The University of Manitoba

DETAILED STRATIGRAPHY OF THE SLAVE POINT FORMATION IN THE NABESCHE RIVER AREA, NORTHEASTERN BRITISH COLUMBIA

by

Valdis Budrevics

A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfillment of the Requirements for the Degree of

Master of Science

Department of Earth Sciences

Winnipeg, Manitoba

1974

DETAILED STRATIGRAPHY OF THE SLAVE POINT FORMATION IN THE NABESCHE RIVER AREA, NORTHEASTERN BRITISH COLUMBIA

by

Valdis Budrevics

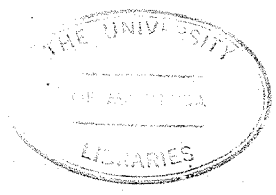
A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

© 1974

Permission has been granted to the LIBRARY OF THE UNIVERSITY OF MANITOBA to lend or sell copies of this dissertation, to the NATIONAL LIBRARY OF CANADA to microfilm this dissertation and to lend or sell copies of the film, and UNIVERSITY MICROFILMS to publish an abstract of this dissertation.

The author reserves other publication rights, and neither the dissertation nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.



ABSTRACT

The Middle Devonian Slave Point Formation was recently identified in the northern Rocky Mountains, but no detailed stratigraphical analysis of the formation has been published. The purpose of this study is to describe and interpret the detailed stratigraphy of the Slave Point Formation in the Nabesche River area. A secondary objective is to determine the relationship between sphalerite mineralization and rock type.

The Slave Point Formation generally consists of dark grey to black, argillaceous, fossiliferous, lime mudstones, wackestones and packstones. The most abundant fossils in the section are stromatoporoids and brachiopods. On the basis of lithology the formation may be subdivided into four informal members: a Lower Mudstone member, a Reefal member, a Nodular member, and an Upper Mudstone member.

The depositional environment of the formation in the Nabesche River area is interpreted to have been a subsiding carbonate platform margin. The rock sequence within the Slave Point Formation is representative of a marine transgression. Both the upper and lower contacts were found to be gradational and interpreted to be conformable.

Diagenetic alteration of the rocks has occurred in the form of dolomitization, silicification, and cementation by several generations of calcite and dolomite. Sphalerite mineralization is closely associated with Presqu'ile type dolomite and bladed quartz. The distribution of the

mineralization shows that the dolomitized mudstone facies and especially the dolomitized crinoid-bearing mudstone facies of the Reefal member were the most favourable locations for sphalerite mineralization.

TABLE OF CONTENTS

PAGE

LIST OF FIGURES.....i

LIST OF PLATES.....ii

LIST OF TABLES.....iii

CHAPTER ONE - INTRODUCTION.....1

Introduction.....1

Objectives of the Study.....1

Previous Work.....3

Methods.....4

Acknowledgements.....6

CHAPTER TWO - GENERAL GEOLOGY.....7

Structural Geology.....7

Structural Style of the Northern Rocky Mountains.....7

Structural Geology of the Nabesche River Area.....7

Faults.....8

Folds.....8

The Middle Devonian Geological History: A Synopsis.....9

The Middle Devonian Stratigraphy of the Nabesche River Area.....19

CHAPTER THREE - GEOLOGY OF THE SLAVE POINT FORMATION IN THE NABESCHE RIVER AREA.....24

Introduction.....24

General Geology.....25

Distribution in Northeastern British Columbia.....25

Regional Lithofacies.....25

PAGE

Regional Correlation.....26

Thickness of the Slave Point Formation in the Nabesche River Area.....28

Contacts.....29

Regional Interpretation of the Upper Contact of the Slave Point Formation.....29

Contacts of the Slave Point Formation in the Nabesche River Area.....30

Local Stratigraphy.....32

Introduction.....32

Lower Mudstone Member.....33

Lithological Description.....33

Contacts.....38

Environmental Interpretation.....38

Reefal Member.....39

Lithological Description.....39

Crinoid-Bearing Mudstone Facies.....40

Lamellar Stromatoporoid Facies.....41

Branching Stromatoporoid Facies.....43

Massive Stromatoporoid Facies.....44

Tabulate Coral Facies.....44

Contacts.....45

Biofacies Distribution.....46

Environmental Interpretation.....53

Discussion.....55

Nodular Member.....62

Lithological Description.....62

Nodules.....62

PAGE

Matrix.....64

Allochems.....65

Contacts.....67

Environmental Interpretation.....67

The Origin of the Nodular Fabric.....68

Upper Mudstone Member.....72

Lithological Description.....72

Contacts.....73

Environmental Interpretation.....73

Geological History.....74

Summary of the Geology of the Slave Point Formation in the Nabesche River Area.....75

CHAPTER FOUR - DIAGENESIS AND MINERALIZATION IN THE SLAVE POINT FORMATION.....78

Dolomitization.....78

Cementation.....81

Silicification.....83

Authigenic Quartz Crystals.....83

Bladed Quartz.....84

Aggregates of Subhedral Quartz Crystals.....84

Breccia.....85

Pseudobreccia.....86

Porosity.....88

Mineralization.....88

Mode of Occurrence.....89

Distribution and Relationship to Rock Type....91

Origin of the Sphalerite Mineralization.....91

Summary of the Diagenetic History.....95

PAGE

CHAPTER FIVE - SUMMARY AND CONCLUSIONS.....97

Summary.....97

Conclusions.....98

REFERENCES.....100

APPENDIX 1

Staining Method.....119

APPENDIX 2

Insoluble Residue.....121

APPENDIX 3

Detailed Drill Logs.....130

APPENDIX 4

Measured Outcrop Sections.....163

LIST OF FIGURES

PAGE

Figure 1. Location map of the Nabesche River area....2

Figure 2. Surface geology map of the thesis area...in pocket

Figure 3. Diamond drill hole location plan.....5

Figure 4. Index map for the Middle Devonian correlation chart.....10

Figure 5. Middle Devonian geotectonic correlation chart for Western Canada.....11

Figure 6. Lower Devonian (Emsian) sedimentary facies distribution map.....13

Figure 7. Middle Devonian (Eifelian) sedimentary facies distribution map.....15

Figure 8. Middle Devonian (Givetian) sedimentary facies distribution map.....16

Figure 9. Upper Devonian (Frasnian) sedimentary facies distribution.....17

Figure 10. Summary of the Middle Devonian stratigraphy in the Nabesche River area.....21

Figure 11. Informal subdivision of the Slave Point Formation.....34

Figure 12. Composite total isopach map of the Lower Mudstone and Reefal members in the drilled area.....47

Figure 13. A fence diagram illustrating the distribution of biofacies in the Reefal member of the Slave Point Formation in the drilled area - Nabesche River area...in pocket

Figure 14. The vertical zonation of biofacies in the Reefal member.....48

Figure 15. Legend of the biofacies of the Reefal member.....49

Figure 16. Areal distribution of biofacies at 5 and 10 foot levels.....50

PAGE

Figure 17. Areal distribution of biofacies at the 15 and 20 foot levels.....51

Figure 18. Areal distribution of biofacies at the 25 and 30 foot level.....52

Figure 19. Energy - Biofacies relationships in the Niagran Reefs in the Great Lakes area.....56

Figure 20. Composition of the principal faunal communities and their interpreted environments. Middle Devonian carbonate shelf in the South Nahanni River area NWT.58

Figure 21. Hypothetical depositional facies distribution in the Slave Point sea - Nabesche River area.....60

Figure 22. Fence diagram showing stratigraphy of the Slave Point Formation in the drilled area - Nabesche River area.....79

Figure 23. Distribution of insoluble residue - Section A.....126

Figure 24. Distribution of insoluble residue - Section B.....127

Figure 25. Distribution of insoluble residue - Section C.....128

Figure 26. Distribution of insoluble residue - Section N.....129

Figure 27. Trend surfaces of insoluble residue data.....in pocket

LIST OF PLATES

page

Plate 1. The gradational nature of the contact between the Watt Mountain Formation and the Lower Mudstone member of the Slave Point Formation.....106

Plate 2. An illustration of auloporid corals found in the Reefal member.....107

Plate 3. Lamellar stromatoporoid wackestone fabrics of the Reefal member.....108

Plate 4. Some rock fabrics found in the Slave Point Formation.....109

Plate 5. Branching stromatoporoid facies of the Reefal member.....110

Plate 6. Representative fabrics of the Nodular member.....111

Plate 7. Representative fabrics of the Nodular member in thin section.....112

Plate 8. Macrodolomite fabrics.....113

Plate 9. The relationship of bladed quartz and sphalerite mineralization.....114

Plate 10. The silicification of dolomite.....115

Plate 11. Pseudobreccia fabrics.....116

Plate 12. Sphalerite mineralization in thin section.....117

Plate 13. Sphalerite mineralization in surface samples from crinoid-bearing mudstone facies of the Reefal member.....118

LIST OF TABLES

page

Table 1. The distribution of Insoluble Residue.....124

CHAPTER ONE - INTRODUCTION

Introduction

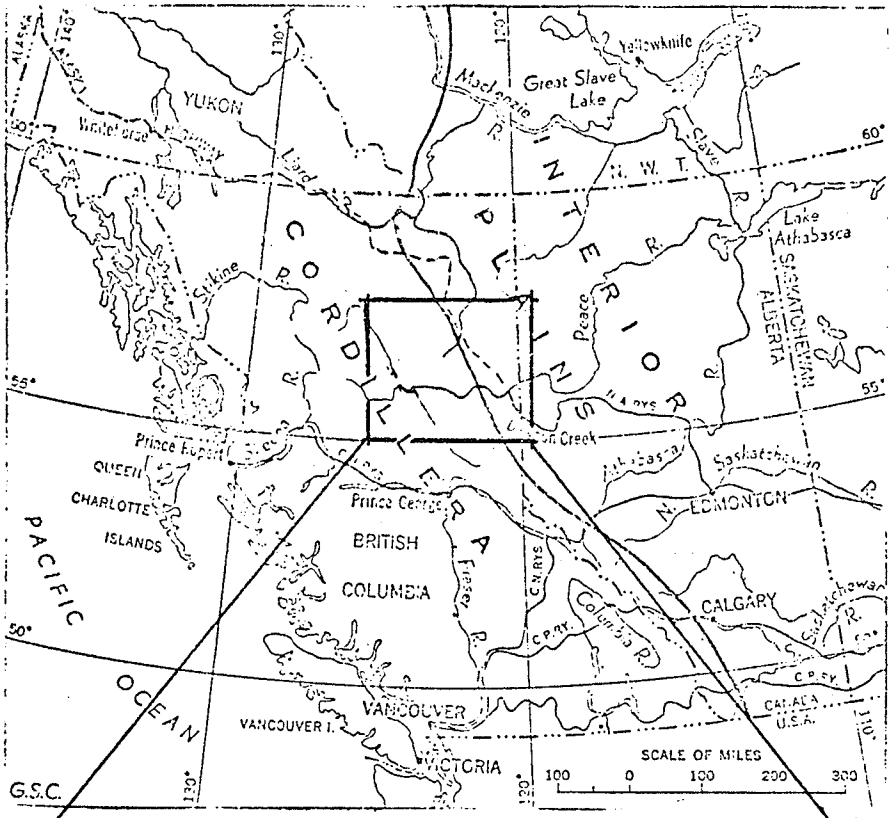
Only recently have the rocks within the disturbed belt of the Rocky Mountains been mapped beyond a cursory examination and subdivided into formations. This mapping was necessary because many of the rocks within the region have mineral economic potential. The majority of the regional mapping is being done by the Geological Survey of Canada, but many geological reports are being completed by mining companies with interests in the area. These reports should be available in the British Columbia Department of Mines and Petroleum Resources assessment files. The present study stems from a detailed study conducted by Cominco Limited. The area was mapped during the summer season of 1973 by the author while employed by Cominco Limited.

The study area lies near the West Nabesche River in northeastern British Columbia, approximately 100 miles north of the town of Mackenzie (Figure 1). The coordinates of the area are latitude 56°15'-18' N, and longitude 123° 24'-28' W. The area is in alpine country at an elevation of 5000-7000 feet and is generally underlain by good outcrop exposure.

