Calcrete nodules in massive red mudstone (facies Fm) of the flood ~~plain system.~~ The nodules are marly and show some concentric layering. Stratigraphic level III, drill hole F-2, 12.0 m. depth.

Figure 3: Honeycomb calcrete structure and isolated nodules in massive mudstone of the flood plain system. Stratigraphic interval II-3, drill hole F-1, 256.5 m. depth.

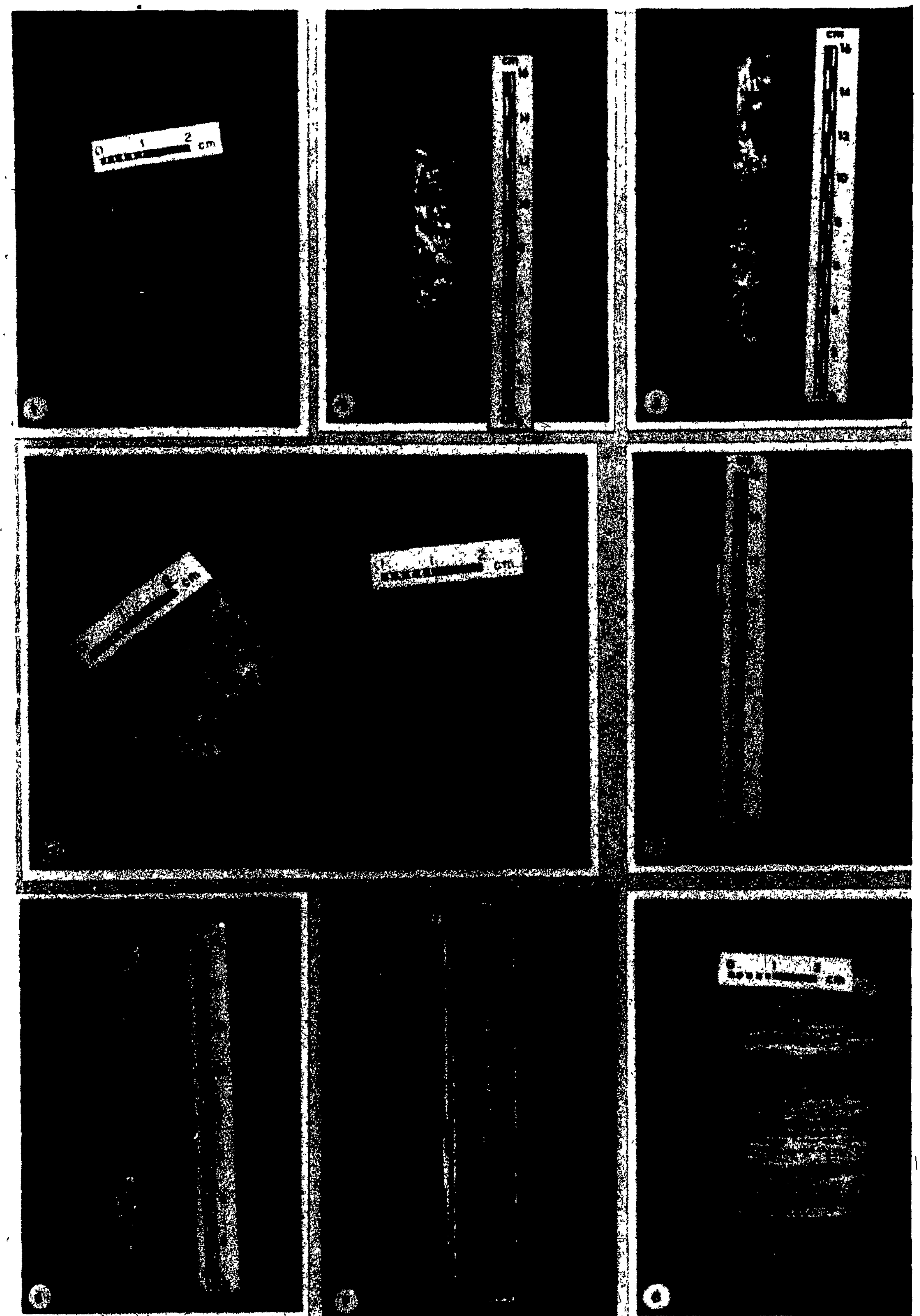
Figure 4: Spaced lateritic ferricrete pisolites developed in the flood plain system. Cross-section (right) and bedding plane view (left). Stratigraphic interval I-2, drill hole F-2, 739.4 m. depth.

Figure 5: Ferricrete nodules (a) forming concentric layers around a core of calcrete (b). In Fm facies of the flood plain system. Stratigraphic interval II-3, drill hole F-13, 252.2 m. depth.

Figure 6: Mottled soil horizon interpreted as representing root networks. Facies Fr, flood plain system. Stratigraphic interval II-2-C, drill hole F-11, 330 m. depth.

Figure 7: Thick mottled soil horizon (facies Fr) developed in the flood plain depositional system (left hand box) overlain by siltstones of facies Fl and a 2 m. thick interval of cross-bedded sandstones of facies St (right hand box). Stratigraphic interval II-2-C, 314-326 m. depth, drill hole F-13. Box length in photo is 1.5 m.

Figure 8: Thin organic coaly laminae developed at top of a prominent seat earth in the flood plain system. Stratigraphic interval PH-2, II-3, drill hole F-13, 210 m. depth.



Seat Earth Facies (*Fr*)

The Fr facies consists of mottled seat earth. Colours range through yellow, green, red, blue and grey. The mottled pattern is generally anastomosing or branching, suggesting a complex root network (Plate 3.4, Figure 6). The seat earths are highly crumbly in texture. They are almost always top truncated by the Fl or Fm facies, but are locally marked by an upper layer of coaly laminae (C facies). The seat earths range in thickness from 10 or 20 centimeters to as much as 5 meters, and grade downward into massive mudstone (Plate 3.4, Figure 7). Ironstone nodules and ferricrete pisolites commonly occur within the seat earths but calcretes are relatively rare. Facies Fr does not correlate from one hole to the next which indicates limited sporadic vegetation in the flood plain.

Carbonaceous Laminae Facies (C)

This facies consists of carbonaceous laminae or thin coals up to 10 centimeters in thickness. They are in places associated with fine rippled sandstones, and can occur as isolated laminae or horizons at the top of seat earths (Plate 3.4, Figure 8) laterally continuous over hundreds of square kilometers. Three such horizons (labelled PH-1, PH-2 and PH-3) can be used as effective marker horizons in structural studies of the basin (Figures 2.3 and 2.4). The coaly, thin laminated structure of this facies and widespread occurrence at the top of seat earth profiles (facies Fr) suggests organic accumulation in laterally extensive paludal environments.

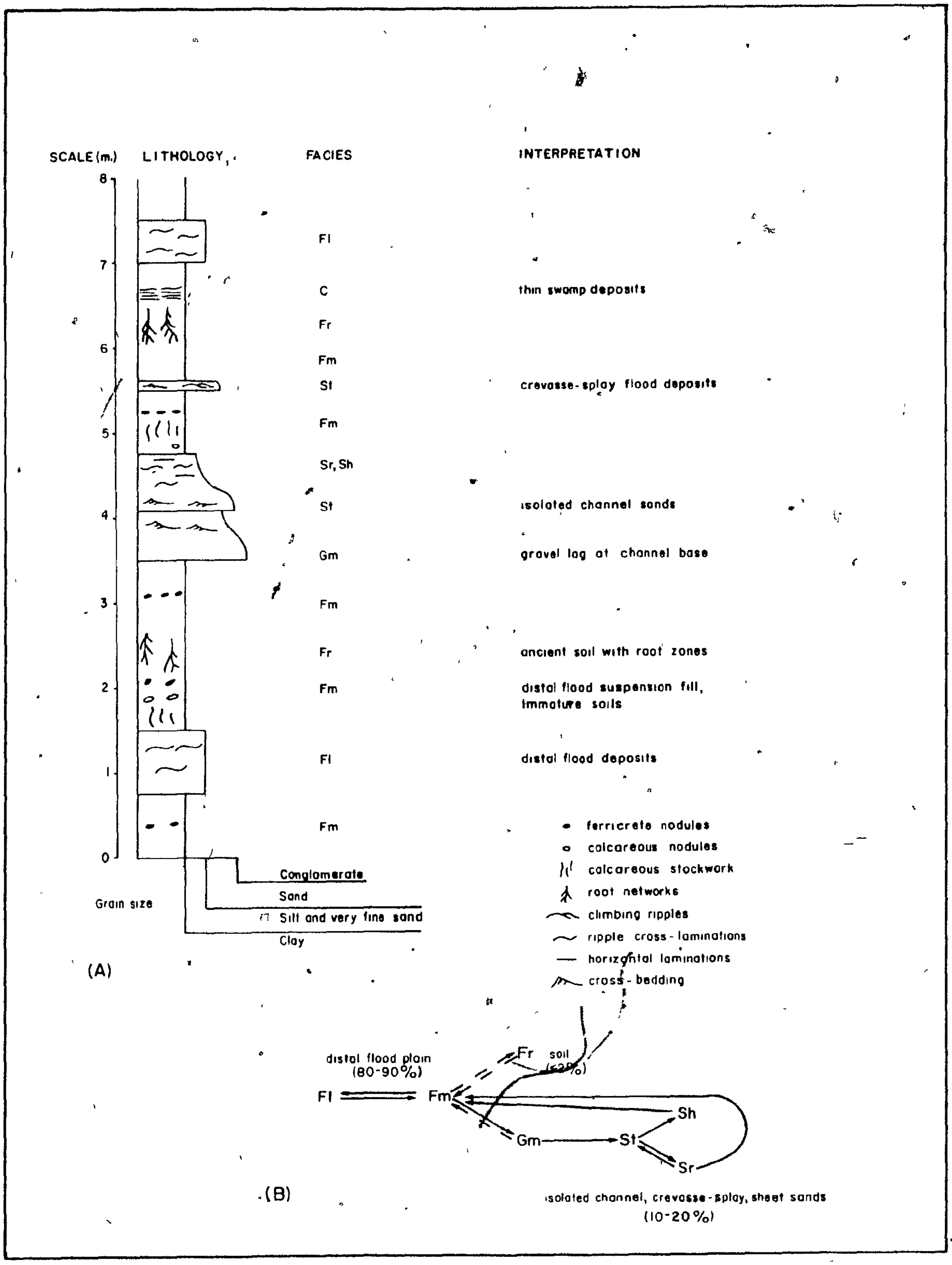
3.5.2 Facies Sequence

A similarly derived synthetic facies sequence for the flood plain system contrasts sharply with that of the fluvial channel system (Figure 3.4). Coarser grained sandstone and conglomerate make up less than 20% of the typical vertical sequence in the flood plain system. In some thick intervals, they are altogether absent. They form 1 to 5 meter thick fining upward sequences, typically consisting of a thin basal interval of pebble and clay chip (intraclast) conglomerate (facies Gm), followed by cross-bedded silty sandstone (facies St). These sequences occur as isolated bodies in thick mud and silt-dominated successions (Fl and Fm facies) and are nowhere traceable from one drill hole to the next. These characteristics suggest small isolated channels developing in a finer grained flood plain system. Very abrupt top truncation by soil and root zones may indicate that some of the channels were ephemeral (Picard and High, 1973, p.181). Exact definition of channel geometries and processes of deposition is impossible from the drill hole data. Channel deposits associated with crevasse-splay sheet sands are often difficult to distinguish from small fluvial channels in modern alluvial plains (McKee et al., 1967). Similarly, channels may commonly form from both active fluvial systems and from post-flood drainage in alluvial plains (Allen 1965). In the flood plain system of the Pictou Group a broad category of channel sequences can be distinguished from sheet sands from the well log patterns (Figure 3.2).

Figure 3.4: Flood Plain Depositional System, Upper Succession of the Cycles:

A) Synthetic or ideal vertical facies sequence.

B) Facies transition pathways derived from Markov analysis. The percentage of each facies type in the typical vertical profile is marked.



SCALE (m.)
LITHOLOGY
FACIES
INTERPRETATION
Fl
C
thin swamp deposits
Fr
Fm
St
crevasse-splay flood deposits
Fm
Sr, Sh
St
isolated channel sands
Gm
gravel lag at channel base
Fm
Fr
ancient soil with root zones
Fm
distal flood suspension fill, immature soils
Fl
distal flood deposits
Fm
Conglomerate
Sand
Silt and very fine sand
Clay
Grain size
(A)
ferricrete nodules
calcareous nodules
calcareous stockwork
root networks
climbing ripples
ripple cross-laminations
horizontal laminations
cross-bedding
distal flood plain (80-90%)
Fl
Fm
Fr
soil
Gm
St
Sh
Sr
(B)
isolated channel, crevasse-splay, sheet sands (10-20%)

Flood basin deposits of alluvial plains typically represent accumulation of fine grained material suspended in flood waters that became still after flood periods (Allen, 1965). Somewhat coarser material can be transported in sheet deposits kilometers from major fluvial channels (Allen, 1965; McKee et al., 1967). The fine grained deposits of facies Fl and Fm which make up over 80% of the vertical sections in the flood plain system contain low energy current features and pedogenic structures which are characteristic of frequently flooded alluvial plains (Allen, 1965; McKee et al., 1967; Collinson, 1978). Rapid and waning flow, followed by deposition of blanketing mudstone, is indicated by climbing ripple laminated and the parallel laminated Fl facies interbedded with massive mudstone (Fm). The abundance of these finer grained deposits indicates that they must have originated from the flooding of major fluvial systems rather than the thin isolated channel profiles seen in the flood plain system itself. A significant feature of these fine alluvial deposits is the presence of various pedogenic features such as soil profiles and duricrusts.

In the fine grained dominantly red coloured sediments of the flood plain system, calcrete and ferricrete nodules are found together in facies Fm. Thick soil horizons with mottled rootlet zones and ferricrete nodules (Fr facies) occur throughout the sequence. This would appear to present a conflicting climatic regime since red bed sequences and calcretes are commonly associated with arid to semi-arid climates (Walker, 1967; Allen, 1974; Reeves, 1976, p.84) while leached soil zones and ferricrete nodules are more characteristic of laterites developed in humid vegetated environments (McFarlane, 1976). Duricrusts and associated soil horizons are, however, more dependent on the local soil climate than general atmospheric climate (Goudie, 1973). The equatorial palaeolatitude reconstruction for the Carboniferous of New Brunswick (Scotese et al., 1979) can accomodate various more specific palaeoclimatic types ranging from arid to humid conditions. The contrasting ferricrete and calcrete features observed in the core can be reconciled by considering instead a seasonally semi-arid climatic interpretation. In the suggested model (Figure 3.5), the flood plain would be composed of: a) vegetated soil areas (facies Fr); and b) non-vegetated areas (facies Fl and Fm). Humid conditions in vegetated soil areas could be maintained by the plants themselves or by locally ponded waters. Organic material in the remaining areas of the plain would be restricted to rafted material transported and deposited during floods and preserved only as imprints in the mudstones of the Fm facies. Immature calcretes would form near the surface in fine grained alluvial plain sediments during prolonged dry periods. They would be susceptible to erosion, transport and redeposition during brief seasonal flood periods, depending on the proximity of the flood plain with respect to a major fluvial channel system. Fluctuating groundwater during flood stages would produce brief changes in Eh-pH conditions favouring precipitation of coated ferricrete pisolites near the surface and at depth (Baas Becking et al., 1960; Collins and Buol, 1970). In contrast, adjacent vegetated areas would maintain a more constant reducing environment in their soil climate due to more humid conditions and production of organic acids (Leeper, 1964; Meek et al., 1968). This would favour the leaching of these soils and production of ferricrete nodules during the seasonal groundwater fluctuations (Leeper, 1964; McFarlane, 1976, p.42-43). Sustained periods of high water table caused by either wetter climatic conditions or a change in hydrologic conditions would lead to the laterally extensive coaly horizons (facies C) deposited in peat swamps (Huddle and Patterson, 1961; Falini, 1965). This seasonally semi-arid climatic interpretation contrasts somewhat with the semi-arid interpretation suggested by Legun (1980) and Legun and Rust (1982) from Pictou sediments of the same age and similar character in the northwest Central Basin. This may suggest local climatic variations throughout the basin.

3.6 REGIONAL BASIN EVOLUTION

The facies sequences of the fluvial channel and flood plain depositional systems occur as large and small scale cyclic repetitions in the vertical stratigraphy of the Oromocto Sub-basin. This

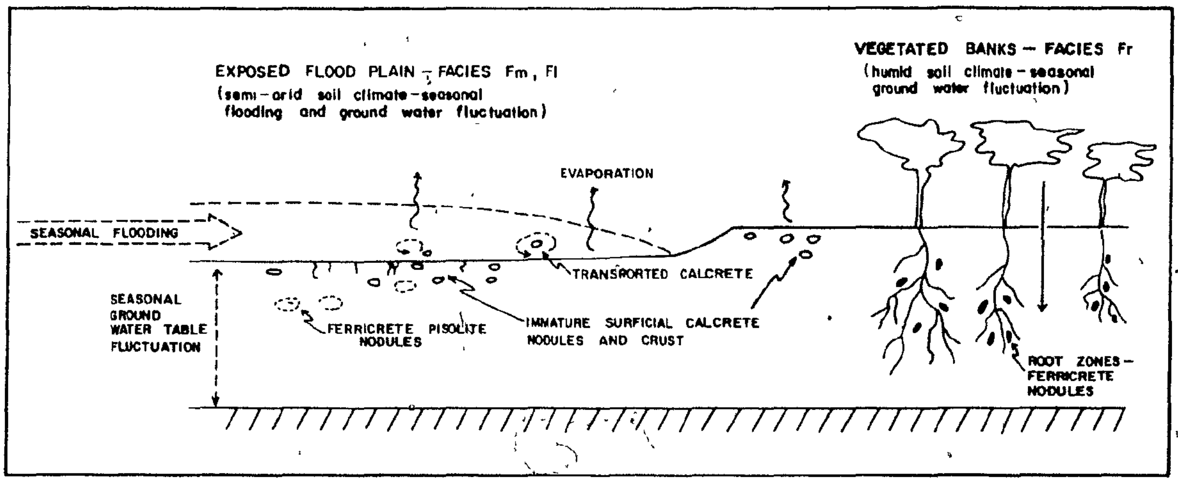


Figure 3.5: Schematic Model for the Development of Calcrete and Ferricrete Nodules in the Flood Plain Depositional System.