Objectives of the Study

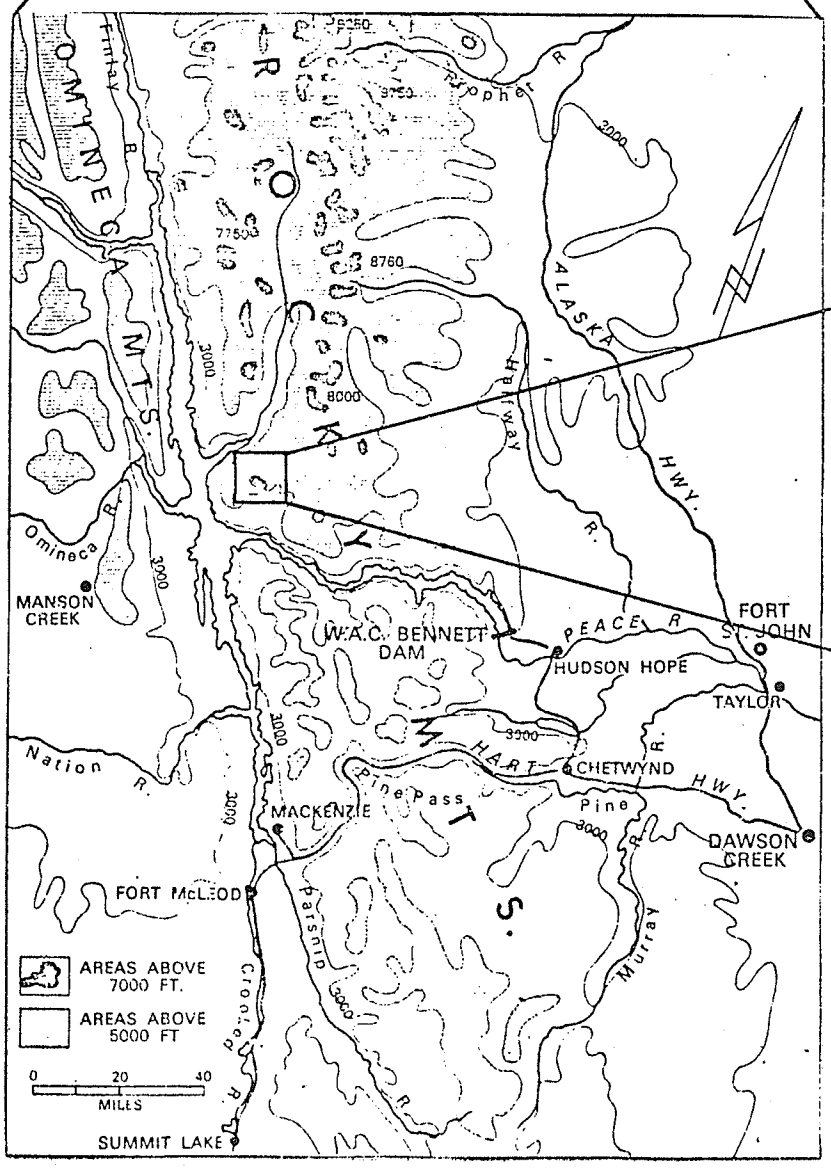
The objectives of this thesis are to describe in detail the stratigraphy of the Slave Point Formation, interpret the environment of deposition and to determine the relationship

FIGURE 1



LOCATION MAP OF THE NABESCHE RIVER AREA

SEE SURFACE GEOLOGY MAP



between host rock type and sphalerite mineralization present.

New data presented here might shed some light on the problem of the delineation of the Slave Point Formation within the northern Rocky Mountains. As part of a regional geological study in the southwestern part of the Halfway River area, Macqueen and Taylor (1974) noted that the stratigraphic limits of the Slave Point Formation both vertically and horizontally were difficult to recognize. Their mapping showed that the Slave Point Formation grades upwards and laterally into shale of the Besa River Formation.

Previous Work

One of the earliest traverses through the area was made by Kidd (1963). He described the Middle Devonian carbonates very briefly, because his main interest was the overlying Besa River Formation. Fitzgerald and Braun (1965) examined the folding within the Besa River Formation and also noted the presence of the underlying undeformed carbonate outcrops. During the sixties and early seventies the Geological Survey of Canada began a comprehensive study of the Devonian outcrops in northeastern British Columbia. Taylor (1969), Taylor and Bamber (1970), Taylor and MacKenzie (1970) and Irish (1970) mapped the outcrops within and near the thesis area as part of larger regional studies. Macqueen and Taylor (1974) conducted the most recent Geological Survey of Canada mapping in the area.

M e t h o d s

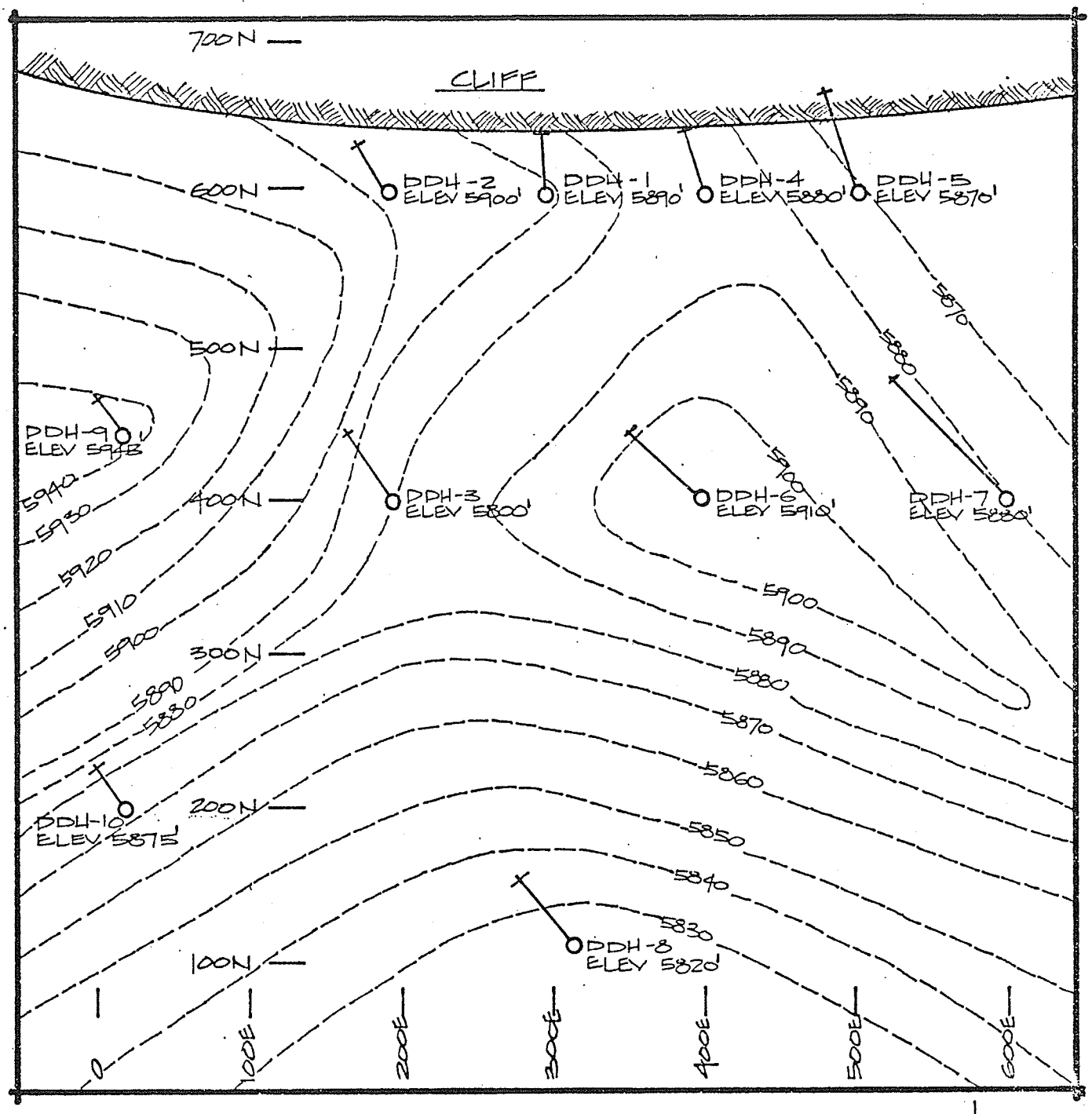
The field mapping consisted of measuring the outcrops on two east-west trending ridges that transected the study area. The measured sections are presented in Appendix 4. A drilling target was delineated within the Slave Point Formation on the southern ridge (Figure 2). Within the outlined area (Figure 3) ten AQ drill holes were completed. The recovered one inch diameter core was studied in detail. The core from one drill hole located approximately 4 miles to the north of the study area was also examined. Primarily the core and to a lesser degree the outcrop data provide the basis for this study. For detailed core descriptions see Appendix 3.

The samples were slabbed and examined under a binocular microscope. In many cases the slabs were etched in dilute HCL and stained by a potassium ferricyanide and alizarin red S solution to determine the composition of the rock. For details of the staining method used see Appendix 1.

Some samples were thin sectioned and studied under a petrographic microscope. Selected thin sections were stained to provide more detailed information about the composition of the rock.

For the purposes of insoluble residue studies part of the sample was ground up and digested in dilute HCl. For details of the method used see Appendix 2. A few insoluble residues were subjected to X-ray diffraction analysis to identify mineral composition.

FIGURE 3



NABESCHE RIVER AREA

DIAMOND DRILL HOLE LOCATION PLAN

TOPOGRAPHIC CONTOUR INTERVAL - 10'
SCALE - 1" = 100'

To help interpret the results of the insoluble residue study the data were statistically analysed to produce trend surfaces. A computer program, available in the Department of Earth Sciences, was used to calculate the surfaces (Figure 27).

A c k n o w l e d g e m e n t s

I am greatly indebted to Dr. R.S. Harrison for supervision of this thesis and his many helpful suggestions. Thanks are also extended to Dr. P.C. van de Kamp (University of Manitoba) and to Dr. R.W. Macqueen (Geological Survey of Canada) for critical reading of the manuscript. I am grateful for advice and material furnished by Cominco Limited, without whose permission this study would not have been possible. I also wish to thank Arnis Budrevics for drafting the illustrations and developing the plates. Finally, I would like to especially thank my wife, Dace, for typing the manuscript and for her encouragement and understanding during the writing of this thesis.

CHAPTER TWO - GENERAL GEOLOGY

S t r u c t u r a l G e o l o g y

Structural Style of the Northern Rocky Mountains

Taylor and Stott (1973) have formulated the most recent comprehensive model for the structure of the northern Rocky Mountains on basis of their work in the Tuchodi Lakes area. They proposed that folding and faulting were concurrent and both were equally responsible for total crustal shortening.

The idea of geological packets was developed by Taylor and Stott (1973). Each packet consists of its own type of lithology and its own characteristic style of deformation. The packets are separated from each other by detachment surfaces. Five separate structural packets were outlined: two in the Rocky Mountains, two in the Foothills and one in the Plains. The general age of the rock comprising the packets becomes younger from west to east.

The Nabesche River area falls within Taylor and Stott's (1973) second structural packet. This unit consists of Silurian and Devonian carbonates. It is characterized by large, long wavelength folds and bedding plane thrust faults that have their origin in the detachment zone at the base of the Nonda Formation and disappear into the detachment zone at the base of the Besa River Formation.

Structural Geology of the Nabesche River Area

Irish (1970) mapped the structural geology of the area as part of the Halfway River area. Major folds and subparallel

thrust faults trend northwest, commonly about N25°W. Near the Nabesche River all major folds plunge south or southeast. The surfaces of thrust faults dip west.

Faults

Irish (1970) noted that the main structures evident in the area are large, westward dipping, bedding plane thrust faults, that moved blocks relatively to the northeast. Displacements along these faults vary from tens to thousands of feet. The two major thrust faults cutting the area are the Nabesche Fault and the Mount Burden Fault. Both are folded by the most striking feature in the area, the Bernard Anticline.

The Nabesche Fault follows the west limb of the Bernard Anticline, characteristically changing dip along strike. The fault starts to curve, but is not continuous around the nose of the fold, but ends in a recumbent anticline.

The Mount Burden Fault lies to the west of the Nabesche Fault and essentially parallels it. The fault has a relatively steep dip to the west.

Folds

The Bernard Anticline is the most outstanding structure of the area. Irish (1970) found that the anticline is 4 to 6 miles wide and forms a northwest-southeast trend for 45 miles. South of the Nabesche River the fold plunges southward less than 10°, but south of Mount Burden it becomes obscured

by thrust faulting. The fold is broad, flat topped and asymetrical. The west limb dips toward the west at small angles but increases steeply approaching the axis of the fold. On the east limb dips increase to 65° and then abruptly to 75° - 80°.

The thesis area lies within a thrust sheet bound by the Nabesche Fault to the north and the Mount Burden Fault to the south. With respect to the Bernard Anticline it lies on the southeast side of the nose.

The attitude of beds varied between 36°/16° SE to 26/29° SE with most beds at 36/23° SE (Figure 2). The variance in the dip probably indicates the distance from the axis of the Bernard Anticline. Lower dip angles are near the hinge line while high angles are found on the limbs away from the axis.

The Middle Devonian Geological History: A Synopsis

Many authors have published detailed accounts of the evolution of the Western Canadian Sedimentary Basin. Notable studies include those of Douglas et al (1970), Monger et al (1972), Gabriesle and Wheeler (1961), Gabriesle (1967) and Griffin (1967). Grayston et al (1965) and Belyea (1971) wrote specifically about the Middle Devonian tectonic history of the basin. A brief compilation of the Middle Devonian geological history is presented here to set a regional framework for this study. The regional Middle Devonian stratigraphy is summarized in Figures 4, 5.

During the early Paleozoic, clastic and carbonate

FIGURE 4

INDEX MAP - MIDDLE DEVONIAN CORRELATION CHART OF WESTERN CANADA

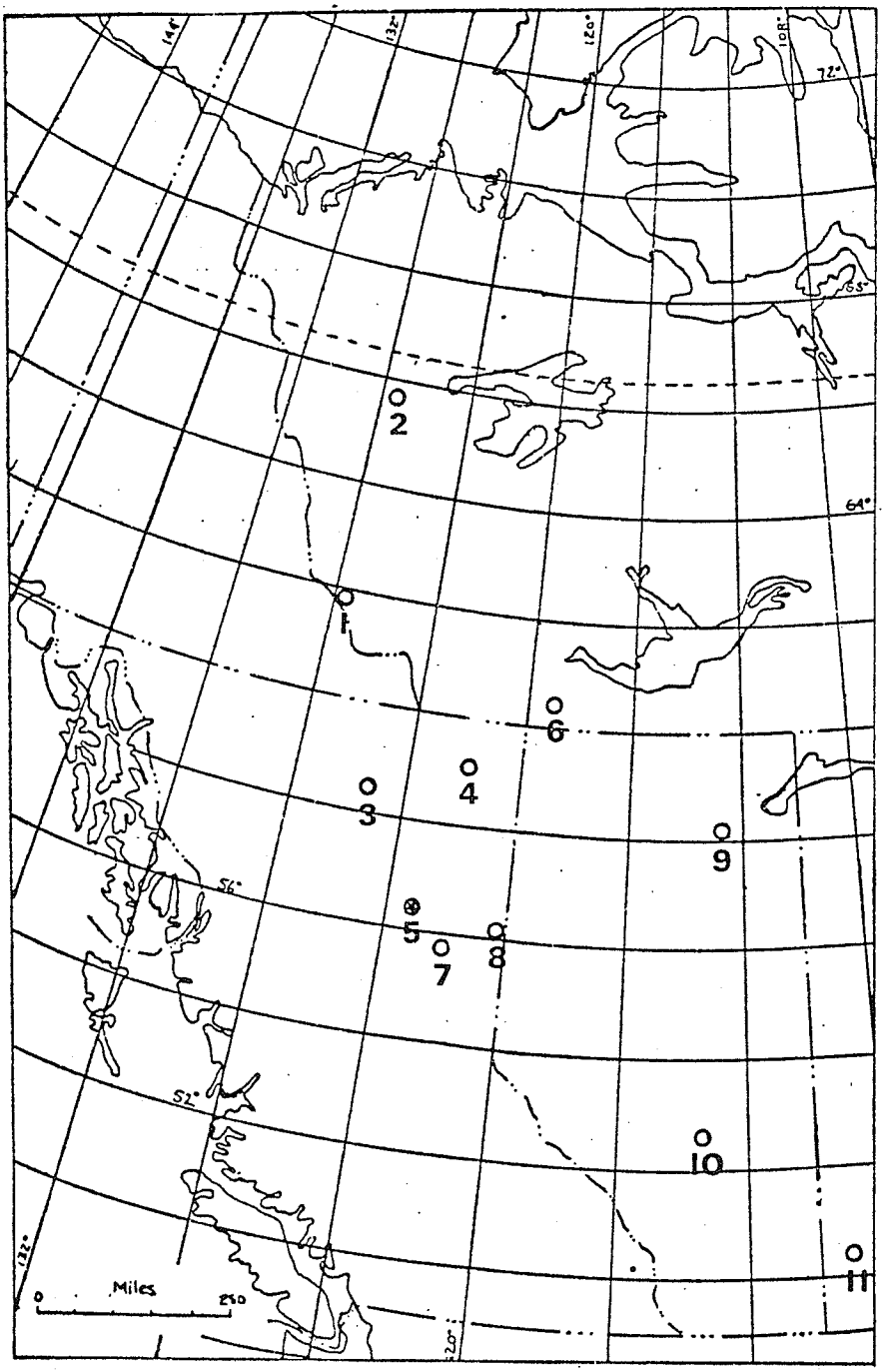
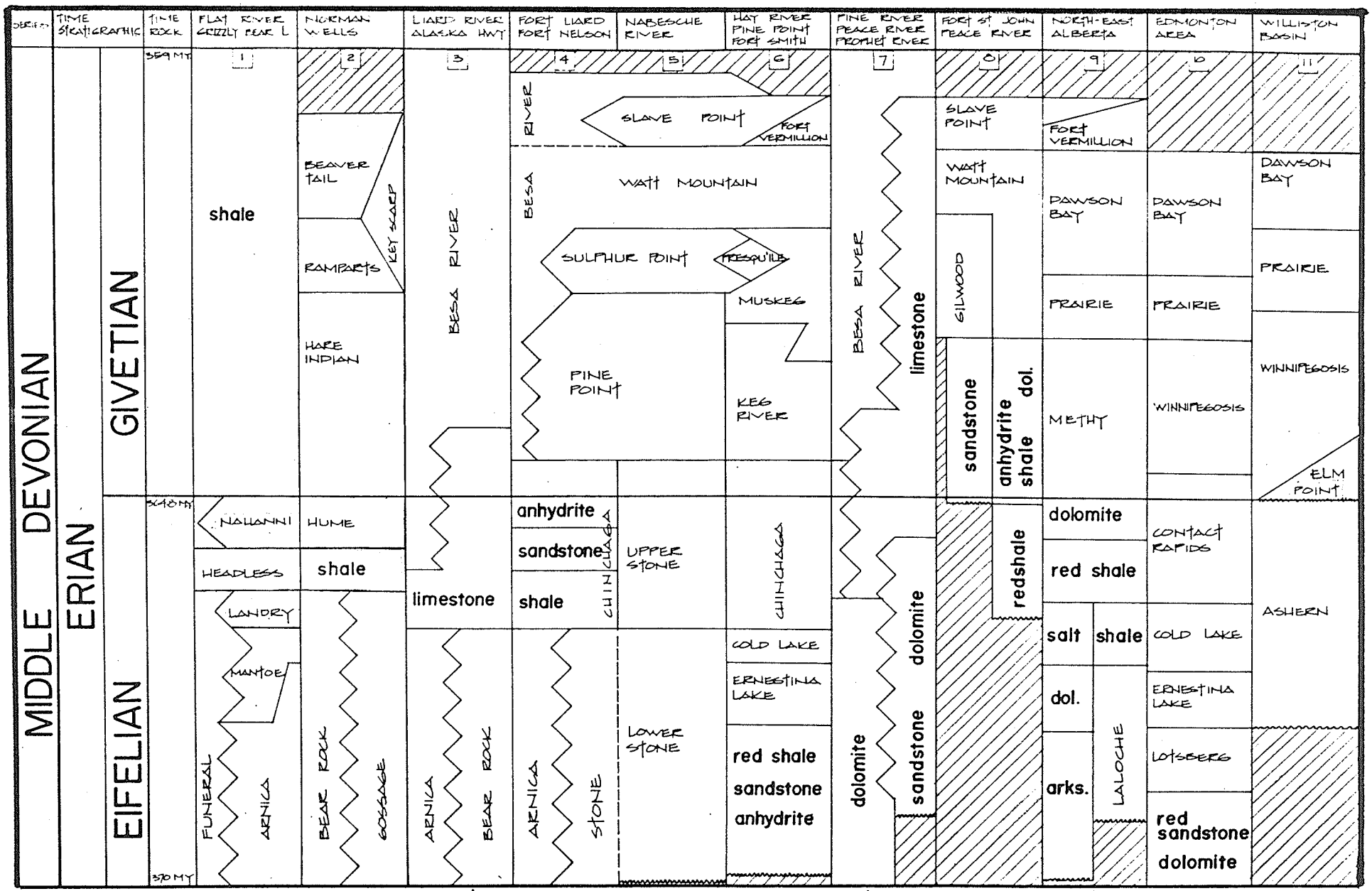


FIGURE 5



MIDDLE DEVONIAN GEOTECTONIC CORRELATION CHART FOR WESTERN CANADA

(ADAPTED FROM R.J.W. DOUGLAS, H. GABRIELSE, J.O. WHEELER, D.F. STOTT & H.R. BELYEA, 1970)

rocks were deposited throughout the Western Canadian Sedimentary Basin. In northeastern British Columbia, Cambrian, Ordivician and Silurian sediments accumulated on a structurally deformed late Precambrian basement.

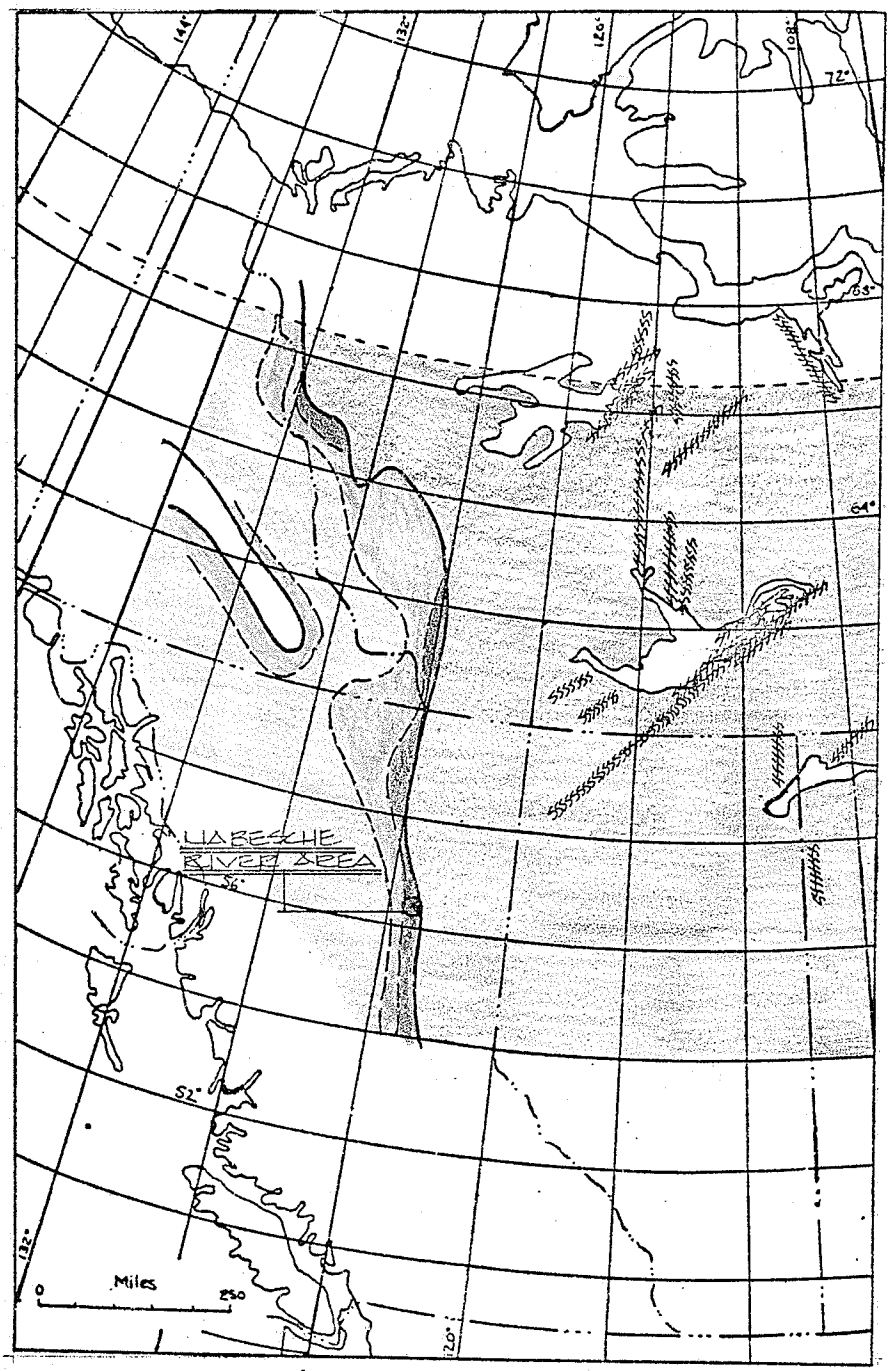
Douglas et al (1970) reported that during the Early Devonian the craton was high and was being actively eroded. Some outstanding topographic structures that controlled the pattern of sedimentation and facies distribution for the rest of the Devonian were developed during this period of erosion. The Meadow Lake Escarpment, the Western Alberta Ridge and the northeastward plunging Peace River Arch were developed. Other local highs such as the Tathlina, Fort Nelson and Cassiar Uplifts also were established.