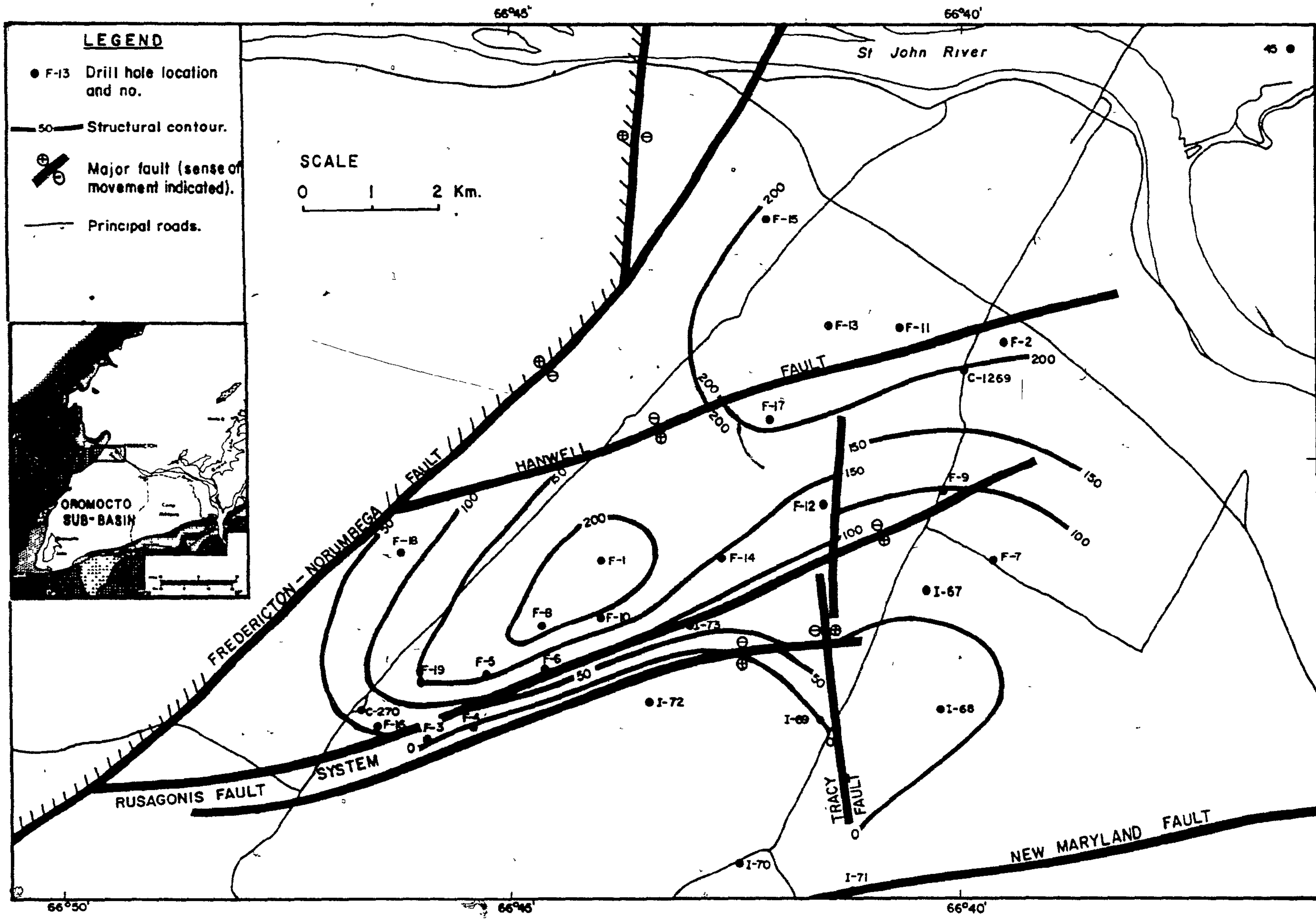

LEGEND
F-13 Drill hole location and no.
50 Structural contour.
Major fault (sense of movement indicated).
Principal roads.
SCALE
0 1 2 Km.
OROMOCTO SUB-BASIN
66°45'
66°40'
66°50'
45°55'
St John River
FREDERICTON - NORUMBEGA FAULT
HANWELL FAULT
RUSAGONIS FAULT SYSTEM
TRACY FAULT
NEW MARYLAND FAULT
F-15
F-13
F-11
F-2
C-1269
F-17
F-12
F-9
F-7
F-18
F-1
F-14
I-67
F-8
F-10
I-73
F-19
F-5
F-6
C-270
F-16
F-3
F-4
I-72
I-69
I-68
I-70
I-71
45
200
150
100
50
0

Figure 3.6: Structural Contours of PH-1 Marker Horizon in the Fredericton Graben and Surrounding Area.

stratigraphy is best defined in the Fredericton area where three 150 to 400 meter thick megacycles are recognized (Figure 2.3). Cycle III, found only in the Fredericton graben, consists of repeated smaller scale cycles (10 to 75 meters thick) of similar character and megacycle II is marked by a prominent transitional zone of small cycles (II-2 interval) between its upper and lower successions. An examination of regional cross-sections and isopach maps, using coaly marker horizons PH-1, PH-2 and PH-3 (facies C) recognized in the flood plain system of interval II-3 (Figures 2.3 and 2.4), reveals major aspects of the basins' sedimentary evolution.

Structural contours on the PH-1 marker horizon reveal the post-depositional (present day) structure of the Pictou strata in the vicinity of Fredericton. Structural displacement of marker horizons confirm large scale warping and faulting in and around the Fredericton graben structure (Figure 3.6). Relative fault displacement range from 50 to 60 meters along the New Maryland, Rusagonis and Hanwell faults and 20 meters along the Tracy Fault (Figure 3.7).

Isopachs of the interval between the PH-1 and PH-3 markers show a variation in thickness of only 4 meters over an area of approximately 300 km^2 near Fredericton. This limited regional variation indicates that differential subsidence during flood plain deposition was slight and palaeorelief was small. Isopachs of the interval between the cycle III base and PH-3 vary by the same magnitude. This indicates that the development of the fluvial channel systems was not accompanied by extensive erosion and ravining of the underlying flood plain deposits. A rapid change in stratigraphic thickness of megacycle I between drill holes 32 and F-2 (Figure 2.3) suggests that differential subsidence played a role in the development of megacycle I. This cannot be fully substantiated because of the lack of other deep holes in the Oromocto Sub-basin.

Thickness of the major sand interval between the II-2-D base and PH-1 vary as much as 12 meters throughout the same area and the isopachs therefore form an asymmetric curvilinear pattern of maximum thickness (Figure 3.7). A comparison between isopachs and the II-2-D facies profile indicates the development of at least one major channel system surrounded by the flood plain system for the Upper II-2-D sand interval, although it is cut off to the northwest by faulting (Figure 3.7). The juxtaposition of the two depositional systems can also be observed in regional cross-sections through the Fredericton graben and across the Oromocto Sub-basin (Figures 3.8, 3.9, 3.10). Unfortunately, holes drilled near the centre of the basin are only deep enough to reveal the lateral change in the transitional smaller scale cycles of megacycle II. The thicker fluvial channel systems making up the base of the megacycles can be expected to behave in a similar fashion. The regional sections (Figures 3.8, 3.9 and 3.10) define a geometry of linear sand bodies of lenticular cross-section comprising the fluvial channel depositional systems.

A schematic model is proposed to illustrate the facies distribution of the contrasting depositional systems and the cross-section geometry

Figure 3.7: Isopach Map of PH-1 Marker Horizon to the Base of the Upper Sand Interval II-2-D (Figures 3.8, and 3.9), and Comparative Stratigraphic Logs.

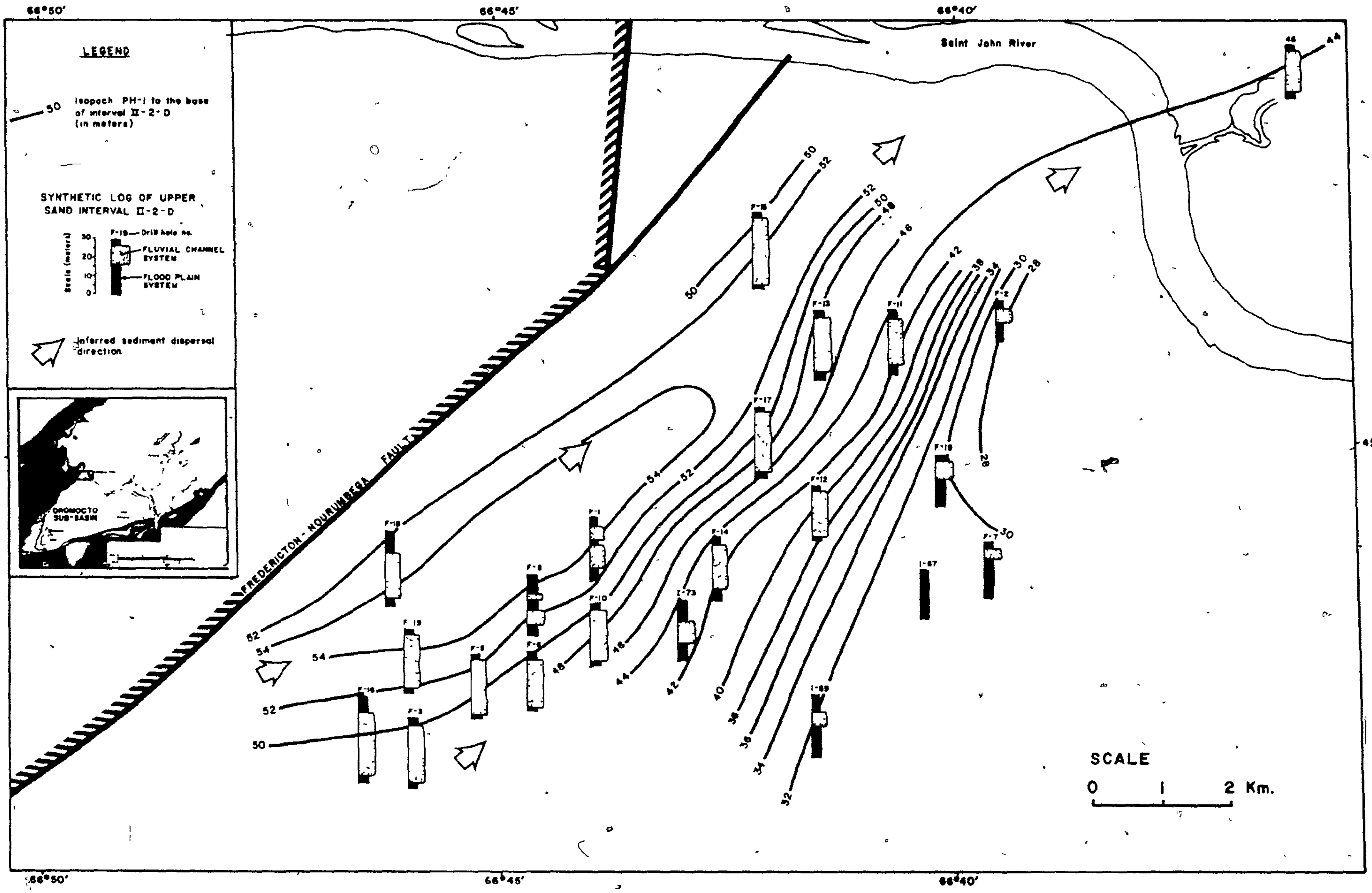

LEGEND
50 Isopach PH-1 to the base of interval II-2-D (in meters)
SYNTHETIC LOG OF UPPER SAND INTERVAL II-2-D
F-19 — Drill hole no.
FLUVIAL CHANNEL SYSTEM
FLOOD PLAIN SYSTEM
Scale (meters)
Inferred sediment dispersal direction
OROMOCTO SUB-BASIN
Saint John River
FREDERICTON - NOURUMBEGA FAULT
SCALE
0 1 2 Km.
66°50'
66°45'
66°40'
45°55'
F-18
F-17
F-13
F-11
F-2
F-19
F-12
F-14
F-1
F-10
F-8
F-9
F-5
F-16
F-3
F-7
I-73
I-67
I-69

Figure 3.8: Northwest to Southeast Cross-Section Showing the Stratigraphic Framework, Cycles and Sandstone Geometry of the Pictou Group across the Oromocto Sub-basin. Marker horizons of coaly facies C are used as datum.

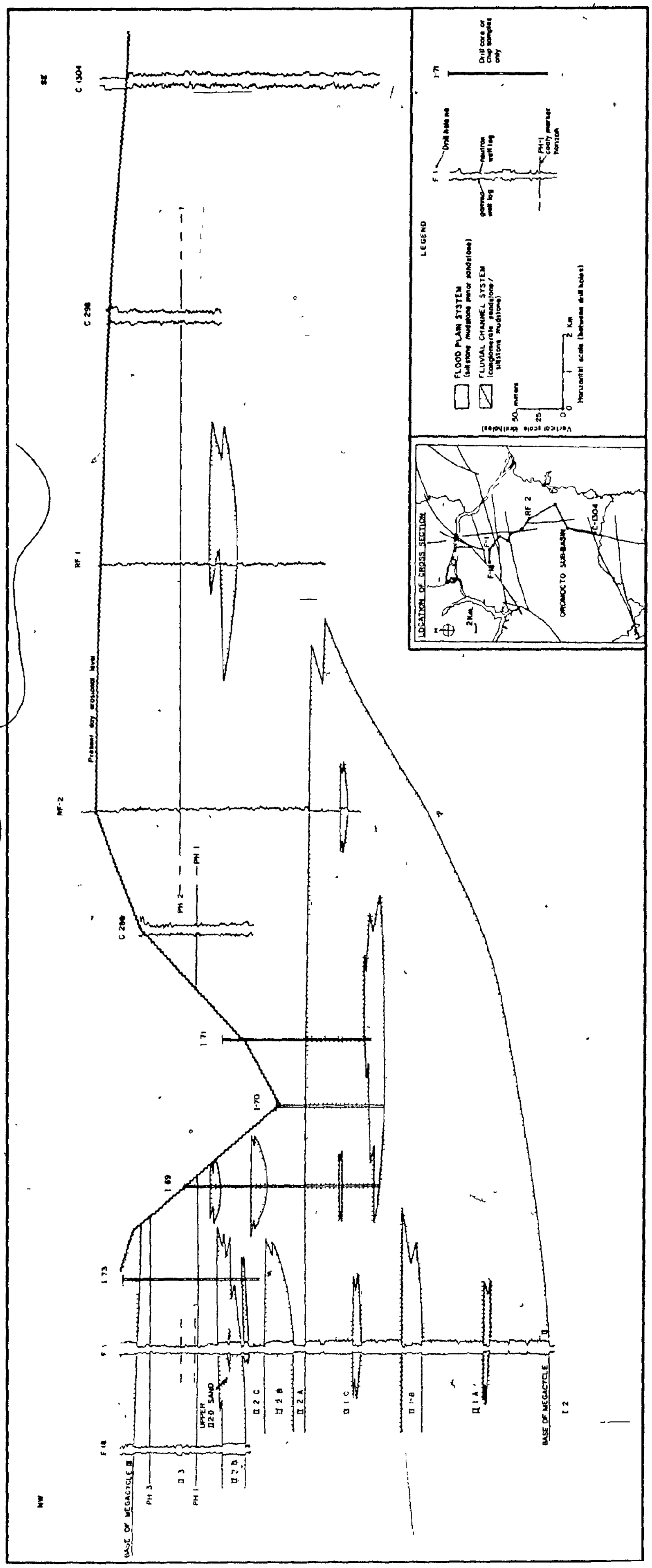

NW
SE
F 18
F 1
I 73
I 69
I-70
I 71
C 286
RF-2
RF 1
C 298
C 1304
Present day erosional level
BASE OF MEGACYCLE III
PH 3
II 3
PH 1
UPPER II 2 D SAND
II 2 D
II 2 C
II 2 B
II 2 A
II 1 C
II 1-B
II 1 A
BASE OF MEGACYCLE II
I 2
PH 2
PH 1
LOCATION OF CROSS SECTION
2 Km
F-18
F-1
RF 2
OROMOCTO SUB-BASIN
C-1304
LEGEND
FLOOD PLAIN SYSTEM (siltstone mudstone minor sandstone)
FLUVIAL CHANNEL SYSTEM (conglomerate sandstone/ siltstone mudstone)
F 1 Drill hole no
gamma well log
neutron well log
PH-1 coaly marker horizon
I-71
Drill core or chip samples only
Vertical scale (drillholes)
50 meters
25
0
1
2 Km
Horizontal scale (between drill holes)

Figure 3.9: North to South Cross-Section Showing the Stratigraphic Framework, Cycles and Sandstone Geometry of the Pictou Group across the Oromocto Sub-basin. Marker horizons of coaly facies C are used as datum.

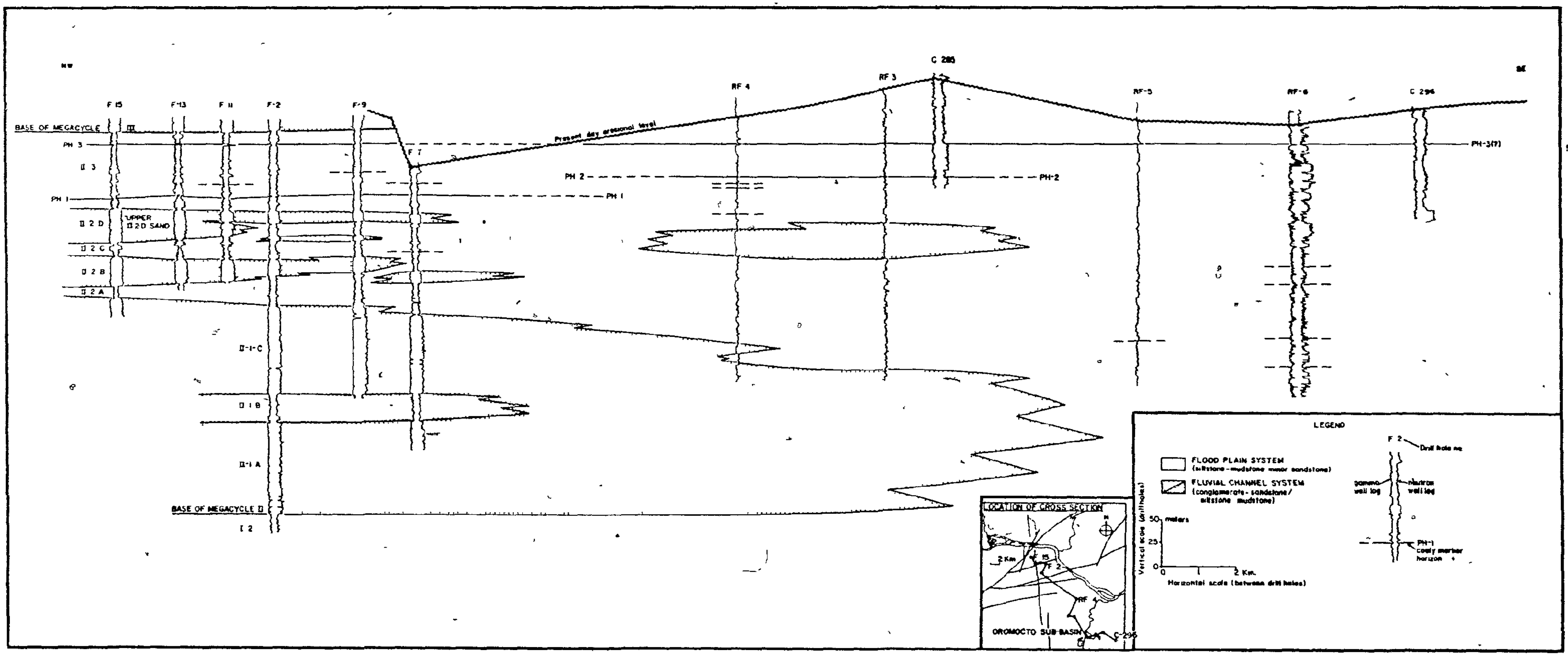
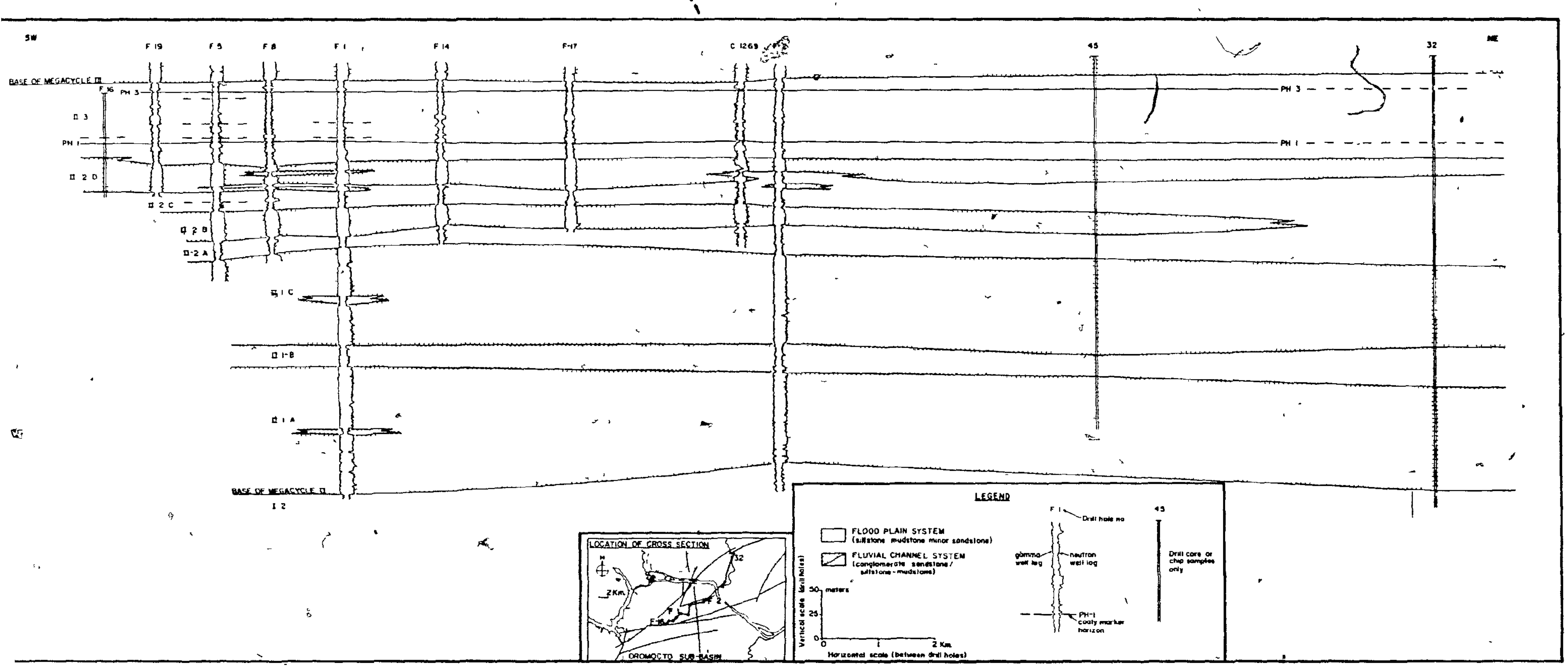

NW
SE
F 15
F-13
F 11
F-2
F-9
F 7
RF 4
RF 3
C 285
RF-5
RF-6
C 296
BASE OF MEGACYCLE III
PH 3
PH-3(?)
PH 2
PH-2
PH 1
Present day erosional level
UPPER
II 2 D SAND
LEGEND
FLOOD PLAIN SYSTEM
(siltstone - mudstone minor sandstone)
FLUVIAL CHANNEL SYSTEM
(conglomerate - sandstone/
siltstone mudstone)
Drill hole no.
gamma well log
neutron well log
PH-1
coaly marker horizon
Vertical scale (drillholes)
50 meters
25
0
2 Km.
Horizontal scale (between drill holes)
LOCATION OF CROSS SECTION
2 Km
OROMOCTO SUB-BASIN
BASE OF MEGACYCLE II

Figure 3.10: Cross-Section along the Structural Axis of the Fredericton Graben Showing the Stratigraphic Framework and Depositional Systems, and Cyclicity of the Pictou Group. Marker horizons of coaly facies C are used as datum.


SW
NE
F 19
F 5
F 8
F 1
F 14
F-17
C 1269
45
32
BASE OF MEGACYCLE III
F 16
PH 3
PH 1
II 3
II 2 D
II 2 C
II 2 B
II-2 A
II 1 C
II 1-B
II 1 A
BASE OF MEGACYCLE II
I 2
LOCATION OF CROSS SECTION
2 Km.
OROMOCTO SUB-BASIN
LEGEND
FLOOD PLAIN SYSTEM
(siltstone mudstone minor sandstone)
FLUVIAL CHANNEL SYSTEM
(conglomerate sandstone / siltstone - mudstone)
Vertical scale (drill holes)
50 meters
25
0
1
2 Km.
Horizontal scale (between drill holes)
Drill hole no
gamma well log
neutron well log
PH-1 coaly marker horizon
Drill core or chip samples only

of the regional cyclic stratigraphy (Figure 3.11). The model illustrates one or more wide rivers (2 to 15 km wide) flowing across an extensive flat-lying alluvial plain at any given time during the Pennsylvanian. Vertical and lateral stratigraphic patterns would clearly be a product of the dynamic interreaction between the two depositional systems and lateral migration of the fluvial belts. The actual causes of stratigraphic repetition in the form of small and large scale cycles are less clear. The vertical and lateral scale of the cycles suggests that the major controls were likely allocyclic mechanisms of extrabasinal origin (Beerbower, 1964; Miall, 1977a, 1980). These controls could include climatic, tectonic and base level changes. The dynamics of basin evolution over long periods of time may be so complex that more than one mechanism must be considered (Beerbower, 1964).

Base level changes (rise in sea level) can cause alluviation and aggradation in adjacent paralic or deltaic environments if they are of sufficient magnitude (McCave, 1969). Base level changes could conceivably be an influencing factor in the cyclicity of the Pictou Group since the Pennsylvanian is well known as a time of widespread eustatic sea level variation (Wanless, 1967; Duff et al., 1967), but specific evidence is lacking and cannot be demonstrated without regionally adjacent and correlatable marine or paralic sequences, which are not present in the Central Basin (Ball et al., 1981). Tectonic and climatic controls are likely more applicable to the Central Basin but are nevertheless difficult to assess because

Figure 3.11: Schematic Model for the Evolution of the Pictou Group, Oromocto Sub-basin, New Brunswick:

(1) wide fluvial belt system, dominated by coarse sand and gravel

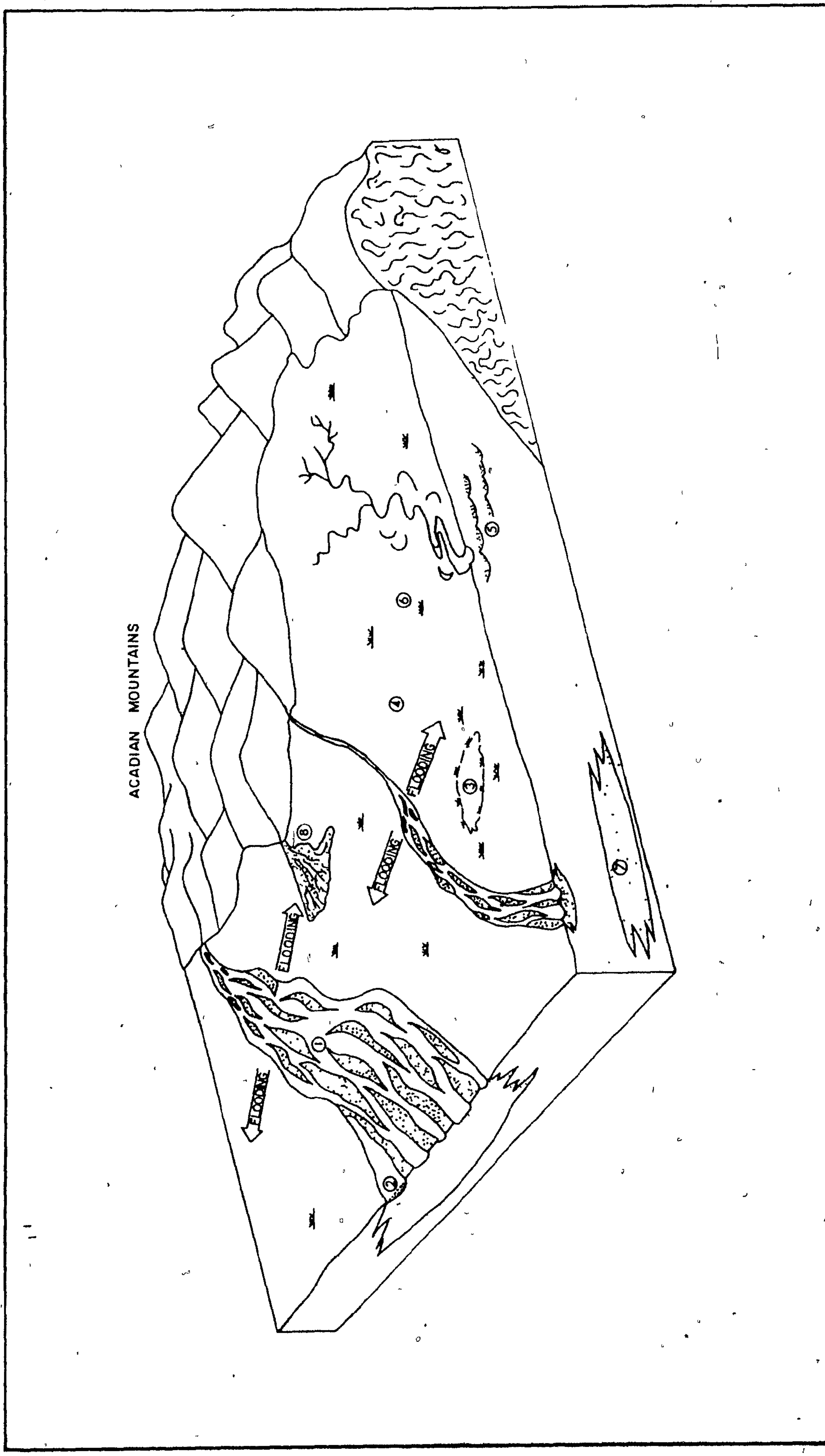
(2) abandoned channel with deposition of fine organic material

(3,4) ephemeral lakes and swamps forming coaly marker horizons.

(5) exposed alluvial plain subject to seasonal flooding and with (6) thin ephemeral alluvial channels

(7) previous fluvial channel system

(8) alluvial fans forming near the basin edge


ACADIAN MOUNTAINS
FLOODING
FLOODING
FLOODING
FLOODING
1
2
3
4
5
6
7
8

of the difficulties in evaluating extreme contrasts in source and sedimentation environments inherent in large scale river systems (Garner, 1959; Miall, 1978b). The Brahmaputra-Ganges basin of India (Coleman, 1969) represents a modern alluvial basin composed of several major fluvial belt systems surrounded by a much larger flood plain, comparable to the model presented for the Pictou Group in the Oromocto Sub-basin area. Coleman documents essentially autocyclic variations within the major river belts as produced by seasonal flooding, but implies that major changes in the position of the river belts, although representing river avulsion, are initiated by tectonic and/or unusual extremes in flooding (i.e. source area climate). Miall (1980) discusses some of the complex interrelationships between allocyclic triggering mechanisms of fluvial avulsion. The facies characteristics of the fluvial belt systems in the Pictou Group indicate an extremely high sediment charge and extensive seasonal flooding. Such river systems would be extremely unstable and subject to periodic migrations of the major river course initiated by climatic and/or tectonic controls originating in source areas.

3.7 CONCLUSIONS

In this study, two major depositional systems which can be used to characterize and define the stratigraphy in the Pictou Group of the study area were described and compared. Evidence for the lateral juxtaposition of these depositional systems through time and across the basin was proposed. In a suggested depositional model for the basin evolution, evidence from this study suggests development of wide fluvial belts (of probable braided channel pattern) with a heavy sediment charge cutting across a flat alluvial flood plain. Intrabasinal and extrabasinal tectonic and climatic controls have been considered to account for regional facies patterns and depositional cycles. The scale of the cyclicity and a comparison with possible modern day analogues suggest that allocyclic controls, particularly source area climate, may have dominated although no conclusive evidence can be used to favour one mechanism over another.

Documentation of regional Pennsylvanian depositional history in the Oromocto Sub-basin was made easier by the lack of formal stratigraphic units which allowed for the definition of facies related depositional systems unencumbered by the constraints of stratigraphic nomenclature. The author's suggested model remains to be tested in other areas of the Central Basin. It remains open to others to add and define additional depositional systems which likely existed in other areas of the basin. These might include extensive coal swamps, alluvial fans and meandering belt systems.

REFERENCES

CHAPTER III

ALCOCK, F.J. (1935) — Geology of Chaleur Bay Region: Geological Survey of Canada, Memoir No.183, 146 p.

ALLEN, J.R.L. (1965) — A Review of the Origin and Characteristics of Recent Alluvial Sediments: Sedimentology, v.5, p.89-191

ALLEN, J.R.L. (1974) — Studies in Fluviatile Sediments: Implications of Pedogenic Carbonate Units, Lower Red Sandstone, Anglo-Welsh Outcrop: Geological Journal, vol.9, pt.2, pp.181-208

BAAS BECKING, L.G.M., KAPLAN, I.R., MOORE, D. (1960) — Limits of the Natural Environment in Terms of pH and Oxidation-Reduction Potentials: Journal of Geology, v.68, No.3, p.243-284

BALL, F.D., SULLIVAN, R.M., and PEACH, A.R. (1981) — Carboniferous Drilling Project: Report of Investigations 18, Department of Natural Resources, New Brunswick, 109 p.

BEERBOWER, J.R. (1964) — Cyclothems and Cyclic Depositional Mechanisms in Alluvial Plain Sedimentation: in: Merriam, D.F. (ed.), Symposium on Cyclic Sedimentation: State Geological Survey of Kansas, Bulletin 169, v.1, p.31-42

BELL, W.A. (1962) — Flora of Pennsylvanian Pictou Group of New Brunswick: Geological Survey of Canada, Bulletin No.87, 71 p.

CANT, D.J., and WALKER, R.G. (1976) — Development of a Braided-Fluvial Facies Model for the Devonian Battery Point Sandstone, Quebec: Canadian Journal of Earth Science, v.13, p.102-119

CARR, P.A. (1964) Geology and Hydrology of the Moncton Map-Area, New Brunswick, Canada: Unpublished Ph.D. Thesis, University of Illinois, USA, 104 p.