In northeastern British Columbia, shales and carbonates were deposited unconformably on Silurian rocks during Lower Devonian time, (Figure 6). Griffin (1967) reported that up to 1400 feet of marine carbonates comprising the Muncho McConnell Formation were deposited at that time. A period of tectonic adjustment followed during which the siliciclastic rocks of the Wokkpash Formation were deposited. The Lower Devonian successions were then exposed to a period of erosion. Upon this framework Middle Devonian sedimentation began.

The Eifelian submergence commenced with the depression of the northwest margin(MacDonald Platform) of the craton. The direction of marine transgression was from the north and northwest. Platform carbonates were deposited west of

FIGURE 6

LOWER DEVONIAN (EMSIAN) SEDIMENTARY FACIES DISTRIBUTION MAP



(ADAPTED FROM DOUGLAS ET AL, 1970)

LEGEND

- SHALE
- CARBONATES LIMESTONE AND DOLOMITE
- CONGLOMERATE AND SANDSTONE
- PRE-DEVONIAN ROCKS

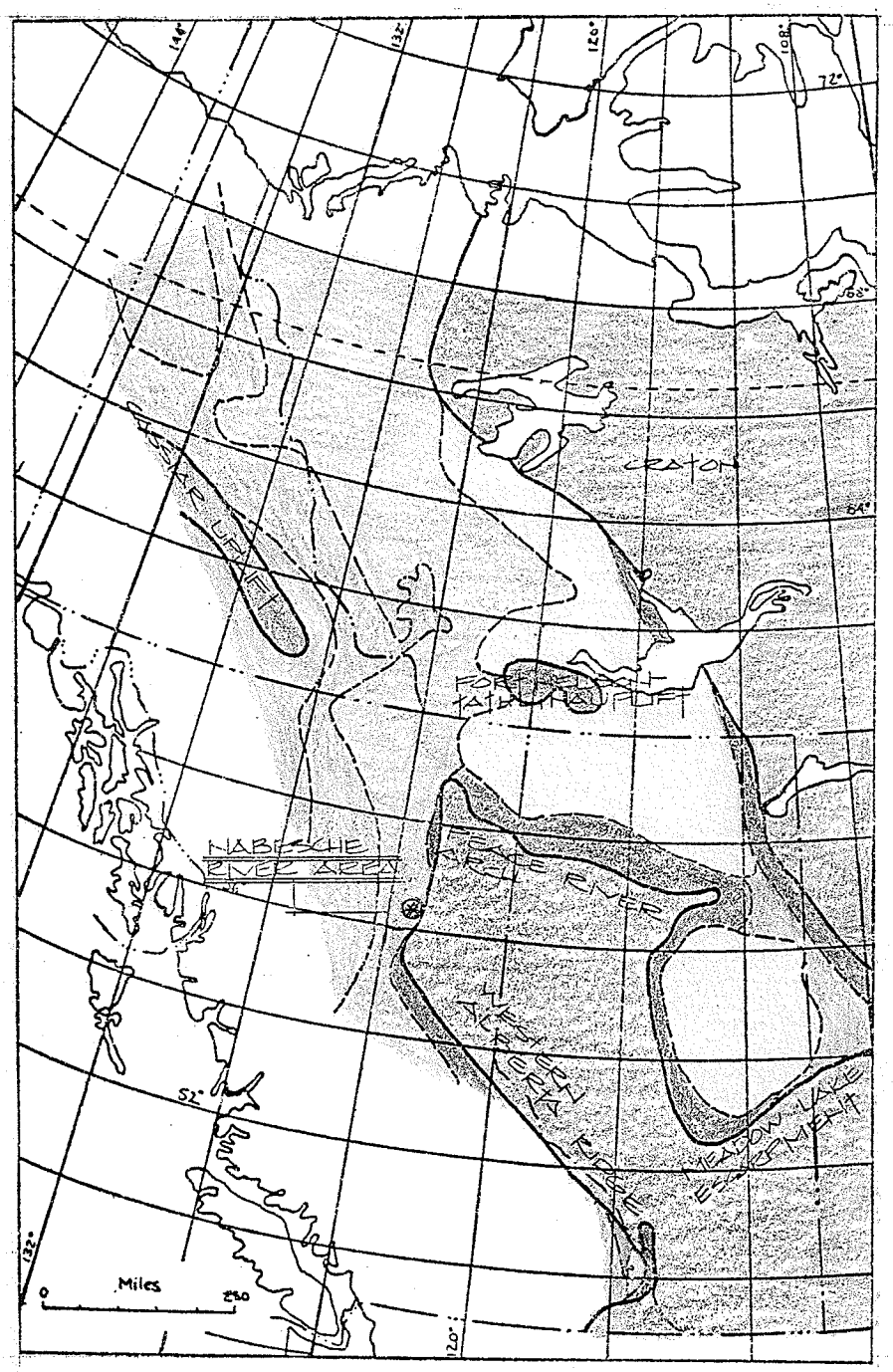
a hinge line that developed approximately parallel to 124° W longitude. In the western, deeper part of the basin, marine shales accumulated. Abrupt lateral facies changes between carbonates and shales are commonly found throughout northern British Columbia and southern Yukon. During this period a barrier probably existed west of the Fort Nelson Uplift. This barrier restricted the free circulation of marine water to the south and consequently the lower Elk Point evaporite basin was established. The widespread Ernestina Lake dolomites and Chinchaga evaporites and siliciclastics were laid down (Figure 7).

During this time the Nabesche River area was the scene of carbonate sedimentation as indicated by the deposition of the Stone Formation. This period of sedimentation was brought to a close by uplift and erosion.

Givetian sedimentation began with renewed submergence. The Eifelian barrier restricting the Lower Elk Point Basin was breached and a period of widespread carbonate deposition ensued (Figure 8). In northern Alberta and northeastern British Columbia, including the Nabesche River Area, Keg River, Muskeg and Pine Point reefal carbonate rocks respectively accumulated. The Keg River, Muskeg and Pine Point reefs again restricted the basin to the south forming the Upper Elk Point Basin. The carbonate rocks of the barrier pass laterally into shales to the north and into evaporites to the south. Pine Point deposition was ended by uplift and erosion.

FIGURE 7

MIDDLE DEVONIAN (EIFELIAN) SEDIMENTARY FACIES DISTRIBUTION MAP



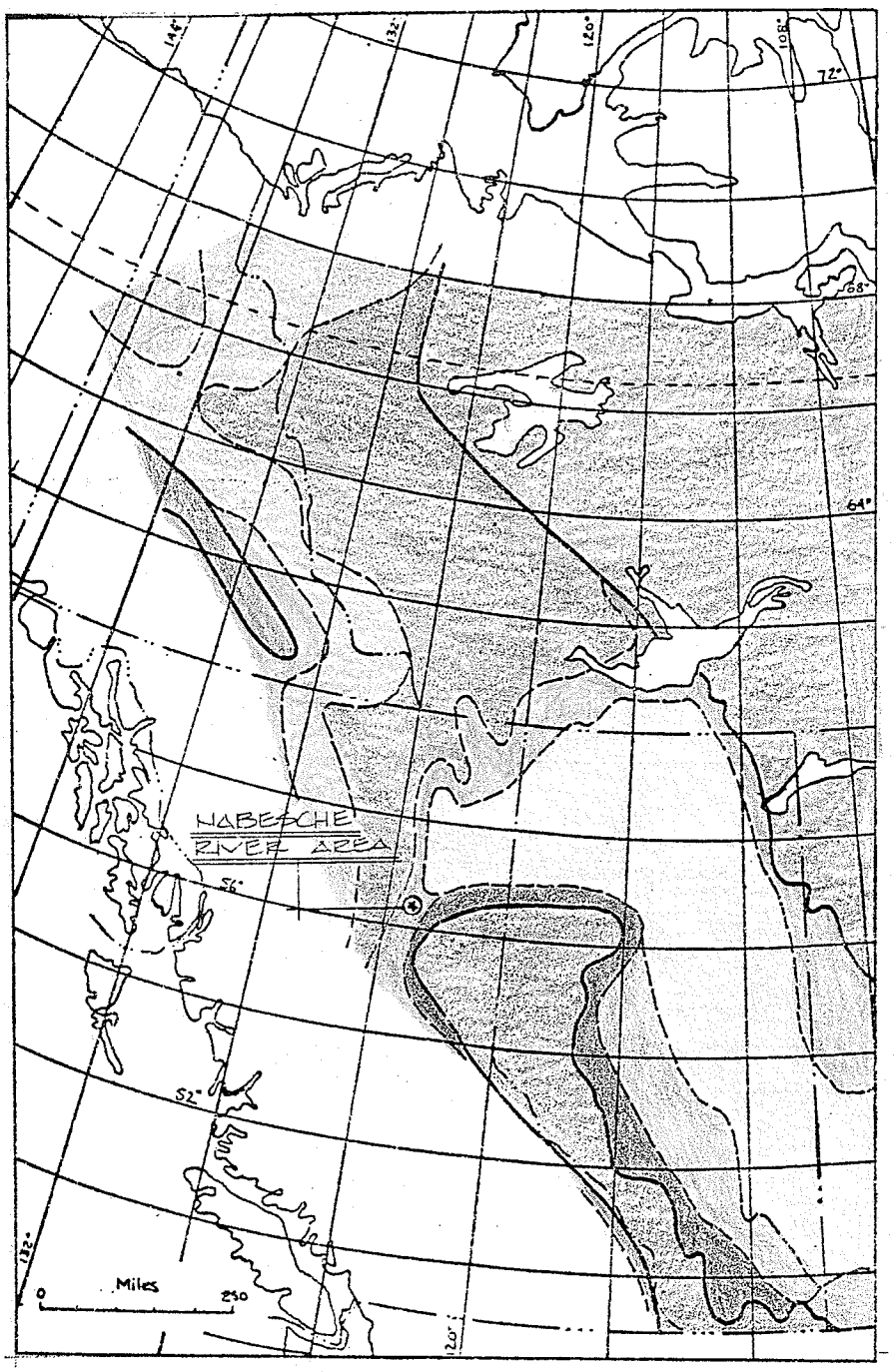
(ADAPTED FROM DOUGLAS ET AL, 1970.)

LEGEND

- EVAPORITES
- CARBONATES LIMESTONE AND DOLOMITE
- SHALE
- CONGLOMERATE AND SANDSTONE
- PRE-DEVONIAN ROCKS

FIGURE 8

MIDDLE DEVONIAN (GIVETIAN) SEDIMENTARY FACIES DISTRIBUTION MAP



(ADAPTED FROM DOUGLAS ET AL, 1970)

LEGEND

- EVAPORITES
- SHALE
- CARBONATES LIMESTONE AND DOLOMITE
- CONGLOMERATE AND SANDSTONE
- ARGILLACEOUS CARBONATES
- PRE-DEVONIAN ROCKS