COLEMAN, J.M. (1969) Brahmaputra River Channel Processes and Sedimentation: Sedimentary Geology, 3, pp.129-239

COLLINS, J.F., BUOL, S.W. (1970) Effects of Fluctuations in Eh-pH Environment on Iron and Magnesium Equilibrium: Soil Science, v.110, p.111-118

COLLINSON, J.D. (1978) Alluvial Sediments: in: Reading, H.G. (ed.), Sedimentary Environments and Facies, Elsevier, New York, p.15-64

DUFF, P. McL.D., HALLAM, A., and WALTON (1967) Chapter 4. Transitional Regimes, I-North America: in: Cyclic Sedimentation, Developments in Sedimentology 10, Elsevier Publishing Co., New York, p.81-104

FALINI, F. (1965) On the Formation of Coal Deposits of Lacustrine Origin: Geological Society of America Bulletin, v.76, p.1317-1346

FISHER, W.L., and MCGOWEN, J.H. (1967) Depositional Systems in the Wilcox Group of Texas and their Relationship to Occurrence of Oil and Gas: Gulf Coast Association, Geological Society Transactions, v.17, p.105-125

FISHER, W.L. (1982) Terrigenous Depositional Systems - a Genetic Approach to Facies Analysis in Petroleum Exploration, Texas Bureau of Economic Geology: Canadian Society of Petroleum Geology Short Course, Calgary, Alberta, October 21, 22, 1982, 409 p.

GARNER, H.F. (1959) Stratigraphic-Sedimentary Significance of Contemporary Climate and Relief in Four Regions of the Andes Mountains: Geological Society of America Bulletin, v.70, p.1327-1368

GOUDIE, A. (1973) Duricrusts in Tropical and Subtropical Landscapes:
Clarendon Press, Oxford, 175 p.

GUSSOW, W.C. (1953) Carboniferous Stratigraphy and Structural Geology of New Brunswick, Canada:
Bulletin of the American Association of Petroleum Geologists, v.37, p.1713-1816

HORNE, J.C., FERM, J.C., CARUCCIO, F.T., and BAGANTZ, B.P. (1978) Depositional Models in Coal Exploration and Mine Planning in Appalachian Region:
American Association of Petroleum Geologists Bulletin, v.62, No.12, p.2379-2411

HUDDLE, J.W., PATTERSON, S.H. (1961) Origin of Pennsylvanian Underclay and Related Seat Rocks:
Geological Society of America Bulletin, v.72, p.1643-1660

KELLEY, D.G. (1967) Some Aspects of Carboniferous Stratigraphy and Depositional History in the Atlantic Provinces:
Geological Association of Canada, Special Paper No.4, p.213-229

LEEDER, M.R. (1975) Pedogenic Carbonate and Flood Sediment Accretion Rates: a Quantitative Model for Alluvial Arid Zone Lithofacies:
Geological Magazine, v.112, p.257-270

LEEPER, G.W. (1964) Introduction to Soil Science:
Melbourne University Press, Melbourne, 353 p.

LEGUN, A. (1980) Sedimentology of the Clifton Formation (Upper Carboniferous) of Northern New Brunswick: a Semi-Arid Depositional Setting for Coal:
Unpublished M.Sc. Thesis, University of Ottawa, 97 p.

LEGUN, A.S., and RUST, B.R. (1982) The Upper Carboniferous Clifton Formation of Northern New Brunswick: Coal-Bearing Deposits of a Semi-Arid Alluvial Plain:
Canadian Journal of Earth Sciences, v.19, p.1775-1785

LEOPOLD, L.B., and WOLMAN, M.G. (1957) — River Channel Patterns, Braided, Meandering and Straight: United States Geological Survey Professional Paper 282B, p.39-73

MCCAVE, I.N. (1969) — Correlation of marine and Non-Marine Strata with Example from Devonian of New York State: American Association of Petroleum Geologists Bulletin, v.53, No.1, p.155-162

MCFARLANE, M.J. (1976) — Laterite and Landscape: Academic Press, New York, 151 p.

MCKEE, E.D., CROSBY, E.J., and BERRYHILL, H.L. Jr. (1967) — Flood Deposits, Bijou Creek, Colorado, June 1965: Journal of Sedimentary Petrology, v.37, p.829-851

MEEK, B.D., MACKENZIE, A.J., and GRASS, L.B. (1968) — Effects of Organic Matter, Flooding Time and Temperature on the Dissolution of Iron and Manganese from Soil in Situ: Soil Science Society of America Proceedings, v.32, p.634-638

MIALL, A.D. (1977a) — Fluvial Sedimentology, Short Course Notes: Stacs Data Service Ltd., Calgary, Alberta

MIALL, A.D. (1977b) — A Review of the Braided River Depositional Environment: Earth Science Reviews, v.13, p.1-62

MIALL, A.D. (1978a) — Lithofacies Types and Vertical Profile Models in Braided Rivers; a Summary: in: Miall, A.D. (ed.), Fluvial Sedimentology: Canadian Society of Petroleum Geologists, Memoir 5, p.597-604

MIALL, A.D. (1978b) — Tectonic Setting and Syndepositional Deformation of Molasse and Other Non-Marine-Paralic Sedimentary Basins: Canadian Journal of Earth Sciences, v.15, p.1613-1632

MIALL, A.D. (1980) — Cyclicity and the Facies Model Concept in Fluvial Deposits: Bulletin of Canadian Petroleum Geology, v.28, No.1, p.59-80

MULLER, J.E. (1952) — Geology and Coal Deposits of Minto and Chipman Map-Areas, New Brunswick: Geological Survey of Canada, Memoir No.260

PICARD, M.D., HIGH Jr., L.R. (1973) — Sedimentary Structures of Ephemeral Streams: Elsevier, Amsterdam, 223 p.

POTTER, P.E. (1978) — Significance and Origin of Big Rivers: Journal of Geology, v.86, p.13-33

REEVES, C.C. (1976) — Caliche: Estacado Books, Texas, 233 p.

REINECK, H.E., and SINGH, I.B. (1980) — Depositional Sedimentary Environments: Springer Verlag, New York, 549 p.

SCOTESE, C.R., BAMBACH, R.K., BARTON, C., VAN DER VOO, R., and ZEIGLER, A.M. (1979) — Paleozoic Base Maps: Journal of Geology, v.87, p.217-277

VAN DE POLL, H.W. (1970) — Stratigraphical and Sedimentological Aspects of Pennsylvanian Strata in Southern New Brunswick: Unpublished Ph.D. Thesis, University of Wales, 140 p.

VAN DE POLL, H.W. (1973a) — Stratigraphy, Sediment Dispersal and Facies Analysis of the Pennsylvanian Pictou Groups in New Brunswick: Maritime Sediments, v.9, No.3, p.72-77

VAN DE POLL, H.W. (1973b) — Feasibility Report Concerning the Hydrocarbon and Coal Potential of the Fredericton Area: New Brunswick Department of Natural Resrouces, Mineral Resources Branch, Report No.35

WALKER, T.R. (1967) — Formation of Red Beds in Modern and Ancient Deserts: Geological Society of America Bulletin, v.78, p.353-368

WANLESS, H.R. (1967) Marine and Non-Marine Facies of the Upper Carboniferous of North America: Compte Rendu, Sixième Congrès International de Stratigraphie et de Géologie du Carbonifère, p.293-336

WILLIAMS, P.F., and RUST, B.R. (1969) The Sedimentology of a Braided River: Journal of Sedimentary Petrology, v.39, p.649-679

CHAPTER IV : JOINT SUMMARY AND CONCLUSIONS

Strata of the Pictou Group in the southwestern end of the Central Carboniferous Basin in New Brunswick (Oromocto Sub-basin) are arranged in large and small scale cycles. These cycles form the basis for stratigraphic correlation at different scales. Three large scale megacycles (150 to 400 meters thick) are recognized in the regional examination of drill holes. Megacycles I and II are characterized by a thick basal succession dominated by grey, coarse grained sandstones and conglomerates overlain by a red succession, dominated by shales and siltstones. Megacycle III consists of repeated smaller scale cycles (10 to 75 meters thick) of similar character to the megacycles. Megacycle III is preserved only in a large scale post-sedimentary graben structure in the Fredericton area. Megacycles I and II can be correlated with a high degree of confidence throughout the study area although they are characterized by major lateral facies changes and variations in thickness. The most prominent large scale lateral facies change is a thining and lateral pinching-out of the basal coarse grained successions into the fine grained successions. Characteristic geophysical well log signature facilitates lateral correlation and recognition of the cycles and their internal facies sequences.

The cycles can be defined in terms of depositional systems composed of assemblages of genetically linked lithofacies. Two contrasting depositional systems, a fluvial channel and a flood plain system are recognized in the stratigraphy from detailed facies analysis.

The fluvial channel system dominates the basal portions of cycles, and the flood plain system the upper part. The fluvial channel system is mostly made up of stacked conglomerate-sandstone facies sequences representing high energy channel deposition. Low energy fine grained bar top deposits and organic matter-rich mud deposited in abandoned channels record cycles of waning flow within the fluvial system. The fluvial channel system is interpreted as representing the development of major river belts of a braided character. Physical characteristics of similar modern day rivers suggest high bed and suspension load and an unstable hydrology for the fluvial channel systems of the Pictou.

The flood plain system is dominated by fine grained sediments with small scale low energy current features and massive mudstones indicating distal flood deposits. These fine grained flood deposits are more likely derived from the flooding of the major fluvial channel systems, rather than the thin channel sequences contained within the flood plain system itself. Calcrete and ferricrete nodules found throughout the flood plain deposits indicate both a wet and semi-arid soil climate controlled by fluctuating groundwater initiated by flooding from the major rivers (fluvial channel systems). The ferricrete nodules were deposited in soils where groundwater levels fluctuated during flooding and in pedogenic seat earths where local vegetation maintained a humid soil climate throughout the dry season. A seasonal lowering of the groundwater table during post-flood run-off created semi-arid soil conditions favouring the development of immature calcretes. Areas of the flood plain distal to the major channels, which would escape seasonal flooding, developed calcretes which were subject to erosion during a following flood phase. Periodic and local rises in the water table for longer periods of time developed laterally extensive swamp environments on the alluvial plain which favoured preservation of organic material as thin coaly laminae. These formed marker horizons that can be used in structural studies and in the correlation of drill holes. These marker horizons indicate an extremely low topography during flood plain deposition and delineate curvilinear channel patterns in some of the smaller scale fluvial channel systems. Varying degrees of differential synsedimentary subsidence are indicated.

Regional cross-sections through the basin indicate the lateral equivalence of the flood plain and fluvial channel systems. Detailed facies patterns within each depositional system can be explained by autocyclic migration of individual channels, controlled by seasonal flooding of major rivers. Although the larger scale cyclicity is clearly a result of the mutual development of the two major depositional systems, specific mechanisms of control are less clear. The vertical and lateral scale of the cycles suggests major allocyclic or extrabasinal controls such as tectonic or source area climate. Major avulsion events accompanied by lateral migration of the fluvial belts may have been triggered by tectonic or source area climate fluctuations. Similar mechanisms have been suggested in studies of the Brahmaputra-Ganges alluvial plain, which may represent a modern day analogue to the Pictou depositional models.

REFERENCES

ALCOCK, F.J. (1935) Geology of Chaleur Bay Region: Geological Survey of Canada, Memoir No.183, 146 p.

ALLEN, J.R.L. (1965) A Review of the Origin and Characteristics of Recent Alluvial Sediments: Sedimentology, v.5, p.89-191

ALLEN, J.R.L. (1974) Studies in Fluviatile Sediments: Implications of Pedogenic Carbonate Units, Lower Red Sandstone, Anglo-Welsh Outcrop: Geological Journal, Vol.9, pt.2, pp.181-208

ALLEN, D.R. (1975) Identification of Sediments - their depositional environment and degree of compaction from well logs, in: Chilingarian, G.V., and Wolf, K.H., (ed.), Compaction of coarse grained sediments: Developments in Sedimentology, v.18A, Elsevier, New York, p.349-402

BAAS BECKING, L.G.M., KAPLAN, I.R., MOORE, D. (1960) Limits of the Natural Environment in Terms of pH and Oxidation-Reduction Potentials: Journal of Geology, v.68, No.3, p.243-284

BALL, F.D., SULLIVAN, R.M., and PEACH, A.R. (1981) Carboniferous Drilling Project, Report of Investigations 18, Department of Natural Resources, New Brunswick, 109 p.

BARSS, M.S., and HACQUEBARD, P.A. (1967) Age and the Stratigraphy of the Pictou Group in the Maritime Provinces as Revealed by Fossil Spores: Geological Association of Canada, Special Paper No.4, pp.267-283

BARSS, M.S., BAJAK, J.P., and WILLIAMS, G.L. (1979) Palynological Zonations and Correlation of Sixty-Seven Wells, Eastern Canada: Geological Survey of Canada, Paper 78-24, 118 p.

BARSS, M.S. (1982) Palynological Analysis of Samples for Age Determinations from Cominco Drill Holes South of Fredericton: Report No. EPGS-PAL.16-82MSB, New Brunswick Department of Natural Resources in cooperation with the Eastern Petroleum Geology Subdivision, Bedford Institute, Dartmouth, Nova Scotia, 4 p.

BEERBOWER, J.R. (1964) = Cyclothems and Cyclic Depositional Mechanisms in Alluvial Plain Sedimentation, in: Merriam, D.F. (ed.), Symposium on Cyclic Sedimentation: State Geological Survey of Kansas, Bulletin 169, v.1, p.31-42

BELL, W.A. (1962) Flora of Pennsylvanian Pictou Group of New Brunswick: Geological Survey of Canada, Bulletin No.87, 71 p.

BERNER, R.A. (1971) Principles of Chemical Sedimentology: McGraw Hill Co., New York, p.197, 198

BUSCH, D.A. (1974) Stratigraphic Traps in Sandstones - Exploration Techniques: American Association of Petroleum Geologists, Memoir 21, Tulsa, Oklahoma, 174 p.

CANT, D.J., and WALKER, R.G. (1976) Development of a Braided-Fluvial Facies Model for the Devonian Battery Point Sandstone, Quebec: Canadian Journal of Earth Science, v.13, p.102-119

CARR, P.A. (1964) Geology and Hydrology of the Moncton Map-Area, New Brunswick, Canada: Unpublished Ph.D. Thesis, University of Illinois, USA, 104 p.

CHANDRA, J.J., FIFE, L., RUITENBERG, A.A., and WALLACE, J.W. (1982) Structural Map of New Brunswick - compiled from geologic, gravimetric, aeromagnetic and Landsat data: New Brunswick Department of Natural Resources, Geophysics Branch, Plate 82-178

COLEMAN, J.M. (1969) Brahmaputra River Channel Processes and Sedimentation: Sedimentary Geology, 3, pp.129-239

COLLINS, J.F., BUOL, S.W. (1970) Effects of Fluctuations in Eh-pH Environment on Iron and Magnesium Equilibrium: Soil Science, v.110, p.111-118

COLLINSON, J.D. (1978) Alluvial Sediments: in: Reading, H.G. (ed.), Sedimentary Environments and Facies, Elsevier, New York, p.15-64

DUFF, P. McL. D., HALLAM, A., and WALTON (1967) Chapter 4. Transitional Regimes, I - North America: in: Cyclic Sedimentation, Developments in Sedimentology 10, Elsevier Publishing Co., New York, p.81-104

FALINI, F. (1965) On the Formation of Coal Deposits of Lacustrine Origin: Geological Society of America Bulletin, v.76, p.1317-1346

FISHER, W.L., and MCGOWEN, J.H. (1967) Depositional Systems in the Wilcox Group of Texas and their Relationship to Occurrence of Oil and Gas: Gulf Coast Association, Geological Society Transactions, v.17, p.105-125

FISHER, W.L. (1982) Terrigenous Depositional-Systems - a Genetic Approach to Facies Analysis in Petroleum Exploration, Texas Bureau of Economic Geology: Canadian Society of Petroleum Geology Short Course, Calgary, Alberta, October 21, 22, 1982, 409 p.

FOLK, R.L. (1959) Petrology of Sedimentary Rocks: Hemphill Publishing Co., 154 p.

GARNER, H.F. (1959) Stratigraphic-Sedimentary Significance of Contemporary Climate and Relief in Four Regions of the Andes Mountains: Geological Society of America Bulletin, v.70, p.1327-1368

GOUDIE, A. (1973) Duricrusts in Tropical and Subtropical Landscapes: Clarendon Press, Oxford, 175 p.

GUSSOW, W.C. (1953) Carboniferous Stratigraphy and Structural Geology of New Brunswick, Canada: Bulletin of the American Association of Petroleum Geologists, v.37, p.1713-1816

HACQUEBARD, P.A. (1971) — The Carboniferous of Eastern Canada: Compte Rendu, Septième Congrès International de Stratigraphie et de Géologie du-Carbonifère, pp.69-69

HACQUEBARD, P.A., and AVERY, M.P. (1982) — Geological and Geothermal Effects on Coal Rank Variations in the Pennsylvanian Basin of New Brunswick: Abstract, Atlantic Geoscience Society Colloquium on Current Research in the Atlantic Provinces, Amherst, Nova Scotia, January 23rd, 1982

HALLENBURG, J.K. (1979) — Geophysical Logging for Mineral and Non-Petroleum Exploration and Development: Unpublished Manual Short Course, Mineral Logging, Oil and Gas Consultants International, Inc., Tulsa, Oklahoma

HAMILTON, J.B. (1962) — Correlation of the Pennsylvanian Rocks in the Western Part of the Central Pennsylvanian Basin of New Brunswick by Means of Fossil Spores: Unpublished M.Sc. Thesis, University of New Brunswick, Fredericton, 118 p.

HASAN, Z. (1977) — New Maryland Claim Group Assessment Report, Imperail Oil (Canada) Ltd.: New Brunswick Mineral Resources Branch Assessment Files, Assessment Report No.472125

HASAN, Z. (1978) — New Maryland Claim Group Assessment Report, Imperial Oil (Canada) Ltd.: New Brunswick Mineral Resources Branch Assessment Files, Assessment Report No.472235

HORNE, J.C., FERM, J.C., CARUCCIO, F.T., and BAGANTZ, B.P. (1978) — Depositional Models in Coal Exploration and Mine Planning in Appalachian Region: American Association of Petroleum Geologists Bulletin, V.62, No.12, p.2379-2411

HUDDLE, J.W., PATTERSON, S.H. (1961) — Origin of Pennsylvanian Underclay and Related Seat Rocks: Geological Society of America Bulletin, v.72, p.1643-1660

ITENBERG, S.S. (1971) — Study of Oil and Gas Series from Well Logs: Mir Publishers, Moscow, 268 p.

KELLEY, D.G. (1967) Some Aspects of Carboniferous Stratigraphy and Depositional History in the Atlantic Provinces:
Geological Association of Canada, Special Paper No.4, p.213-229

KIPLING, R.W. (1980) Oro Project Assessment Report, Cominco Canada Limited: New Brunswick Department of Natural Resources, Assessment Report Nos. 47244 and 472563

KIPLING, R.W. (1981) Rustigonis Property Assessment Report, Cominco Canada Limited:
New Brunswick Department of Natural Resources, Assessment Report No.472759

KUAN, Soong (1970) The Geology of Carboniferous Volcanic Rocks in the Harvey Area, New Brunswick:
Unpublished M.Sc. Thesis, University of New Brunswick, 78 pages

LEEDER, M.R. (1975) Pedogenic Carbonate and Flood Sediment Accretion Rates: a Quantitative Model for Alluvial Arid Zone Lithofacies:
Geological Magazine, v.112, p.257-270

LEEPER, G.W. (1964) Introduction to Soil Science:
Melbourne University Press, Melbourne, 353 p.

LEGALLAIS, C.J. (1980) Fredericton Claim Group Assessment Report, SERU Nucléaire (Canada) Limitée:
New Brunswick Mineral Resources Branch Assessment Files, Assessment Report 472474.

LEGALLAIS, C.J. (1982) Fredericton Drilling Project - unofficial assessment report submitted on open file by permission of SERU Nucléaire (Canada) Limitée:
New Brunswick Mineral Resources Branch Assessment Files, Assessment Report 472919.

LEGUN, A. (1980) Sedimentology of the Clifton Formation (Upper Carboniferous) of Northern New Brunswick: a semi-arid depositional setting for coal:
Unpublished M.Sc. Thesis, University of Ottawa, 97 p.

LEGUN, A., and RUST, B.R. (1981) — Coal Accumulation on a Semi-Arid Alluvial Plain: the Carboniferous Clifton Formation of Northern New Brunswick: Abstract, Geological Association of Canada - Mineralogical Association of Canada Annual Convention, Calgary, Alberta

LEGUN, A.S., and RUST, B.R. (1982) — The Upper Carboniferous Clifton Formation of Northern New Brunswick: Coal-Bearing Deposits of a Semi-Arid Alluvial Plain: Canadian Journal of Earth Sciences, v.19, p.1775-1785

LEOPOLD, L.B., and WOLMAN, M.G. (1957) — River Channel Patterns, Braided, Meandering and Straight: United States Geological Survey Professional Paper 282B, p.39-73

MCCAVE, I.N. (1969) — Correlation of Marine and Non-Marine Strata with Example from Devonian of New York State: American Association of Petroleum Geologists Bulletin, v.53, No.1, p.155-162

MCFARLANE, M.J. (1976) — Laterite and Landscape: Academic Press, New York, 151 p.

MCKEE, E.D., CROSBY, E.J., and BERRYHILL, H.L. Jr. (1967) — Flood Deposits, Bijou Creek, Colorado, June 1965: Journal of Sedimentary Petrology, v.37, p.829-851

MEEK, B.D., MACKENZIE, A.J., and GRASS, L.B. (1968) — Effects of Organic Matter, Flooding Time and Temperature on the Dissolution of Iron and Manganese from Soil in Situ: Soil Science Society of America Proceedings, v.32, p.634-638

MIALL, A.D. (1977a) — Fluvial Sedimentology, Short Course Notes: Stacs Data Service Ltd., Calgary, Alberta

MIALL, A.D. (1977b) — A Review of the Braided River Depositional Environment: Earth Science Reviews, v.13, p.1-62

MIALL, A.D. (1978a) — Lithofacies Types and Vertical Profile Models in Braided Rivers; a Summary: <u>in</u> Miall, A.D. (ed.), Fluvial Sedimentology: Canadian Society of Petroleum Geologists, Memoir 5, p.597-604

MIALL, A.D. (1978b)	Tectonic Setting and Syndepositional Deformation of Molasse and Other Non-Marine-Paralic Sedimentary Basins: Canadian Journal of Earth Sciences, v.15, p.1613-1632
MIALL, A.D. (1980)	Cyclicity and the Facies Model Concept in Fluvial Deposits: Bulletin of Canadian Petroleum Geology, v.28, No.1, p.59-80
MULLER, J.E. (1952)	Geology and Coal Deposits of Minto and Chipman Map-Areas, New Brunswick: Geological Survey of Canada, Memoir No.260
PETTIJOHN, F.J. (1975)	Sedimentary Rocks: Harper and Row Publishers, New York, 628 p.
PICARD, M.D., HIGH Jr., L.R. (1973)	Sedimentary Structures of Ephemeral Streams: Elsevier, Amsterdam, 223 p.
PIRSON, S.J. (1963)	Handbook of Well Log Analysis: Prentice-Hall, New Jersey, 326 p.
PIRSON, S.J. (1977)	Geological Well Log Analysis: Gulf Publishing Co., Houston, 377 p.
POOLE, W.H. (1967)	Tectonic Evolution of Appalachina Region of Canada: Geological Association of Canada, Special Publication No.4, p.9-51
POTTER, P.E. (1978)	Significance and Origin of Big Rivers: Journal of Geology, v.86, p.13-33
POTTER, P.E., MAYNARD, J.B., and PRYOR, W.A. (1980)	Sedimentology of Shale: Springer Verlag, New York, 306 p.
REEVES, C.C. (1976)	Caliche: Estacado Books, Texas, 233 p.
REINECK, H.E., and SINGH, I.B. (1980)	Depositional Sedimentary Environments: Springer Verlag, New York, 549 p.
SCOTESE, C.R., BAMBACH, R.K., BARTON, C., VAN DER VOO, R., and ZEIGLER, A.M. (1979	Paleozoic Base Maps: Journal of Geology, v.87, p.217-277

SKIPPER, K. (1976)	Use of Geophysical Wireline Logs for Interpreting Depositional Processes: Geoscience Canada, v.3, p.279-280
STEEVES, B., and KINGSTON, P.W. (1981)	Carboniferous Seismic Survey: New Brunswick Department of Natural Resources, Open File 81-1, 83 p.
TELFORD, W.M., GELDART, L.P., SHERIFF, R.E., and KEYS, D.A., (1976)	Applied Geophysics: Chapter II, Geophysical Well Logging: Cambridge University Press, London, p.771-818
TOMLINSON, C.W. (1916)	Origin of Red Beds: American Journal of Science, v.24, p.153-179
VAN DE POLL, H.W. (1970)	Stratigraphical and Sedimentological Aspects of Pennsylvanian Strata in Southern New Brunswick: Unpublished Ph.D. Thesis, University of Wales, 140 p.
VAN DE POLL, H.W. (1973a)	Stratigraphy, Sediment Dispersal and Facies Analysis of the Pennsylvanian Pictou Group in New Brunswick: Maritime Sediments, v.9, No.3, p.72-77
VAN DE POLL, H.W. (1973b)	Feasibility Report Concerning the Hydrocarbon and Coal Potential of the Fredericton Area: New Brunswick Department of Natural Resources, Mineral Resources Branch, Report No.35
VAN HOUTEN, F.B. (1961)	Climatic Significance of Red Beds: in: Nairn, A.E.M. (ed.), Descriptive Palaeoclimatology: Wiley Interscience, New York, p.89-139
WALKER, T.R. (1967)	Formation of Red Beds in Modern and Ancient Deserts: Geological Society of America Bulletin, v.78, p.353-368

WANLESS, H.R. (1967) Marine and Non-Marine Facies of the Upper Carboniferous of North America: Compte Rendu, Sixième Congrès International de Stratigraphie et de Géologie du Carbonifère, p.293-336

WILLIAMS, P.F., and RUST, B.R. (1969) The Sedimentology of a Braided River: Journal of Sedimentary Petrology, v.39, p.649-679

APPENDIX A

MARKOV CHAIN ANALYSIS AND LITHOLOGIES OF REPRESENTATIVE STRATIGRAPHIC INTERVALS
(from facies analysis study of drill core, Fredericton area)

MARKOV ANALYSIS

Markov chain analysis (after Miall, 1977a) was performed on the vertical facies sequence in three stratigraphic intervals of drill hole F-2 (SERU):

1) Stratigraphic interval I-1 (fluvial channel system)
2) Stratigraphic interval II-1 (fluvial channel system)
3) Stratigraphic interval II-3 (flood plain system)

The Markov analysis constructs a number of probability matrices from the initial data matrix fij.

a) Transitional count matrix (data matrix)

   fij - number of facies transitions,
   lower beds are row numbers,
   upper beds column numbers.

b) Independent trials matrix which represents the probability of a given transition occurring randomly

   rij = Sj/(t-Si)
   where Sj = column totals
   Si = row totals
   t = total number of transitions.

c) Transitional probability matrix which represents the actual probability of the facies transition

   Pij = fij/Si

d) Difference matrix substracts the random element of the facies transitions from the observed probability

$$d_{ij} = P_{ij} - r_{ij}.$$

Path diagrams showing the principal facies relationships can be constructed from the difference matrix. Positive entries in dij indicate which transitions occur with greater than random frequency.

1) <u>Stratigraphic interval I-1, drill hole F-2</u>

a) Transitional count matrix (fij)

	Gm	St	Sr	Sh	Se	Fsc
Gm	0	27	3	1	0	0
St	27	0	9	7	0	2
Sr	4	6	0	2	4	4
Sh	0	4	3	0	1	1
Se	1	0	2	0	0	0
Fsc	0	5	2	0	0	0

b) Independent trials matrix (rij)

	Gm	St	Sr	Sh	Se	Fsc
Gm	.38	.50	.23	.12	.18	.06
St	.45	.60	.27	.14	.21	.07
Sr	.34	.44	.20	.10	.16	.05
Sh	.30	.40	.12	.09	.14	.05
Se	.29	.37	.17	.09	.13	.04
Fsc	.30	.39	.18	.09	.14	.05

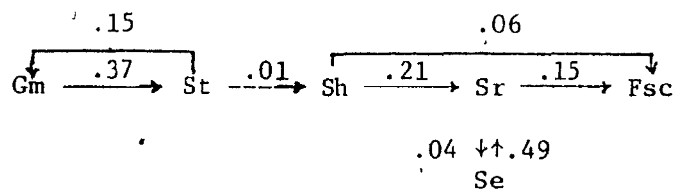
c) Transition probability matrix (Pij)

	Gm	St	Sr	Sh	Se	Fsc
Gm	0	.87	.10	.03	0	0
St	.60	0	.20	.15	0	.04
Sr	.20	.30	0	.10	.20	.20
Sh	0	.44	.33	0	.11	.11
Se	.33	0	.66	0	0	0
Fsc	0	.71	.28	0	0	0

d) Difference matrix (dij)

	Gm	St	Sr	Sh	Se	Fsc
Gm	-.38	.37	-.13	-.09	-.18	-.06
St	.15	-.60	-.07	.01	-.21	-.03
Sr	-.14	-.14	-.20	0	.04	.15
Sh	-.30	.04	.21	-.09	-.03	.06
Se	.04	-.37	.49	-.09	-.13	-.04
Fsc	-.30	.32	.10	-.09	-.14	-.05

e) Path diagram of preferred facies relationships (from difference matrix dif)



2) Stratigraphic interval II-1, drill hole F-2

a) Transitional count matrix (fij)

	Gm	St	Sr	Sh	Se	Fsc
Gm	0	43	1	1	0	0
St	32	0	15	23	3	3
Sr	4	11	0	3	0	5
Sh	5	13	1	0	5	1
Se	0	10	1	2	0	0
Fsc	0	2	5	0	3	0

b) Independent trials matrix (rij)

	Gm	St	Sr	Sh	Se	Fsc
Gm	.28	.54	.16	.20	.07	.06
St	.35	.68	.20	.25	.09	.08
Sr	.24	.47	.14	.17	.06	.05
Sh	.24	.47	.14	.17	.06	.05
Se	.23	.44	.13	.16	.06	.05
Fsc	.22	.43	.13	.16	.06	.05

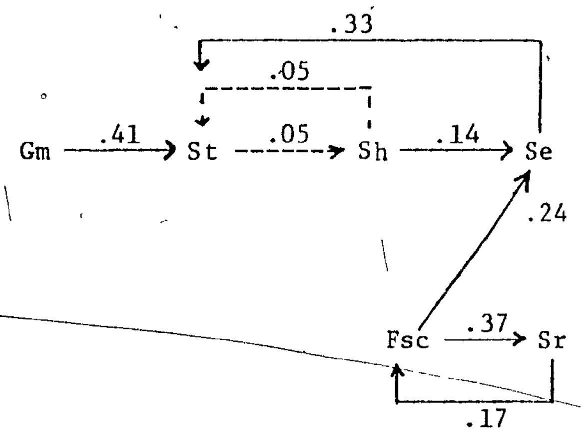
c) Transition probability matrix (Pij)

	Gm	St	Sr	Sh	Se	Fsc
Gm	0	.95	.02	.02	0	0
St	.42	0	.20	.30	.04	.04
Sr	.17	.48	0	.13	0	.22
Sh	.20	.52	.04	0	.20	.04
Se	0	.77	.08	.15	0	0
Fsc	0	.20	.50	0	.30	0

d) Difference matrix (dij)

	Gm	St	Sr	Sh	Se	Fsc
Gm	¯.28	.41	¯.14	0	¯.07	¯.06
St	.07	¯.68	0	.05	¯.05	¯.04
Sr	¯.07	.01	¯.14	¯.04	¯.06	.17
Sh	¯.04	.05	¯.10	¯.17	.14	¯.01
Se	¯.23	.33	¯.05	¯.01	¯.06	¯.05
Fsc	¯.22	¯.23	.37	¯.16	.24	¯.05

e) Path diagram of preferred facies relationships (from difference matrix dij)



3) Stratigraphic interval II-3, drill hole F-2

a) Transitional count matrix (fij)

	Gm	St	Sr	Sh	Fl	Fm	Fr
Gm	0	1	0	0	0	0	0
St	0	0	3	1	1	1	0
Sr	0	1	0	0	0	2	0
Sh	0	0	0	0	0	1	0
Fl	0	0	0	0	0	11	0
Fm	1	3	0	0	9	0	3
Fr	0	0	0	0	1	2	0

b) Independent trials matrix (rij)

	Gm	St	Sr	Sh	Fl	Fm	Fr
Gm	.02	.12	.07	.02	.27	.42	.07
St	.03	.14	.09	.03	.31	.49	.09
Sr	.03	.13	.08	.03	.29	.45	.08
Sh	.02	.12	.07	.02	.27	.42	.07
Fl	.03	.17	.10	.03	.37	.57	.10
Fm	.04	.20	.12	.04	.44	.68	.12
Fr	.03	.13	.08	.03	.29	.45	.08

c) Transitional probability matrix (Pij)

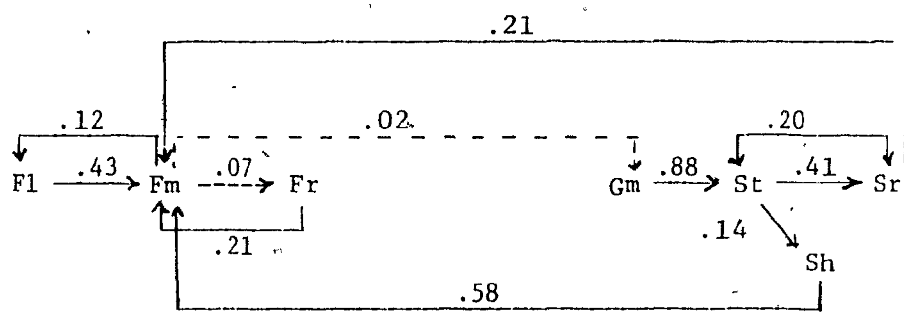
	Gm	St	Sr	Sh	Fl	Fm	Fr
Gm	0	1	0	0	0	0	0
St	0	0	.5	.17	.17	.17	0
Sr	0	.33	0	0	0	.66	0
Sh	0	0	0	0	0	1	0
Fl	0	0	0	0	0	1	0
Fm	.06	.19	0	0	.56	0	.19
Fr	0	0	0	0	.33	.66	0

d) Difference matrix (dij)

	Gm	St	Sr	Sh	Fl	Fm	Fr
Gm	-.02	.88	-.07	-.02	-.27	-.42	-.07
St	-.03	-.14	.41	.14	-.14	-.32	-.09
Sr	-.03	.20	-.08	-.03	-.29	.21	-.08
Sh	-.02	-.12	-.07	-.02	-.27	.58	-.07
Fl	-.03	-.17	-.10	-.03	-.37	.43	-.10
Fm	.02	-.01	-.12	-.04	.12	-.68	.07
Fr	-.03	-.13	-.08	-.03	.04	.21	-.08

e) Path diagram of preferred facies relationships

(from difference matrix dij)



LITHOLOGIES OF REPRESENTATIVE STRATIGRAPHIC INTERVALS

Percentages of different lithologies in representative stratigraphic intervals were calculated to facilitate interpretation of the Markov analysis and facies modelling.