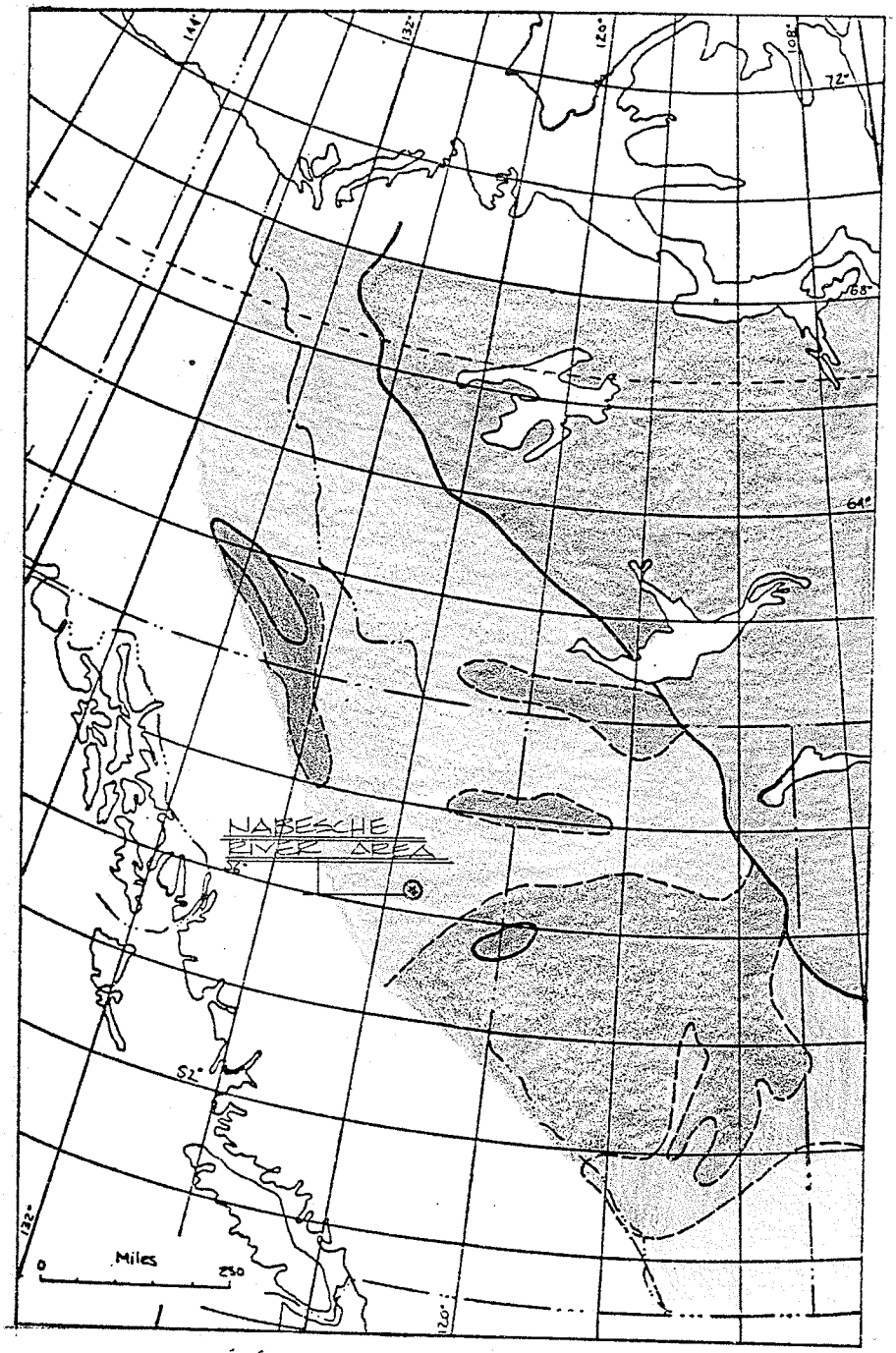
The Sulphur Point Formation marks the return of marine transgression. Reef growth reestablished itself slightly basinward of the underlying Pine Point carbonate front. In the Nabesche River area the Sulphur Point Formation represents the backreef facies of the carbonate platform. A minor disconformity occurs at the top of the Sulphur Point Formation.

The first phase of the final Givetian transgression is represented by the clastic sediments of the Watt Mountain Formation. Sandstone, siltstone and shale, presumably derived from the emergent Peace River Arch, spread out into the basin. The carbonate front eventually reestabished itself just south of the underlying Sulphur Point carbonate front. In the Nabesche River area the Slave Point Formation marks the return of carbonate deposition. Massive stromatoporoids in a muddy matrix represent the barrier facies at this locality. Slave Point sedimentation was brought to a close when the Middle Devonian carbonates were buried by the marine shales of the Besa River Formation that were deposited throughout northern Alberta, northeastern British Columbia, southern Yukon, and southwestern Northwest Territories. Later the carbonate reefs reestablished themselves much further to the south and the great period of Upper Devonian reef growth of central Alberta began (Figure 9).

In summary it may be observed that during the Middle Devonian the sea transgressed from northeastern British Columbia to northern Saskatchewan and western Manitoba.

FIGURE 9

UPPER DEVONIAN (FRASNIAN)
SEDIMENTARY FACIES DISTRIBUTION MAP



(ADAPTED FROM DOUGLAS ET AL, 1970)

LEGEND

- EVAPORITES
- SHALE
- CARBONATES LIMESTONE AND DOLOMITE
- CONGLOMERATE AND SANDSTONE
- ARGILLACEOUS CARBONATES
- PRE-DEVONIAN ROCKS

This major transgression occurred in several separate stages, each marked by extensive carbonate deposition. Perhaps the best way to view the event is by noting the step-wise retreat of the carbonate-shale facies front through the Middle Devonian, summarized in Figure 5.

Two possibilities present themselves with regard to the cause of the cyclical nature of the transgression. Firstly, the area may have been very active tectonically, or secondly, eustatic fluctuations of sea level occurred. There is not much evidence of large scale tectonism during the Middle Devonian, therefore the transgressive cycles may have been produced by real changes in sea level. This is not an unreasonable suggestion in light of recent work done in Pleistocene rocks. The net transgression was probably produced by the tectonic subsidence of the craton.

The Middle Devonian Stratigraphy of the Nabesche River Area

The approximately 2,100 feet of marine carbonate rocks overlying a major unconformity and underlying black marine shales comprise the Middle Devonian section in the Nabesche River area. Taylor and Bamber (1970) subdivided the Middle Devonian sequence into five formations in the Pine Pass area. Listed here in stratigraphical order they are the Stone Formation, Pine Point Formation, Sulphur Point Formation, Watt Mountain Formation and Slave Point Formation. Underlying the Middle Devonian rocks are the carbonate and clastic rocks of the Lower Devonian Muncho McConnell

Formation. Upper Devonian shales belonging to the Besa River Formation overlie the Middle Devonian sequence. The stratigraphy of the Nabesche River area is summarized in Figure 10, however a brief description of the formations is presented below.

The Stone Formation consists of interbedded, buff-brown, sandy dolomites, very minor yellow-grey limestones, white to grey quartzites and buff grey to grey crystalline dolomite. The upper part of the formation is characteristically grey crystalline dolomite. Cross-bedding, dessication cracks, ripple marks, flute marks and laminated beds are commonly found throughout the formation.

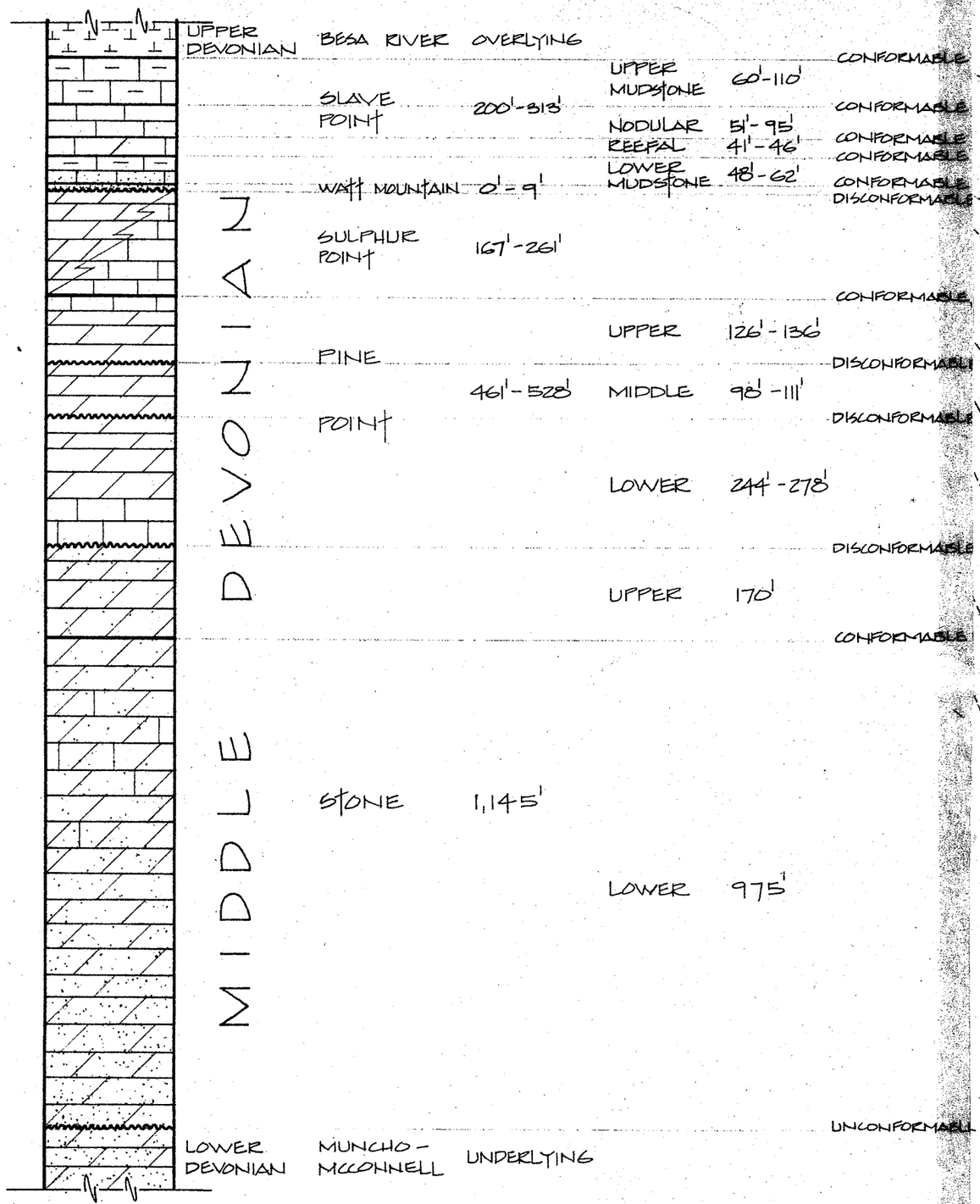
The Pine Point Formation is characterized by dark grey to black fossiliferous limestones and dolomites. Interbedded siltstones and arenaceous carbonates occur locally. The middle part of the formation is heavily pseudobrecciated and cemented. This is also the most fossiliferous part of the formation and probably represents a major reefal buildup. Characteristic fossils found within the formation include Stringocephalus, other brachiopods, massive and lamellar stromatoporoids, Amphipora, solitary rugose tetracorals, colonial and branching tabulate corals, and crinoids.

The Sulphur Point Formation consists predominantly of dark grey to black, fine crystalline lime-mudstone. It is relatively fossil-free except for a few rare beds containing thin shelled brachiopods and gastropods. Large portions of the rock are dolomitized. Within the dolomitized patches

FIGURE 10

	TEXTURE	PARTICLE SIZE	STRUCTURE	WEATHERING	FOSSIL CONTENT	FOSSIL TYPE	OTHER FEATURES	ENVIRONMENT
DDED DS N	MUDSTONE	VERY FINE GRAINED	LAMINATIONS	GREY TO LIGHT BROWN AND EXTREMELY RECESSIVE	NIL	—	COMPOSED MAINLY OF ILLITE, CHLORITE AND QUARTZ.	EXTREMELY LOW ENERGY, SUBTIDAL, DEEP OPEN MARINE
WITH S'	WACKESTONE, LOCALLY PACK-STONE AND MUDSTONE	FINE CRYSTALLINE	—	BLACK AND IS RECESSIVE LOCALLY DOLOMITE WEATHERS LIGHT GREY AND IS RESISTANT	20 - 30% LOCALLY 70 - 80% AND < 10%	BRACHIOPODS THAMNOPORA LAMELLAR, BRANCHING AND MASSIVE STROMATOPOROIDS AND CRINOIDS	UPPER PART OF INTERVAL IS ARGILLACEOUS CLAY CONTENT 10 - 20%	MODERATE TO LOW ENERGY LOCALLY HIGH ENERGY, SUBTIDAL, OPEN MARINE CARBONATE PLATFORM
—	MATURE SANDSTONE AND MUDSTONE	FINE GRAINED	MASSIVE	RUSTY BROWN TO RED AND IS SLIGHTLY RECESSIVE	NIL	—	WELL ROUNDED QUARTZ GRAINS	HIGH ENERGY SUBTIDAL OR INTERTIDAL
EDDED S L	MUDSTONE	FINE CRYSTALLINE	MASSIVE, NEAR TOP OF INTERVAL BECOMES FLAGGY	LIGHT GREY AND IS SLIGHTLY RESISTANT	< 5%	THIN SHELLED BRACHIOPODS, FEW GASTROPODS RARE AMPHIPORA	IRREGULAR SHAPED DOLOMITE ZONES	LOW ENERGY, SUBTIDAL, RESTRICTED LAGOON
DED DS K	MUDSTONE WITH LOCALLY INTERBEDDED WACKESTONES AND PACKSTONES	FINE CRYSTALLINE	MASSIVE, IN PLACES FLAGGY	DARK GREY AND IS RECESSIVE	LOCALLY 10-20% IN RARE THIN BEDS UP TO 50%	THIN SHELLED BRACHIOPODS AND AMPHIPORA RARELY CORALS AND LAMELLAR STROMATOPOROIDS	ARGILLACEOUS IN ZONES HIGH FOSSIL CONTENT BEDS BRECCIATED	LOW ENERGY, SUBTIDAL, LAGOON.
TO DED S CK	WACKESTONE AND PACKSTONE, LOCALLY MUDSTONE	FINE TO MEDIUM CRYSTALLINE	—	LIGHT GREY AND IS RESISTANT	15 — 25% LOCALLY 60 - 70%	MASSIVE STROMATOPOROIDS MINOR TABULATE CORALS BRACHIOPODS AND AMPHIPORA	CHARACTERISTICALLY PSEUDOBRECCIATED	HIGH TO MODERATE ENERGY, SUBTIDAL OPEN MARINE REEF
TO DED S K	LOWER PART WACKESTONE UPPER PART MUDSTONE AND LOCALLY PACKSTONE	FINE TO MEDIUM CRYSTALLINE	—	DARK GREY AND IS RECESSIVE, QUARTZ BEARING BEDS WEATHER LIGHT GREY AND ARE RESISTANT	LOWER PART 20 - 30% UPPER PART < 10% LOCALLY 50 - 60%	AMPHIPORA MASSIVE STROMA-TOPOROIDS, TABULATE CORALS AND BRACHIOPODS, MINOR CRINOIDS, GASTROPODS AND LAMELLAR STROMATOPOROIDS	LOWER PART IS LIMESTONE, UPPER PART IS DOLOMITE AND IS PSEUDOBRECCIATED	LOW TO MODERATE ENERGY, SUBTIDAL, LAGOON WITH ISOLATED ORGANIC BANKS
TO DED S K	MUDSTONE	VERY FINE TO MEDIUM CRYSTALLINE	GENERALLY MASSIVE LOCALLY THIN LAMINATIONS	LIGHT GREY TO WHITE AND IS RESISTANT	NIL	—	INTERBEDS OF ORANGE-BROWN DOLOMITE	LOW ENERGY TIDAL FLATS
WITH 4'	MUDSTONE	FINE TO MEDIUM CRYSTALLINE	DESICATION CRACKS, RIPPLE MARKS, FLUTE MARKS, LAMINATIONS	BROWN AND IS RECESSIVE SANDY BEDS SLIGHTLY RESISTANT	NIL	—	MANY LOCAL DISCONFORMITIES	HIGH ENERGY SHALLOW WATER INTERTIDAL (?) PERIODICAL SUB-AERIAL EXPOSURE
TO DED S CK DDED	MUDSTONE AND SANDSTONE	MEDIUM CRYSTALLINE AND MEDIUM GRAINED	DESICATION CRACKS, RIP-UP CLASTS	DARK BROWN AND IS RESISTANT	NIL	—	INTERBEDS OF YELLOW QUARTZ SANDSTONE	HIGH ENERGY, INTERTIDAL, BEACH, PERIODIC SUBAERIAL EXPOSURE

OLOUR	BEDDING	TEXTURE	PARTICLE SIZE	STRUCTURE	WEATHERING	FOSSIL CONTENT	FOSSIL TYPE	OTHER FEATURES
ACK TO OWN	THIN BEDDED WITH BEDS LESS THAN 1' THICK	MUDSTONE	VERY FINE GRAINED	LAMINATIONS	GREY TO LIGHT BROWN AND EXTREMELY RECESSIVE	NIL	—	COMPOSED MAINLY OF ILLITE, CHLORITE AND QUARTZ.
RY GREY ACK	THIN TO MEDIUM BEDDED WITH BEDS 1'-5' THICK	WACKESTONE, LOCALLY PACK-STONE AND MUDSTONE	FINE CRYSTALLINE	—	BLACK AND IS RECESSIVE LOCALLY DOLOMITE WEATHERS LIGHT GREY AND IS RESISTANT	20-30% LOCALLY 70-80% AND <10%	BRACHIOPODS THAMNOPORA LAMELLAR, BRANCHING AND MASSIVE STROMATOPOROIDS AND CRINOIDS	UPPER PART OF INTERVAL IS ARGILLACEOUS CLAY CONTENT 10-20%
EY TO GHT EY	—	MATURE SANDSTONE AND MUDSTONE	FINE GRAINED	MASSIVE	RUSTY BROWN TO RED AND IS SLIGHTLY RECESSIVE	NIL	—	WELL ROUNDED QUARTZ GRAINS
RK EY ACK	THIN TO MEDIUM BEDDED WITH BEDS 1'-5' THICK	MUDSTONE	FINE CRYSTALLINE	MASSIVE, NEAR TOP OF INTERVAL BECOMES FLAGGY	LIGHT GREY AND IS SLIGHTLY RESISTANT	<5%	THIN SHELLED BRACHIOPODS, FEW GASTROPODS RARE AMPHIPORA	IRREGULAR SHAPED DOLOMITE ZONES
EY TO RK EY	THIN TO THICK BEDDED WITH BEDS 1'-50' THICK	MUDSTONE WITH LOCALLY INTERBEDDED WACKESTONES AND PACKSTONES	FINE CRYSTALLINE	MASSIVE, IN PLACES FLAGGY	DARK GREY AND IS RECESSIVE	LOCALLY 10-20% IN RARE THIN BEDS UP TO 50%	THIN SHELLED BRACHIOPODS AND AMPHIPORA RARELY CORALS AND LAMELLAR STROMATOPOROIDS	ARGILLACEOUS IN ZONES HIGH FOSSIL CONTENT BEDS BRECCIATED
EY	MEDIUM TO THICK BEDDED WITH BEDS 3'-15' THICK	WACKESTONE AND PACKSTONE, LOCALLY MUDSTONE	FINE TO MEDIUM CRYSTALLINE	—	LIGHT GREY AND IS RESISTANT	15—25% LOCALLY 60-70%	MASSIVE STROMATOPOROIDS MINOR TABULATE CORALS BRACHIOPODS AND AMPHIPORA	CHARACTERISTICALLY PSEUDOBRECCIATED
ACK ND SHT EY	MEDIUM TO THICK BEDDED WITH BEDS 4'-20' THICK	LOWER PART WACKESTONE UPPER PART MUDSTONE AND LOCALLY PACKSTONE	FINE TO MEDIUM CRYSTALLINE	—	DARK GREY AND IS RECESSIVE, QUARTZ BEARING BEDS WEATHER LIGHT GREY AND ARE RESISTANT	LOWER PART 20-30% UPPER PART <10% LOCALLY 50-60%	AMPHIPORA MASSIVE STROMA-TOPOROIDS, TABULATE CORALS AND BRACHIOPODS, MINOR CRINOIDS, GASTROPODS AND LAMELLAR STROMATOPOROIDS	LOWER PART IS LIMESTONE, UPPER PART IS DOLOMITE AND IS PSEUDOBRECCIATED
FF EY TO HT EY	MEDIUM TO THICK BEDDED WITH BEDS 3'-10' THICK	MUDSTONE	VERY FINE TO MEDIUM CRYSTALLINE	GENERALLY MASSIVE LOCALLY THIN LAMINATIONS	LIGHT GREY TO WHITE AND IS RESISTANT	NIL	—	INTERBEDS OF ORANGE-BROWN DOLOMITE
FF OWN LLOW EY	THIN TO MEDIUM BEDDED WITH BEDS ½'-4' THICK	MUDSTONE	FINE TO MEDIUM CRYSTALLINE	DESSICATION CRACKS, RIPPLE MARKS, FLUTE MARKS, LAMINATIONS	BROWN AND IS RECESSIVE SANDY BEDS SLIGHTLY RESISTANT	NIL	—	MANY LOCAL DISCONFORMITIES
LLOW FF OWN	MEDIUM TO THICK BEDDED WITH BEDS 5'-20' THICK CROSS-BEDDED	MUDSTONE AND SANDSTONE	MEDIUM CRYSTALLINE AND MEDIUM GRAINED	DESSICATION CRACKS, RIP-UP CLASTS	DARK BROWN AND IS RESISTANT	NIL	—	INTERBEDS OF YELLOW QUARTZ SANDSTONE



MIDDLE DEVONIAN STRATIGRAPHY IN THE NABESCHE RIVER AREA

VERTICAL SCALE - 1 CM. = 100'

NAME OF UNIT		LITHOLOGY	C
BESA RIVER FORMATION		SHALE, CALCAREOUS SHALE, ARGILLACEOUS LIMESTONE	B B
SLAVE POINT FORMATION		FOSSILIFEROUS LIMESTONE, ARGILLACEOUS LIMESTONE, LOCALLY DOLOMITE	D T B
WATT MOUNTAIN FORMATION		QUARTZ SANDSTONE, ARENACEOUS LIMESTONE BRECCIA	E L E
SULPHUR POINT FORMATION		LIMESTONE AND DOLOMITE	D E T R
PINE POINT FORMATION	UPPER MEMBER	DOLOMITE AND LIMESTONE WITH LOCALLY INTERBEDDED FOSSILIFEROUS DOLOMITE	E D E
	MIDDLE MEMBER	FOSSILIFEROUS DOLOMITE	E
	LOWER MEMBER	FOSSILIFEROUS LIMESTONE AND DOLOMITE INTER-BEDDED QUARTZ SILTSTONE AND ARENACEOUS DOLOMITE	E A L E
STONE FORMATION	UPPER MEMBER	DOLOMITE AND SANDY DOLOMITE	E E L E
	LOWER MEMBER	SANDY DOLOMITE, DOLOMITE AND LIMESTONE	E E T E
MUNCHO MCCONNELL FORMATION		QUARTZOSE, SANDY DOLOMITE DOLOMITIC QUARTZ SANDSTONE	T T E R

pseudobrecciation, silicification and authigenic quartz crystals are common. The contact with the surrounding unaltered Sulphur Point limestone is sharp.

The Watt Mountain Formation is primarily quartz sandstone and an arenaceous lime mudstone breccia. The amount of rounded quartz grains and the degree of sorting decreases upwards (Plates 1a, 1b). The characteristic rusty red weathering of the rock makes this unit a valuable marker horizon in this area.

The Slave Point Formation is characterized by grey to black, very fine crystalline, argillaceous, lime mudstones, fossiliferous lime wackestones and interbedded fossiliferous lime packstones. The main fossils present are brachiopods, crinoids, tabulate corals, and massive, lamellar and branching stromatoporoids. The argillaceous content increases gradually upwards.

Collectively the rocks of the Middle Devonian in the Nabesche River area are representative of a major marine transgression. The Stone Formation represents the intertidal to supratidal shoreline facies. The section from the bottom of the Lower Pine Point member to the top of the Slave Point Reefal member documents the deposition of shelf carbonates and the development of two major reef complexes. The top of the Slave Point Formation together with the overlying Besa River shales represent the deep water facies near the end of the transgression.

Within the major transgressive cycle smaller cycles

were observed. They are defined by the unconformities within the section (Figure 10). One cycle typically consists of a mudstone facies and/or a reefal facies. The presence of the smaller cycles may indicate that relative changes in sea level occurred throughout this period of time. The Middle Devonian transgression was not a smooth continuum, but a series of smaller events that together resulted in a major transgression. This hypothesis is consistent with interpretations made by McCamis and Griffith (1967), Grayston et al (1965), Griffin (1967) and Douglas et al (1970) for Middle Devonian rocks throughout northeastern British Columbia and northern Alberta.

CHAPTER THREE - GEOLOGY OF THE SLAVE POINT FORMATION IN THE NABESCHE RIVER AREA

Introduction

The Slave Point Formation was originally described by Cameron (1918, p.25-26) in the Great Slave Lake area. He mapped a 160 foot thick unit consisting of thin bedded, medium grained, dark grey and slightly bituminous limestone. Campbell (1950, 1957) further advanced the definition of the Slave Point Formation on the basis of subsurface work. He placed the lower contact at the base of an 11 foot thick shale bed, the Amco Shale. Law (1955) traced the formation into the subsurface and established its existence in northwestern Alberta and northeastern British Columbia. Belyea (1961) noted that the base of the Slave Point has a characteristic low self potential electric log anomaly and an extremely high gamma ray anomaly. These geophysical features have been adopted by most western Canadian geologists as indicative of the lower contact of the Slave Point Formation in the subsurface.