1) Stratigraphic interval I-1

a) Drill hole F-2

73%	27%	conglomerate	41 m
	46%	sandstone - coarse	70.5 m
27%	23%	sandstone - fine	36 m
	4%	silt, mud and clay	4.5 m
			152 m

2) Stratigraphic interval I-2

a) Drill hole F-1 (incomplete)

12%	1%	conglomerate	3 m
	11%	coarse sandstone	23 m
88%	41%	fine sandstone	88 m
	47%	silt, mud and clay	101 m
			215 m

b) Drill hole F-2

13%	2%	conglomerate	6.5 m
	11%	coarse sand	31.5 m
87%	27%	fine sand	81 m
	60%	silt and clay	176 m
			295

3) Stratigraphic interval II-1

a) Drill hole F-1

74%	22%	conglomerate	57 m
	52%	coarse sandstone	135.5 m
26%	14%	fine sandstone	35.5 m
	12%	silt and clay	33 m
			261 m

b) Drill hole F-2

69%	27%	conglomerate	58 m
	42%	coarse sandstone	94 m
31%	21%	fine sandstone	46 m
	10%	silt and clay	23 m
			221 m

c) Drill hole F-3

88%	40%	conglomerate	96.5 m
	44%	coarse sand	107.5 m
16%	12%	fine sand	30 m
	4%	silt and clay	10 m
			244 m

4) Stratigraphic interval II-3

a) Drill hole F-1

12%	1%	conglomerate	1.5 m
	11%	coarse sand	9.5 m
88%	79%	very fine sand	70 m
	9%	clay and silt	8 m
			89 m

b) Drill hole F-13

21%	2%	conglomerate	2 m
	19%	coarse sands	17 m
79%	40%	very fine sands	36 m
	39%	clay and silt	35 m
			90 m

c) Drill hole F-2

12%	1%	conglomerate	1 m
	11%	coarse sand	9.5 m
88%	31%	very fine sand	26 m
	57%	clay and silt	48.5 m
			85 m

d) Drill hole F-5

15%	3%	conglomerate	2.5 m
	12%	coarse sand	10 m
85%	47%	very fine sand	40.5 m
	38%	clay and silt	32.5 m
			85.5 m

e) Drill hole F-6

1%	0%	conglomerate	0 m
	1%	coarse sand	1 m
99%	45%	very fine sand	38.5 m
	54%	clay and silt	46 m

f) Drill hole F-8

10%	1%	conglomerate	1 m
	9%	coarse sand	8 m
90%	19%	very fine sand	16.5 m
	71%	clay and silt	62 m
			87.5 m

g) Drill hole F-9

5%	0%	conglomerate	0 m
	5%	coarse sand	4.5 m
95%	13%	very fine sand	11 m
	82%	clay and silt	69.5 m
			85 m

h) Drill hole F-10

8%	1%	conglomerate	1 m
	7%	coarse sand	6 m
92%	58%	very fine sand	52 m
	34%	clay and silt	31 m
			90 m

i) Drill hole F-11

5%	1%	conglomerate	1 m
	4%	coarse sand	3 m
95%	16%	very fine sand	13 m
	79%	clay and silt	66 m
			83 m

j) Drill hole F-12

12%	7%	conglomerate	6 m
	5%	coarse sand	4 m
88%	28%	very fine sand	22.5 m
	60%	clay and silt	49 m
			81.5 m

k) Drill hole F-14	9.5%	6% conglomerate	5.5 m
		3.5% coarse sand	3 m
	90.5%	12% very fine sand	10 m
		78.5% clay and silt	67.5 m
			86 m
l) Drill hole F-15	8%	3% conglomerate	2.5 m
		5% coarse sand	4 m
	92%	18% very fine sand	14 m
		74% clay and silt	59.5 m
			80 m
m) Drill hole F-17	7%	2% conglomerate	2 m
		5% coarse sand	4.5 m
	93%	15% very fine sand	13 m
		77% silt and clay	66.5 m
			86 m
n) Drill hole F-18	6.5%	1% conglomerate	1 m
		5.5% coarse sand	5 m
	93.5%	16% very fine sand	15 m
		77.5% silt and clay	72.5 m
			93.5
o) Drill hole F-19	14%	7% conglomerate	6 m
		7% coarse sand	6 m
	86%	22% very fine sand	20 m
		64% clay and silt	57 m
			89 m

Average from all drill holes ± one standard deviation:

9.7 ± 5.4% conglomerate and sand

90.3 ± 4.9% very fine sand, clay and silt

APPENDIX B

GLOSSARY OF TERMS USED THROUGHOUT THE TEXT

The following is a glossary of the most important stratigraphic and depositional terms and how they have been used in the thesis text. The glossary is arranged in a hierarchal fashion.

A) Stratigraphic Terms:

- Stratigraphic Interval: informal terminology for a member, bed or formation defined by a distinctive stratigraphic horizon on upper and lower boundaries.

- Cycle: a sequence of related facies (interpreted in relation to depositional processes) repeated in the same order as recorded in the sedimentary deposit. Used in the thesis in this sense, large scale cycles are referred to as "megacycles", the smaller scale cycles as simply "cycles". Each cycle is made up of a lower succession and and upper succession.

- Succession: a number of rock units or a mass of strata that succeeds one another in chronological order. Used in the thesis in this sense to denote a 'succession' of characteristic strata that make up the lower parts of the cycles.

B) Depositional Terms:

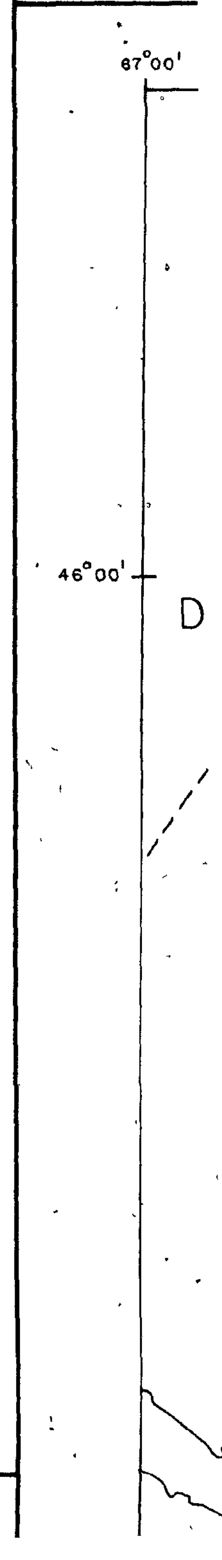
- Depositional System: a depositional system is made up of an association of genetically linked depositional environments inferred from an assemblage of lithofacies.

- Facies: aspect, nature or manifestation of character of rock strata. Used in the thesis as lithofacies characteristics. 'Megafacies' is used to denote a large scale genetically related sequence of facies.

- Sequence: a discrete collection of rock units deposited under related environmental conditions. Used in the thesis in the context of lithofacies description.

- Allocyclic: Controls on sedimentation which result in variations in discharge, load and slope, which originate externally from the sedimentary basin. These are ultimately tectonic or climatic causes.

- Autocyclic: Controls which are produced from hydrologic energy distribution within the sedimentary basin. Examples of these include crevassing, avulsion, chute and neck cutoff, etc.



LEGEND

PENNSYLVANIAN

PICTOU GROUP (lithofacies subdivision)

Unit	Description
III	Megacycle III
II-3	Megacycle II
II-2	
II-1	
I-2	Megacycle I
I-1	

Group	Unit	Description
RIVERSDALE GROUP	Ri	Basal quartz pebble conglomerate, grey sandstone, grey and red siltstone

MISSISSIPIAN

Group	Unit	Description
CANSO AND WINDSOR GROUP (may included older rocks)	Mv	Undifferentiated, predominantly mafic volcanic rocks
	Ms	Undifferentiated clastic sedimentary rocks and minor volcanics
HORTON GROUP (may include younger rocks)	P	PISKAHEGAN GROUP, felsic volcanic rocks
	H	HARVEY GROUP, minor clastic sediments, felsic tuffs and laminated rhyolite

14

Unit	Description
Di	Intrusive granite and granodiorite stocks Mainly Devonian in age but may include younger intrusives
Ss	Pre Carboniferous undifferentiated metasediments predominantly Silurian

- Geological contact, actual, interpreted or inferred
- Fault, interpreted or inferred
- F-2 ● Drill hole (with number)
- ✕ Outcrop (visited in study)
- + Bedding measurement (inclined, horizontal)

Scale 1: 100,000

Kms 0 2 4 6 8 10 12 Kms

Miles 0 2 4 6 8 Miles

STRUCTURE - SECTION ACROSS FREDERICTON GRABEN

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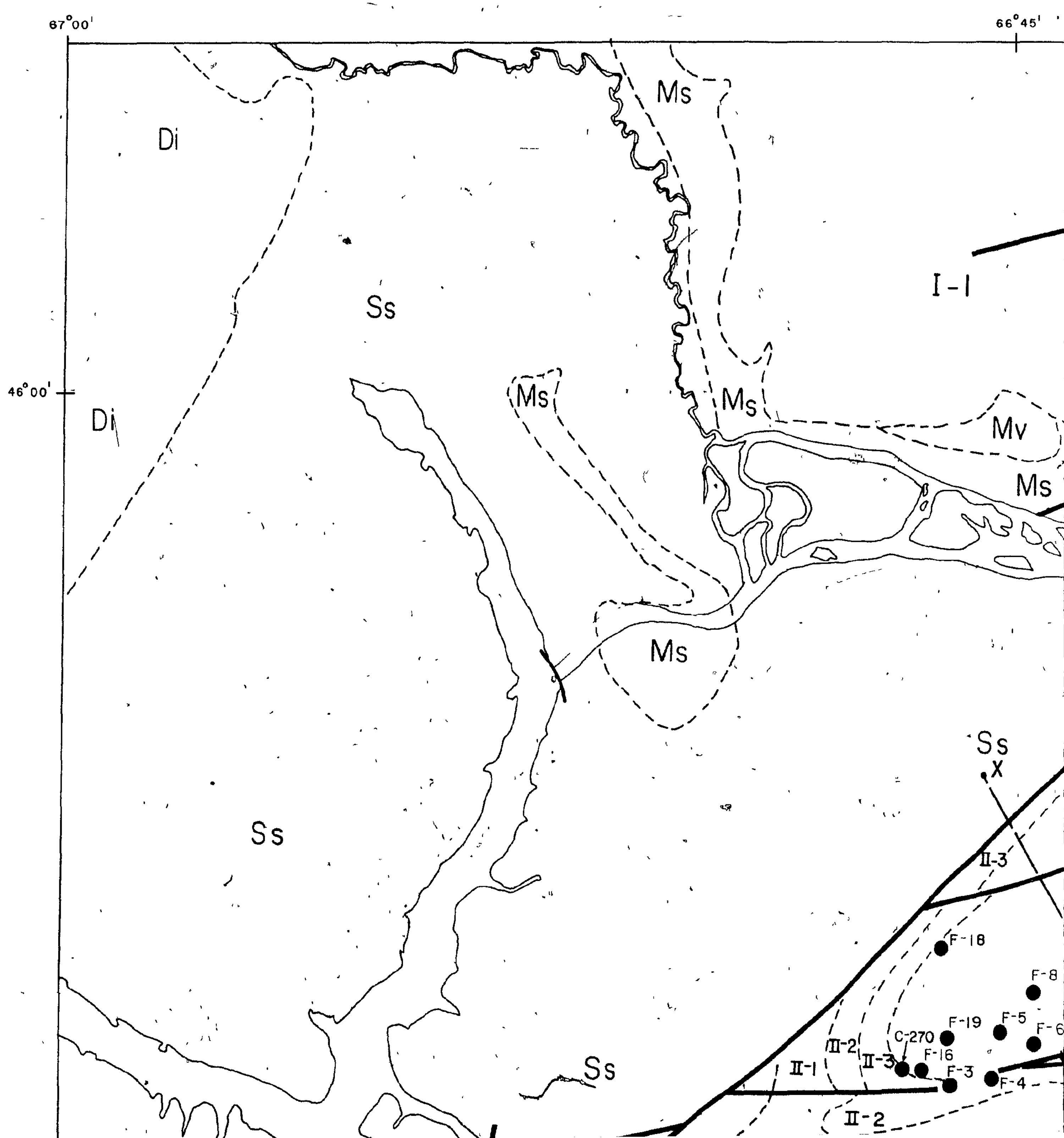

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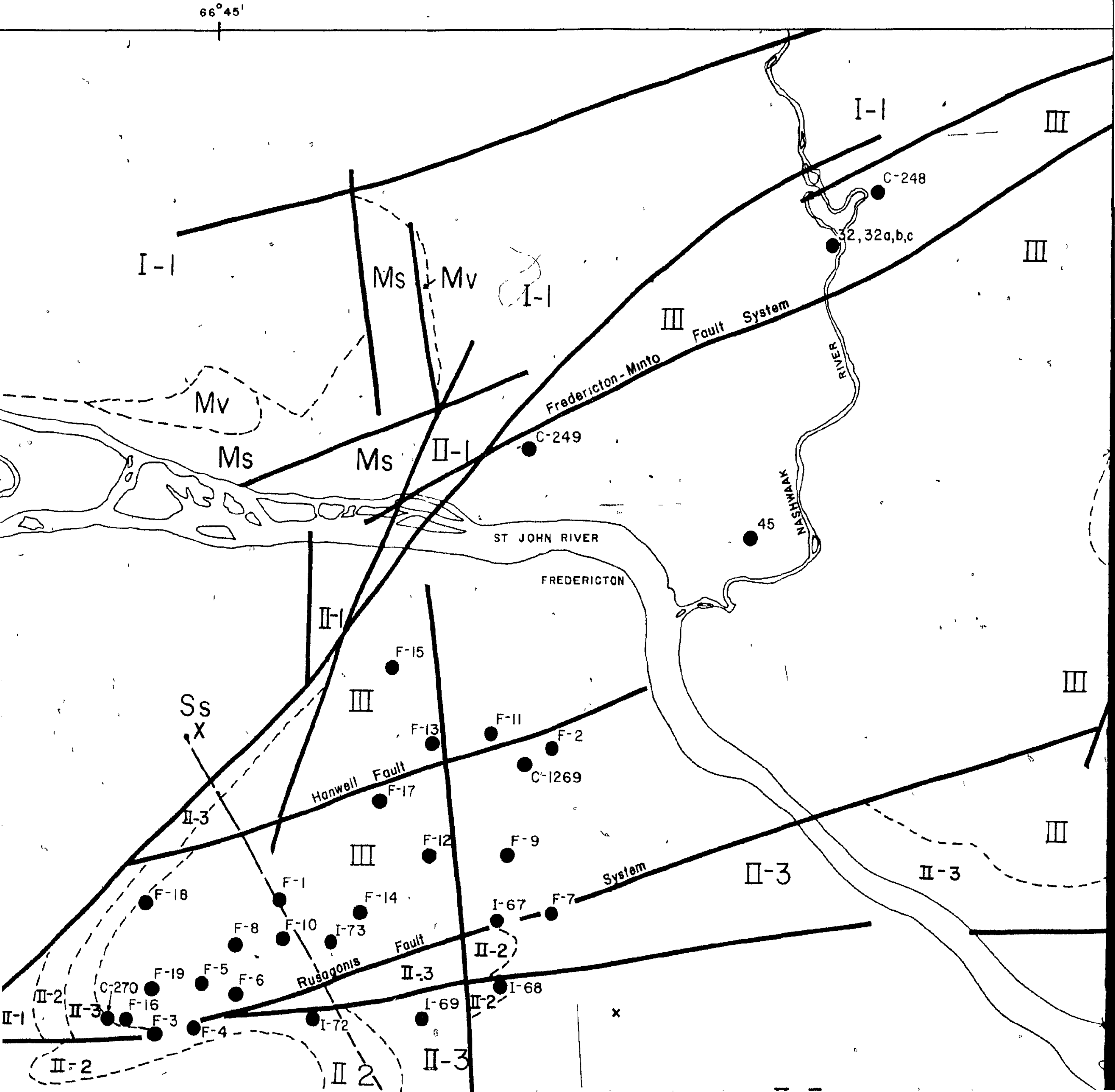

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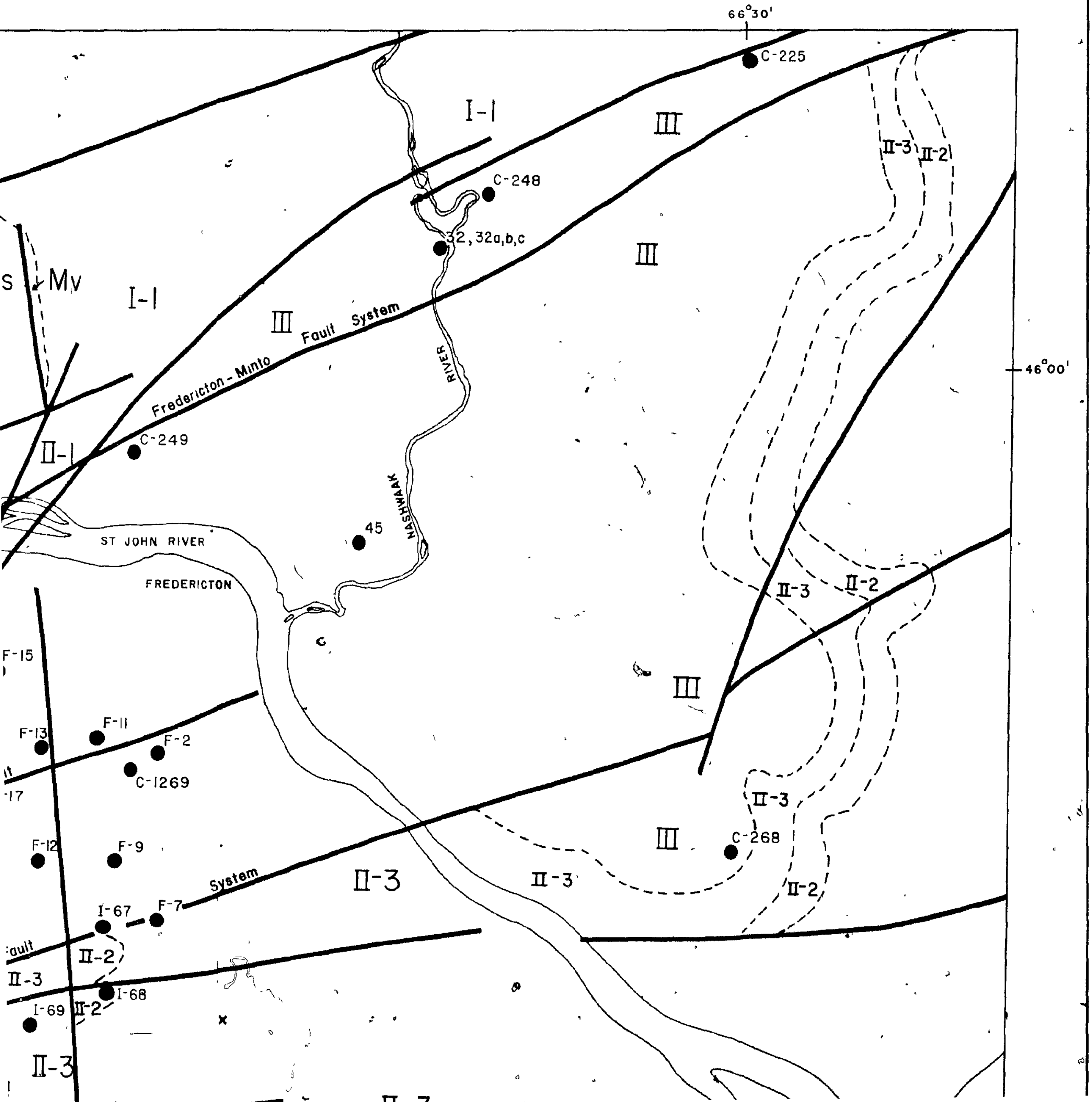

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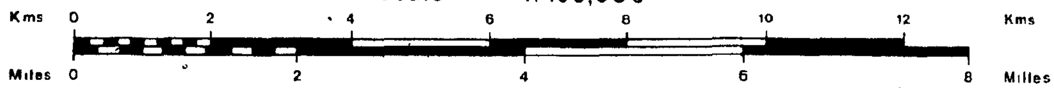

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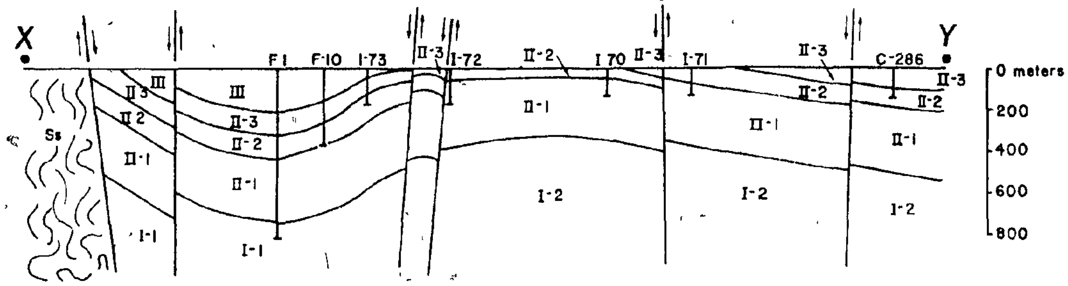

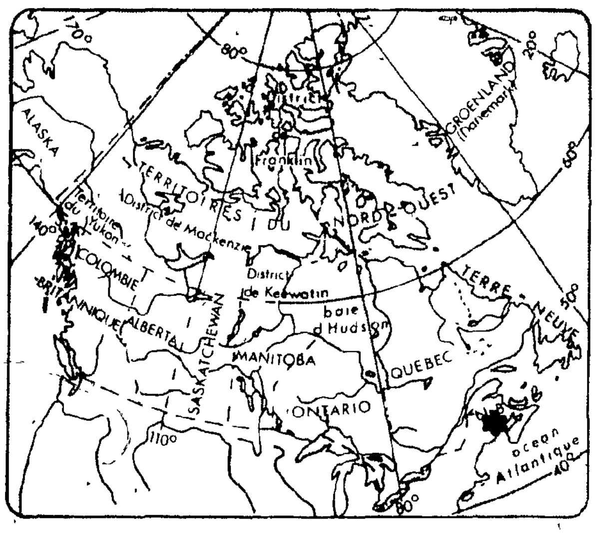

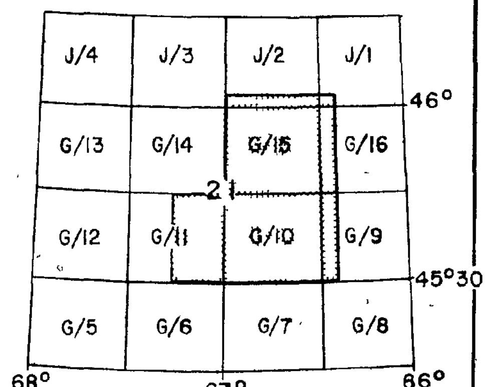

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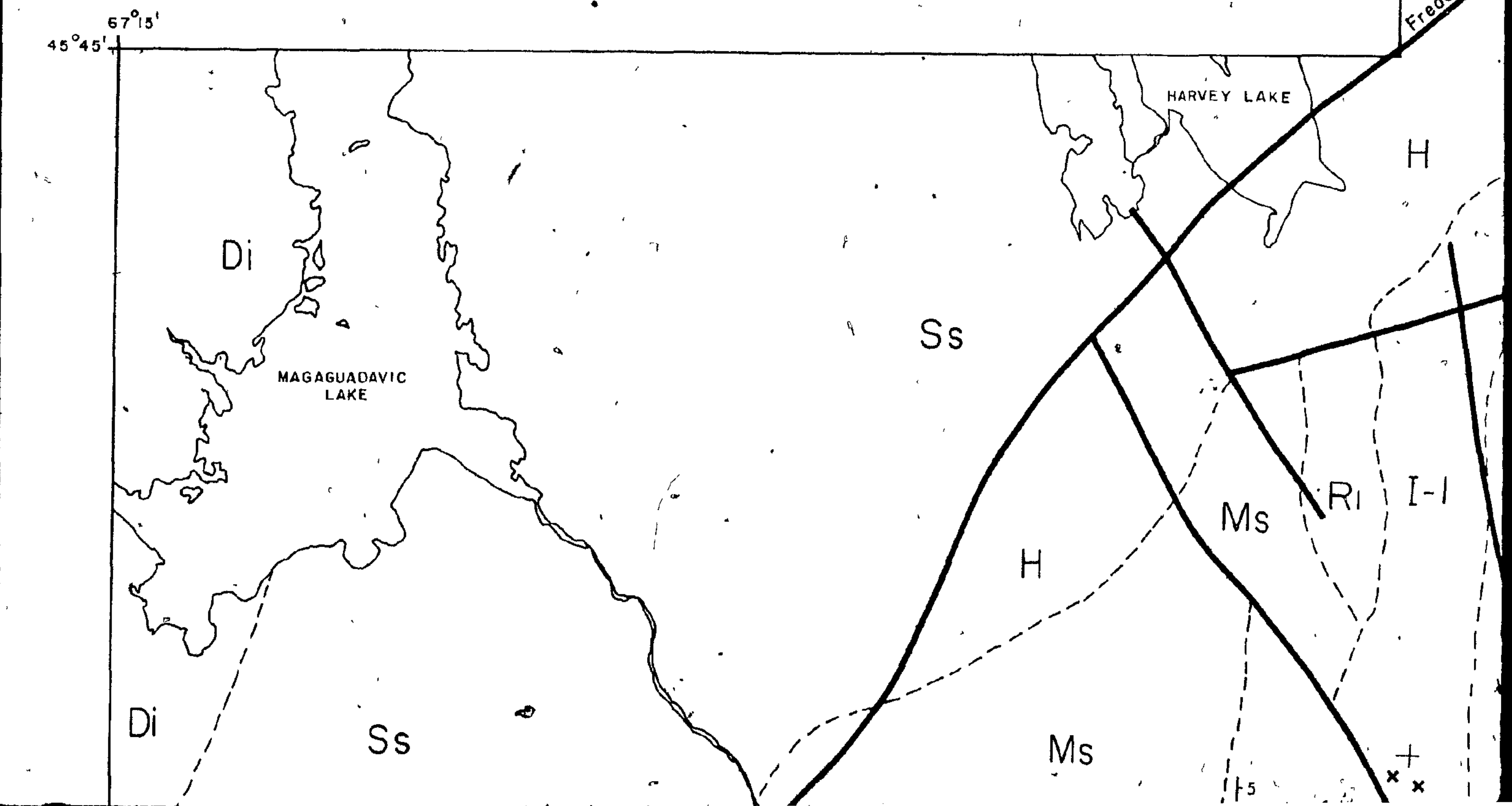

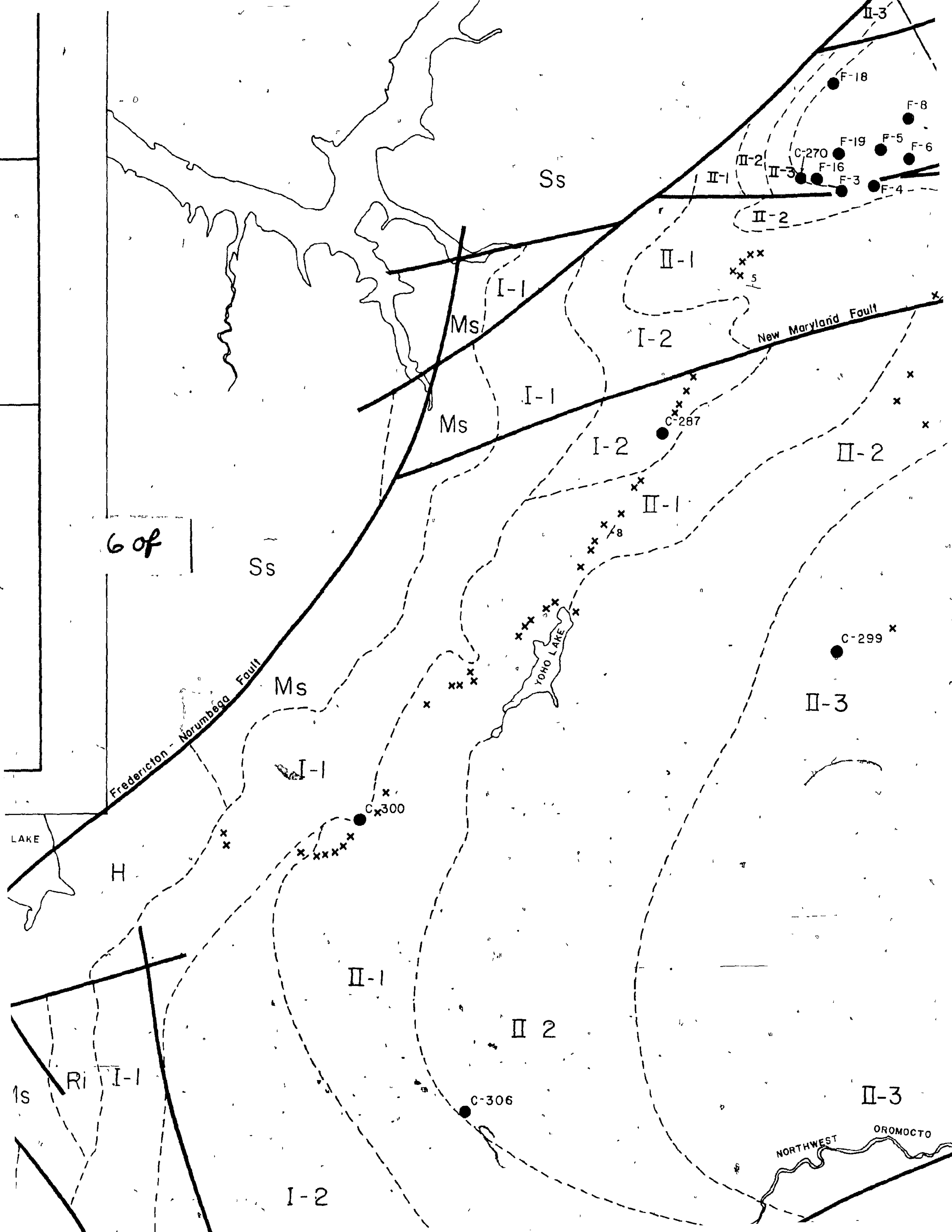

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Ss
Ms
I-1
I-2
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II-3
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F-19
F-5
F-6
C-270
F-16
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F-4
New Maryland Fault
C-287
Fredericton - Norumbega Fault
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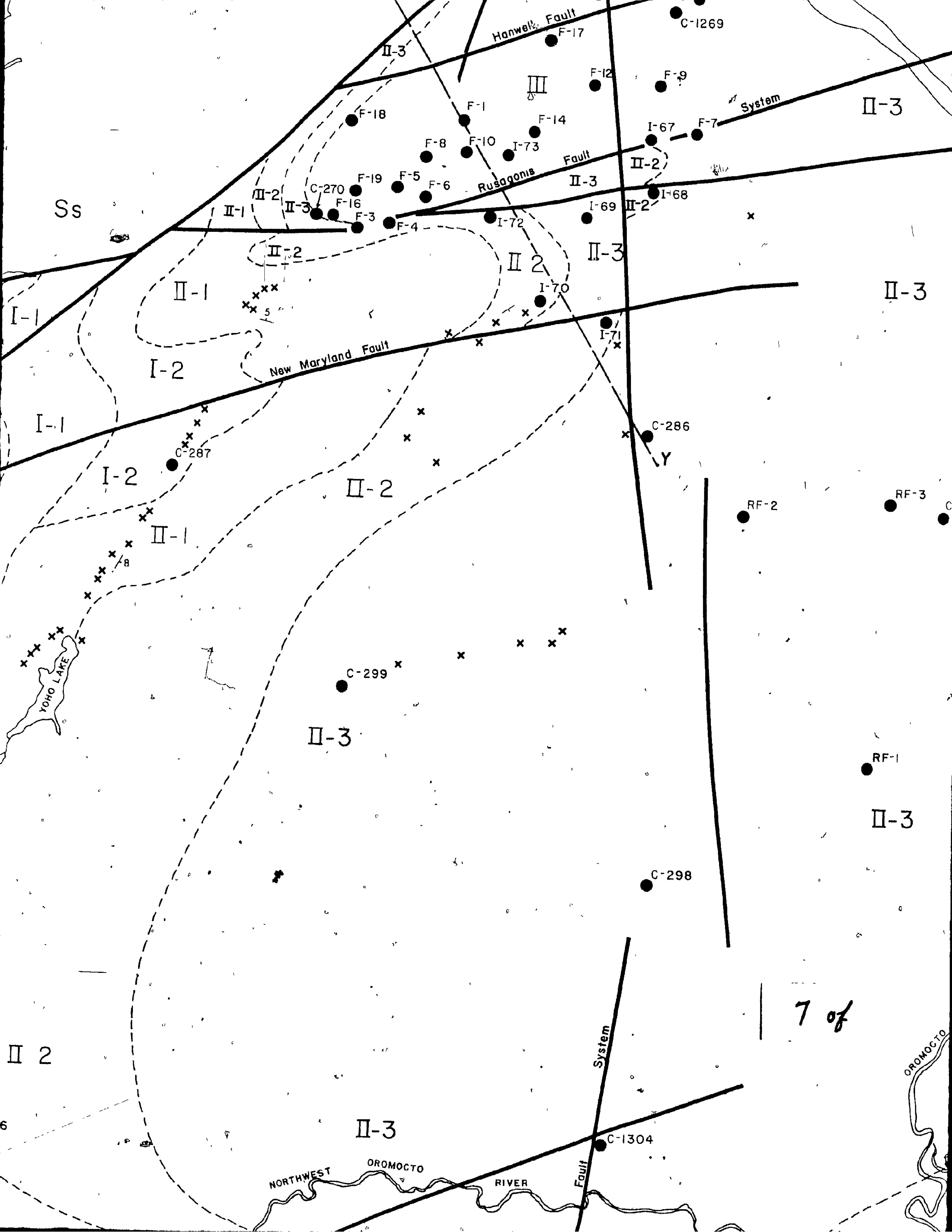
NORTHWEST
OROMOCTO