Belyea and Norris (1962) mapped the Slave Point Formation in the Southern District of Mackenzie. Norris (1963) described the Slave Point Formation in the Gypsum Cliffs area on the Peace River, where he found that the lower part of the unit was represented by minor evaporites. Further to the south a definite evaporite facies at the base of the Slave Point has been established by drilling. This evaporite facies has been called the Fort Vermillion

member by Law (1955). Gray and Kassube (1963) described the Slave Point Formation in the Clarke Lake Gas field as porous dolomitized reservoir rock. Griffin (1965) completed a comprehensive regional study of the Slave Point Formation in northeastern British Columbia east of the disturbed belt. He noted that the thickness of the Slave Point increased greatly to the west. Thicknesses of the order of 500 feet were not uncommon in many wells. The thickest development of the formation was at the carbonate shale facies front. Taylor and Bamber (1970) traced the Slave Point Formation into the disturbed belt where stratigraphic relationships have not yet been well defined.

General Geology

Distribution in Northeastern British Columbia

Griffin (1965) summarized the limits and distribution of the Slave Point Formation in northeastern British Columbia. It is a sheet-like body covering approximately 30,000 square miles with a variable thickness between 200 and 500 feet. To the north and west it passes into shale, to the south it wedges out against the Peace River land mass and to the east, mainly in Alberta, it progressively thins out and eventually passes into evaporites.

Regional Lithofacies

Regionally the Slave Point Formation has been decribed by most authors as a dark grey, stromatoporoid bearing, argillaceous, lime mudstone, and a pelletoid and skeletal

grainstone. Griffin (1965) described the rock as a dark grey, stromatoporoid bearing calcilutite. Characteristically, the unit consists primarily of fossil bearing lime mudstones that are locally argillaceous. According to Belyea (1971) massive stromatoporoids usually occur in a 30 foot thick bed near the middle of the sequence in the Tathlina Uplift area. The stromatoporoid buildups are primarily confined to the vicinity of the carbonate-shale facies fronts and locally they have evolved into barrier-type reefs. Near the reefal complexes skeletal bioclastic wackestones and packstones represent associated lithologies. Away from the carbonate front in the shelf environment, Griffin (1965) described the lithology as consisting of intramicrites, intrasparites and biosparites. In northeastern Alberta, Norris (1963) showed that the formation contained beds of anhydrite and gypsum.

Law (1955) subdivided the Slave Point Formation into two members in northern Alberta, a lower Fort Vermillion Member and an upper unnamed member. The Fort Vermillion Member consists typically of evaporite facies, but the upper member consists of carbonate shelf facies. In the Nabesche River area the Fort Vermillion Member is absent and the whole Slave Point section is represented by Law's (1955) unnamed member.

Regional Correlation

Regional mapping in northeastern British Columbia and northern Alberta (Figures 4, 5, 8) shows that the Slave Point

Formation is readily traceable into the basinal shale facies to the northwest and into the evaporite facies to the southeast. The carbonate facies is localized in a northeastwardly trending barrier separating the deep and shallow water environments.

Through northeastern British Columbia and northern Alberta, the limestones directly underlying the Upper Devonian shales are generally accepted by most geologists as belonging to the Slave Point Formation. In the Horn River area limestones equivalent to the Slave Point Formation have been named the Horn Plateau Formation. According to Douglas et al (1970) the upper parts of the Beavertail and Kee Scarp Formations in the Norman Wells area of the Mackenzie Mountains are probably equivalent to the lower part of the Slave Point Formation.

To the north and west of the carbonate front the Slave Point Formation passes into the Besa River Formation. The name Besa River is used to describe the thick shale wedge thinning to the east, that is equivalent to and/or overlies carbonate rocks from Middle Devonian to Late Mississippian in age in northeastern British Columbia, northern Alberta, southeastern Yukon and southwestern Northwest Territories. Locally individual shale units have been given separate names and described in detail. In the southern Mackenzie Mountains and eastern Yukon, the Slave Point Formation passes into the Horn River shales. Gray and Kassube (1963) found the Otter Park Member (shale) of the Horn River Formation to

be equivalent to the Slave Point Formation in the Fort Nelson-Kotcho Lake area of northeastern British Columbia. In other areas in northeastern British Columbia the Muskwa and Fort Simpson shale have been correlated with the Slave Point Formation.

The evaporitic equivalent of the Slave Point Formation is the Fort Vermillion anhydrite, found in north-central Alberta.

Elsewhere in the Western Canadian sedimentary basin erosion associated with a regional unconformity apparently has removed rocks of the Slave Point Formation. In some areas it may never have been deposited.

Thickness of the Slave Point Formation in the Nabesche River Area

The total thickness of the unit within the boundaries of the study area varied from 200 to 313 + feet. The precise thickness of the formation is difficult to determine because the upper contact with the Besa River Formation is commonly covered. The uppermost beds of the Slave Point consist of argillaceous lime mudstones and the lowermost beds of the Besa River consist of calcareous shales. The contact is transitional. Insoluble residue data helped to establish the top of the Slave Point Formation in section C (Figure 11), on the basis that over 50% insoluble residue was present. In section A (Figure 11) the top of the Slave Point is poorly exposed and sample spacing was too great

for insoluble residue data to be meaningful. Consequently, the upper contact was arbitrarily placed where the rocks appeared to pass upward into shale, approximately 313 feet above the base of the formation. Unfortunately, insoluble residue data showed only 19.1% insoluble material in the sample. A sample taken 417 feet above the base of the formation at the next good outcrop showed 59% insoluble residue. Therefore the contact must lie somewhere in between.

Contacts

Regional Interpretation of the Upper Contact of the Slave Point Formation

The contact in the Nabesche River area is no doubt gradational over short distances, but the nature of the contact is unknown. There is much disagreement on the degree of conformity of the contact, and it appears that regionally the nature of the contact changes.

Belyea (1952), considering an extensive area in northern Alberta, reported a sharp contact between the Slave Point Formation and the overlying shales. She interpreted the contact to be conformable. Likewise, Law (1955) found the contact to be abrupt and probably conformable. Crickmay (1957) reported that on the basis of a limited core study he found the contact to be disconformable. Norris (1963) submitted that the nature of the contact probably varied from region to region. Norris (1965), however, documented an unconformity in the Great Slave Lake area. The Committee on Slave Point and Beaverhill Lake Formations (1965) indicated that a slight disconfor-

mity existed in some areas, but that a conformable contact was found in other areas due to the downwarping of the craton and the continuous transgression of marine shales. Griffin (1965) reported that in the eastern part of northeastern British Columbia the contact was sharp and conformable, but in the western part of the area both conformable and unconformable relationships may be present. McCamis and Griffith (1967) found the contact to be abrupt and probably conformable in the Zama area. Douglas et al (1970, p.394) indicated that regression occurred at the close of the Givetian producing an extensive unconformity. Hriskevich (1970) interpreted relatively rapid subsidence at the end of Slave Point time which produced a conformable contact in the Rainbow area.

Contacts of the Slave Point Formation in the Nabesche River Area

Within the study area the upper contact was not directly observed, but in light of the lithologies present and trend surface plots of insoluble residue data (Figure 27), it is suspected that the upper contact of the Slave Point Formation is gradational and probably conformable.

The lower contact of the Slave Point Formation was identified in the field and the rocks spanning it have been studied in thin section. In the field the contact between the red weathering Watt Mountain Formation and the dark grey weathering Lower Mudstone member is quite sharp and distinctive. In outcrop the contact was seen

to have an undulating nature. It is not an erosional unconformity. Thin section studies showed that the contact is gradational and conformable. Quartz grains and the occasional lithoclast extend as far as 10 to 15 feet up into the Lower Mudstone member, but appear to be more numerous near the base of the member (Plates 1c, 1d). Conversely, the volume of lime mudstone matrix in the Watt Mountain Formation increases towards the top of the formation. The characteristics of the matrix do not appear to change appreciably across the contact. On the basis of the data presented above it is interpreted that the lower contact of the Slave Point Formation is conformable.

Laterally, the Slave Point Formation passes into Besa River shale just north of the study area (G.C. Taylor 1973, personal communication). Although the author did not map this transition personally, it was possible to predict the existence of the carbonate-shale facies front from insoluble residue data derived from available outcrop samples.

The data were subjected to trend surface analysis. A computer program available at the Department of Earth Sciences was used to plot seven trend surfaces. The third, fourth and and fifth order plots are shown in Figure 27. The correlation coefficient of each order is 0.7384, 0.8040, 0.8212 respectively. The correlation coefficient indicates how close the results are to defining the geometry of the actual facies change from carbonate to shale. If insoluble residue values for all points on the diagram were known, then the correlation coefficient would be 1.0, and the exact geometry of the facies change would be

portrayed. On that basis, the fourth and fifth order plots are the most reliable, because the correlation coefficients are the highest. The fifth order plot gives the closest approximation to the actual geometry of the facies change with the number of data points available. The trend surface plots show that this type of statistical analysis may be useful in determining, a) the presence of facies changes in the subsurface from scattered drill hole information and b) the geometry of such changes. In this case a carbonate-shale facies change that has been mapped in outcrop was successfully detected by trend surface analysis of insoluble residue data.

L o c a l S t r a t i g r a p h y

Introduction

The Slave Point Formation within the study area consists of dark grey to black fossiliferous, lime mudstones and wackestones. The predominant fossils present are stromatoporoids, tabulate corals and brachiopods. Crinoids, gastropods and ostracods are also present, but are not volumetrically important.

Norris (1965) considered that the most diagnostic fossils of the Slave Point Formation are Emanuella sp. C. and Emanuella sp. F. On the basis of these data he considered the Slave Point Formation to be of Givetian age. Kidd (1963) identified Productella bellansii Stainbrook, Warrenella aff. W. Kirki (Merriam) and Cyrtina panda, Meek, near the top of the Slave Point Formation in the Nabesche River area. These fossils are characteristically Middle Devonian in age. Although no systematic paleontology was completed in this

study, it is probable that the Slave Point Formation in the Nabesche River area is of Middle Devonian (Givetian) age.

It was found that the Slave Point Formation could be subdivided informally into four members: a Lower Mudstone member, a Reefal member, a Nodular member, and an Upper Mudstone member (Figure 11).

Lower Mudstone Member

Lithological Description

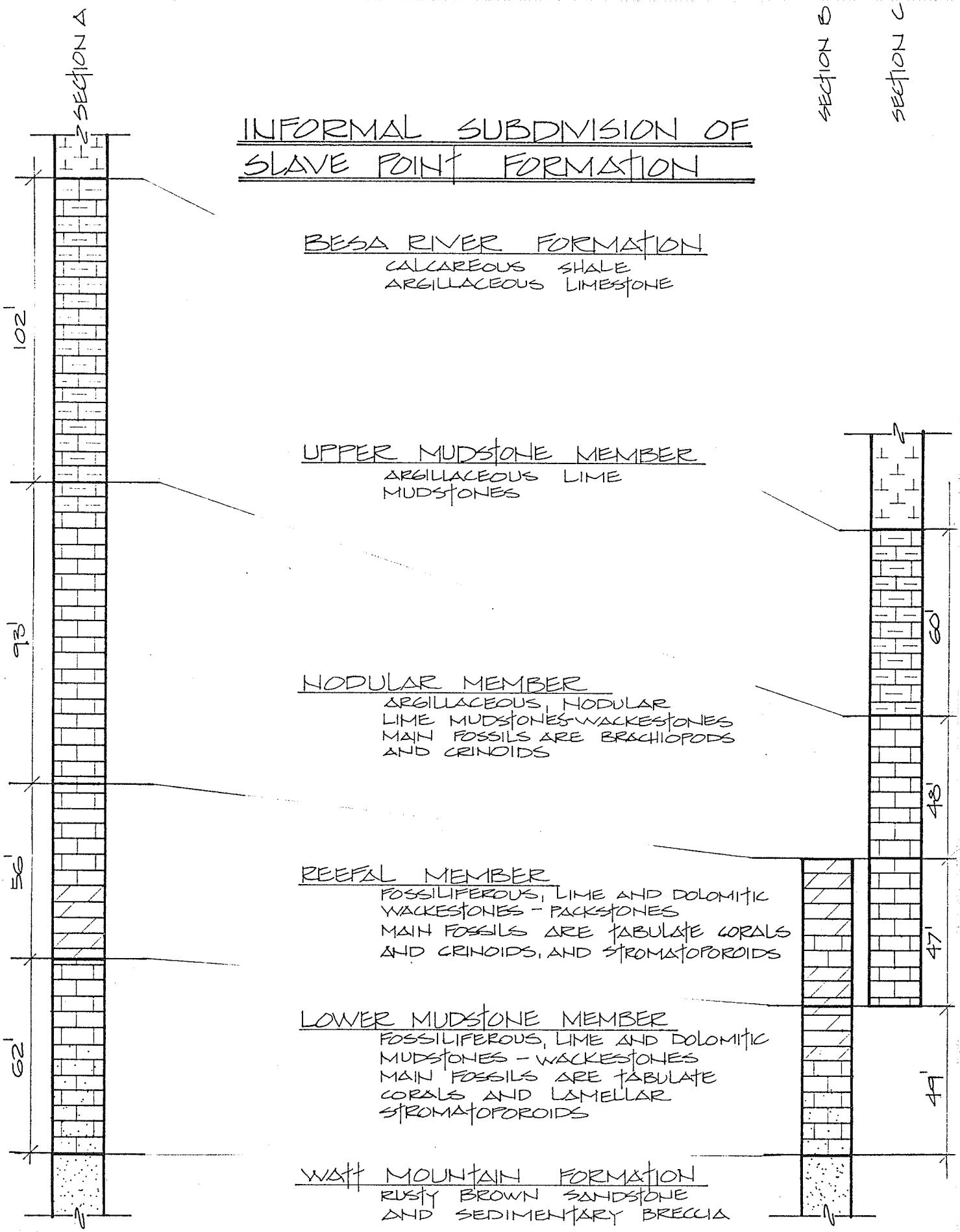
The 55 to 70 foot thick Lower Mudstone member consists predominantly of very fine grained argillaceous lime mudstone. The lower 15-20 feet of the member is fossiliferous, while the upper 40-50 feet is relatively fossil free except for a few fossiliferous beds near the top of the unit.