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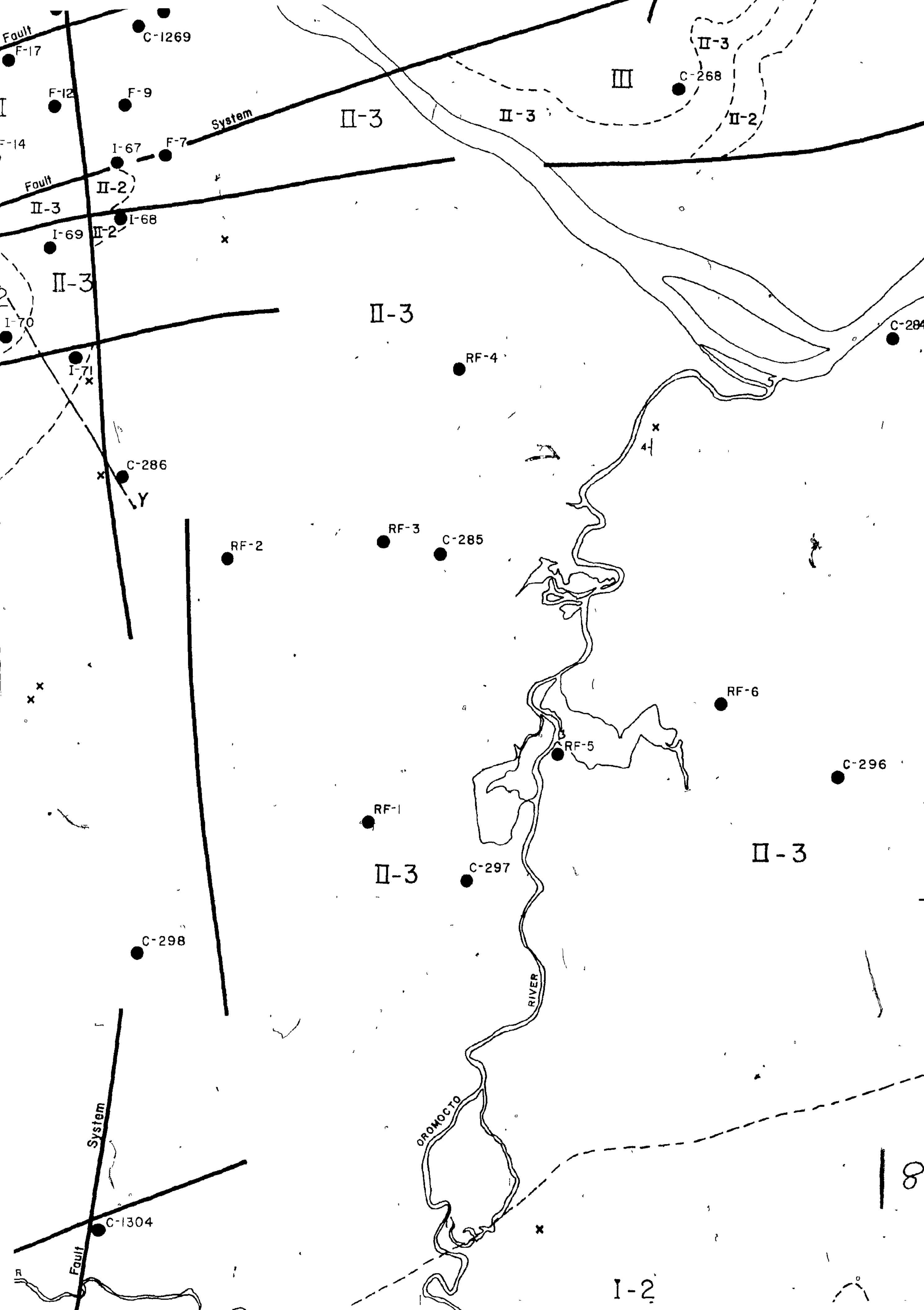
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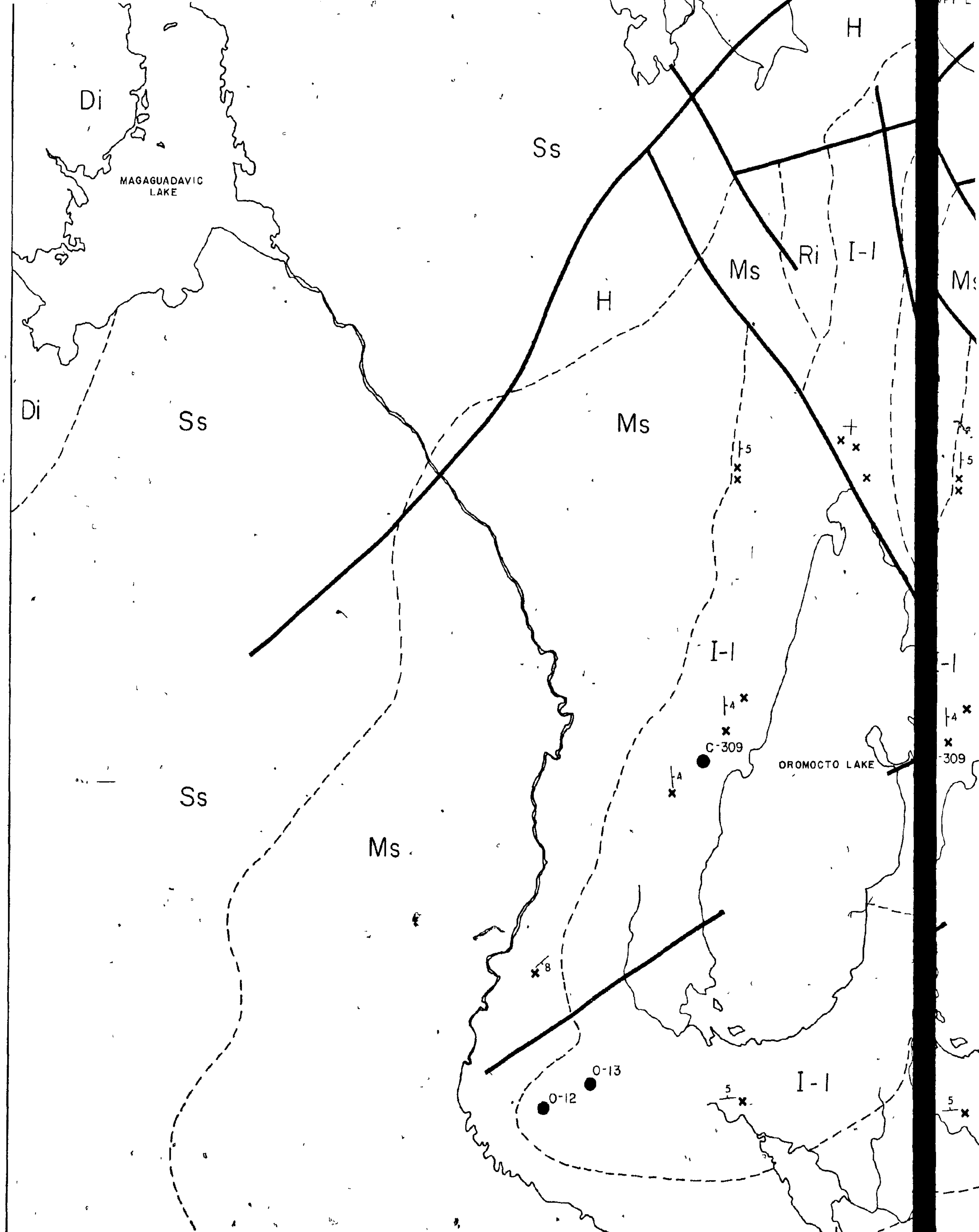
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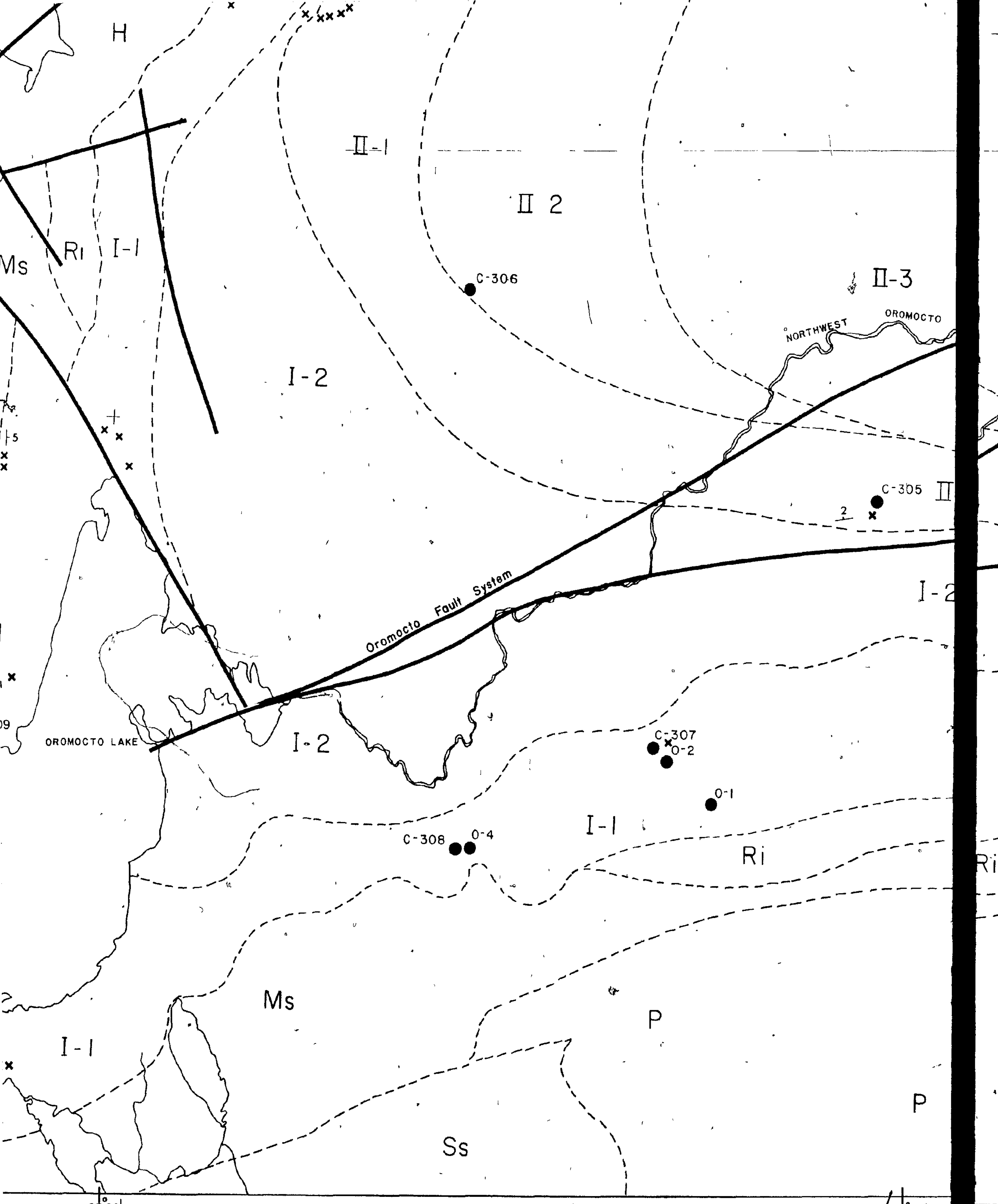
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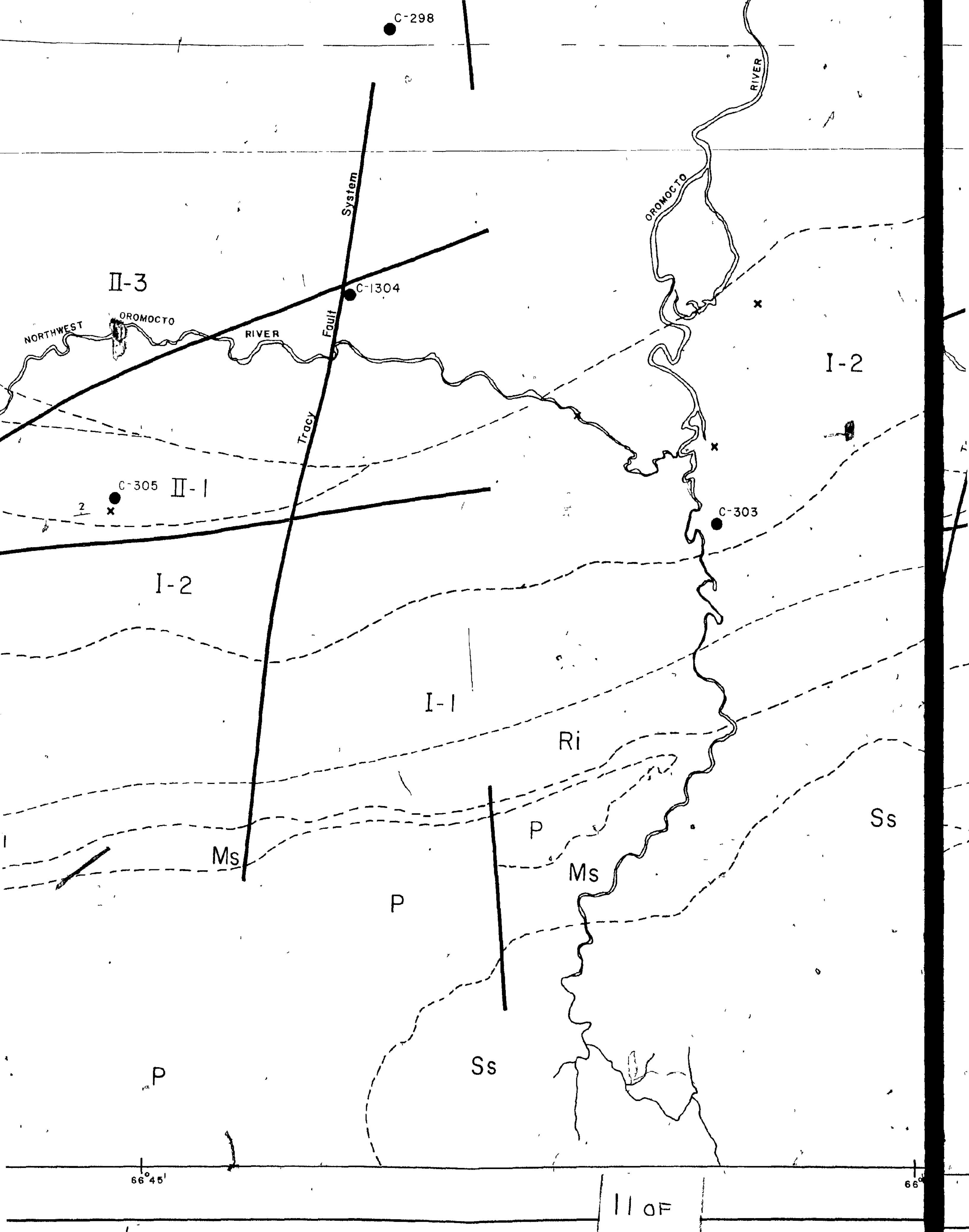
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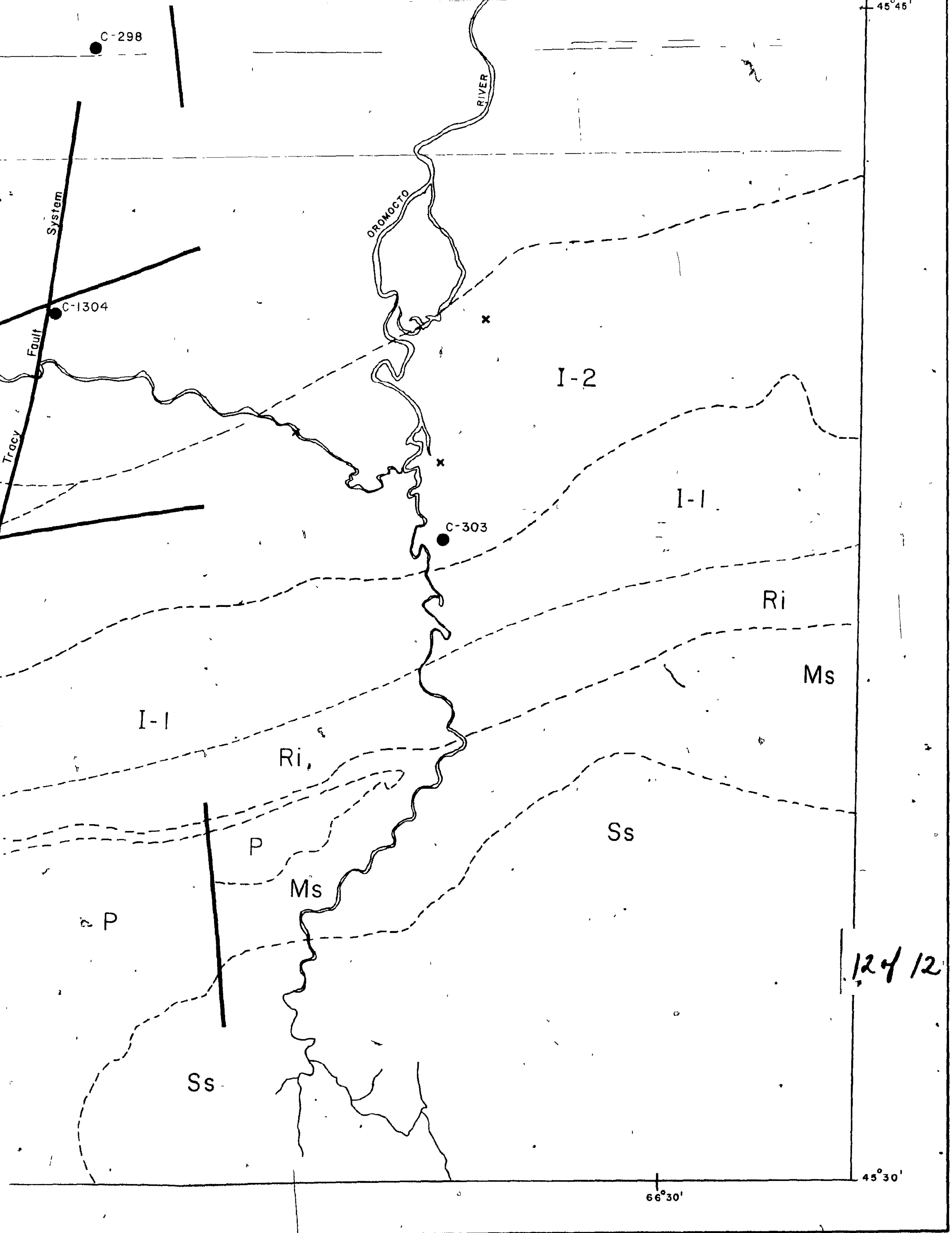

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