Rocks of the Lower Mudstone member weather to a dark grey colour and are generally recessive. In places where it is dolomitized the rock weathers light grey and is more resistant.

The lower 15-20 foot interval of the Lower Mudstone member is represented by fossiliferous lime wackestones and packstones. The main fossils present are lamellar stromatoporoids, branching tabulate corals, mainly Thamnopora, colonial tabulate corals, brachiopods, gastropods, and many unidentified silt-size fossils and fossil fragments. In almost all cases the fossils have been replaced by white sparry calcite. Only in one place where the rock

FIGURE 11

INFORMAL SUBDIVISION OF SLAVE POINT FORMATION



BESA RIVER FORMATION

CALCAREOUS SHALE
ARGILLACEOUS LIMESTONE

UPPER MUDSTONE MEMBER

ARGILLACEOUS LIME MUDSTONES

NODULAR MEMBER

ARGILLACEOUS, NODULAR LIME MUDSTONES-WACKESTONES
MAIN FOSSILS ARE BRACHIOPODS AND CRINOIDS

REEFAL MEMBER

FOSSILIFEROUS, LIME AND DOLOMITIC WACKESTONES - PACKSTONES
MAIN FOSSILS ARE TABULATE CORALS AND CRINOIDS, AND STROMATOPOROIDS

LOWER MUDSTONE MEMBER

FOSSILIFEROUS, LIME AND DOLOMITIC MUDSTONES - WACKESTONES
MAIN FOSSILS ARE TABULATE CORALS AND LAMELLAR STROMATOPOROIDS

WATT MOUNTAIN FORMATION

RUSTY BROWN SANDSTONE AND SEDIMENTARY BRECCIA

VERTICAL SCALE — 1" = 40'

is dolomitized, are the fossils replaced by white sparry dolomite. In some areas the fossils were partly or wholly replaced by pyrite. Many of the elongated fossils and fossil fragments, for example Thamnopora, are found lying parallel to the bedding planes, but colonial tabulate corals and lamellar stromatoporoids appear to be in growth position. In the vicinity of the larger fossils or fossil fragments, bedding in the matrix drapes around the fragments. This feature is most apparent where bedding planes appear closely spaced, displaying a laminated texture.

The number and type of fossils present may vary, but the matrix is black, very fine grained, argillaceous, lime mudstone with varying clay content. Insoluble residue data show that between 2.0% and 6.0% insoluble material is present. Most of the insoluble material is clay, mainly chlorite and illite, as determined by X-ray diffraction analysis. Throughout the unit, scattered, rounded, quartz grains ranging from 30 to 300 microns in size are commonly found.

The basal bed of the Lower Mudstone member is usually lime mudstone, but in a few places it is dolomitized. The rock commonly contains large intraclasts consisting of lime mudstone, coral, brachiopod and gastropod fragments (Plate 1c). Locally this lime mudstone bed is discontinuous and the Watt Mountain Formation is in contact with the fossiliferous beds of the Lower Mudstone member.

Within the fossiliferous part of the Lower Mudstone member that overlies the basal bed, a vertical zonation

of the fossils was noted. The lower wackestone and packston beds contain predominantly Thamnopora and lamellar stromatoporoids. The lamellar stromatoporoids are often found encrusting and binding together two or more coral fragments. There are also many broken and abraded fossil fragments of unknown origin comprising the skeletal silt matrix.

Within the middle part of this unit there is a Thamnopora wackestone-packstone bed. The matrix of the rock is black, extremely argillaceous and laminated. The allochems are Thamnopora fragments and tiny brachiopod shells, replaced by white sparry calcite and small elongated mud clasts measuring in the order of 1-2 mm in the long dimension. Pyrite is disseminated throughout the rock. This very distinctive black and white high contrast bed proved to be a valuable marker horizon (Plate 4b). Above the marker bed the lamellar stromatoporoid and tabulate coral assemblage of the lower part of the unit returns.

Within the upper portions of the fossiliferous unit colonial tabulate corals are abundant. A diverse assemblage consisting of brachiopods, gastropods, ostracods and possibly trilobites is also present at the top of the unit.

Above the fossiliferous beds the rock consists of black, thick bedded, very fine grained, argillaceous, lime mudstone. The shale content is variable throughout the mudstone facies. Insoluble residue data show that insoluble material varies from 2% to 22%. The rock is generally unfossiliferous. However, 0.5 to 1.0 foot

thick interbeds containing fossils occur intermittantly throughout the unit, but tend to occur most commonly near the top. Within the fossiliferous interbeds the fossil content increases to between 5% and 10%. The main fossils present are brachiopods and crinoids. Thamnopora and ostracod fragments occur less frequently. The fossils occur whole or they may be broken, but in all cases they lie parallel to the bedding. Usually they are replaced by white sparry calcite, but in some cases they are replaced by pyrite.

Except for a nodular texture that is found in some places, the rest of the mudstone facies in the unit is a uniform lime mudstone. A more detailed description and a discussion of the origin of the texture is presented in the section describing the Nodular member.

Locally the unit is dolomitized. Dolomite crystals were found to range from 30 to 200 microns in diameter. Many of the larger dolomite crystals have a euhedral quartz crystal 20 to 40 microns in diameter located in their centres.

Commonly the rock is cut by straight walled fractures that have been healed by white sparry calcite. Commonly the centres of these calcite veinlets are filled by pyrite. Many of the rarely occurring veinlets are cut by and displaced along stylolitic shale seams.

Contacts

The lower contact with the Watt Mountain Formation is gradational and conformable. Local sedimentary processes and irregular facies changes are probably responsible for the undulating nature of the contact as revealed by the study of the substrate of the member's fossiliferous section. The occurrence of intraclasts and in a few places lithoclasts within the fossiliferous beds suggests that the contact is vertically gradational (Plate 1).

The upper contact with the overlying Reefal member was placed at the first occurrence of lamellar stromatoporoids above the thick mudstone section in the Lower Mudstone member. This contact is sharp and distinctive in the field and drill core. It is interpreted to be conformable. The nature of the matrix changes little across the contact. The change between the two members is only marked by the appearance of a large number of fossils.

Environmental Interpretation

The presence of reef forming fossils, quartz grains and lithoclasts in the lower portion of the Lower Mudstone member indicates that the rock was deposited in a high energy environment. The proximity of the underlying shallow water Watt Mountain Formation, the gradational contact and the persistence of rounded quartz grains and lithoclasts upward through the lower portion of the member collectively suggest continuous deposition from Watt Mountain to Lower

Mudstone time. Therefore, the shift from siliciclastic to carbonate facies probably represents a deepening of the water. Figure 21 illustrates the hypothetical depositional facies distribution in the Slave Point sea in the Nabesche River area. It shows the seaward relationship of the Lower Mudstone member to the Watt Mountain Formation.

Lamellar stromatoporoids and tabulate corals lived in moderately turbulent to subturbulent environments according to Noble and Ferguson (1971). The organisms probably established themselves in shallow water just below the area of maximum turbulence and developed patch reefs and organic banks as illustrated in Figure 21. The muddy matrix of the rock indicates that the fauna survived in a turbid water environment. The overlying mudstone facies is indicative of a deeper water low energy environment.

The environment of deposition of the Lower Mudstone member is interpreted to be a shallow water backreef lagoon, very similar to Wilson's (1970) backreef open platform.

Reefal Member

Lithological Description

The 40 to 46 foot thick Reefal member consists of dark grey to black fossiliferous lime and dolo-wackestones and packstones with interbedded fossiliferous lime and dolomudstones. The member is medium bedded (individual beds 3

to 5 feet thick) and tends to have a blocky appearance. The limestone weathers a dark grey and is slightly recessive, whereas the dolomite weathers light grey and tends to be resistant. The dolomitized beds are prominent cliff-formers in outcrop. The main fossils present are stromatoporoids, tabulate corals, brachiopods and crinoids.

The Reefal member appears to be biostromal in nature. Detailed study revealed five biofacies within the biostrome, in part laterally equivalent. They are a crinoid-bearing mudstone facies, a lamellar stromatoporoid facies, a branching stromatoporoid facies, a massive stromatoporoid facies and a tabulate coral facies. In all cases there is a very gradational contact between the facies.

Crinoid-Bearing Mudstone Facies

The crinoid-bearing mudstone facies is typically black, very fine crystalline, massive to finely laminated, pyrite rich, lime mudstone-wackestone. Silt sized fossil fragments and crystalline mudstone comprise the black matrix of the rock. In most cases the origin of the fossil fragments is virtually impossible to identify, but in a few rare cases it was possible to distinguish fossils. The main fossils that are found in the facies are crinoids, thick and thin shelled brachiopods and auloporid corals (A.E.H. Pedder 1974, personal communication). The auloporid corals are illustrated in Plate 2. They tend to occur profusely in some beds. At one level near the lower half of the

unit auloporid corals are so numerous that they replace crinoids as the predominant fossil.

Usually the fossil content ranges from 10-20% and in a few cases reaches 50%. Of the fossils present crinoids comprise about 50% of the total, brachiopods 20%, auloporid corals 20% and others 10%. Other allochems occasionally found are ostracod, tabulate coral, stromatoporoid and possibly trilobite fragments.

The fossils and fossil fragments are usually replaced by calcite or dolomite. In areas where the shale content is high the allochems are not recrystallized. Some of the larger crinoid fragments exhibited syntaxial overgrowths in thin section. In a few thin sections small (0.4-0.6 mm) angular lithoclasts composed of carbonate rock were observed. Plate 4d illustrates the fabric of the crinoid-bearing mudstone facies.

Lamellar Stromatoporoid Facies

The lamellar stromatoporoid facies consists of black to dark grey, fossiliferous lime wackestones and packstones. The matrix is black, lime mudstone-wackestone not unlike the lithology of the crinoid-bearing mudstone, except that the broken and abraded skeletal fragments present become coarser, ranging from silt to sand size. The skeletal silt occurs in varying proportion throughout the matrix, but usually comprises between 40-60% of the rock. In places the matrix becomes argillaceous and shale seams and stylolites

are quite common throughout the rock.

The total fossil content of the rock usually ranges from 40-60%. The lamellar stromatoporoids comprise 90% of the total and other fossils account for 10%. The other fossils present are brachiopod shells, broken tabulate coral fragments, a few crinoid fragments and rarely, massive stromatoporoid fragments.

The lamellar stromatoporoids are usually 0.5-3.0 mm thick. They appear to perform a binding role, similar to the role algae play (Plate 3). Embry and Klovan (1971) have named this type of rock a bindstone. In many places the lamellar stromatoporoids were found encrusting and binding together several tabulate coral fragments 5.0-10.0 mm in diameter. Many of the coarser bioclastic sections of the rock are bound by lamellar stromatoporoids. In the absence of any object which they may encrust, the lamellar stromatoporoids established themselves on a muddy substrate, parallel to bedding (Plate 3b). The fossils are usually replaced by calcite, but in a few cases they are also cemented by iron-poor calcite cement.

The bedding of the matrix was observed to wrap around the larger fossil fragments indicating that differential compaction occurred in the rock. In a few places small dolomite filled sub-horizontal fractures were found cutting the rock.

Branching Stromatoporoid Facies

The branching stromatoporoid facies is comprised of grey to dark grey, fossiliferous, dolomitic packstones and wackestones. The matrix is exclusively a fine crystalline, dolomitic mudstone, free of any of the silt sized skeletal fragments so common throughout the rest of the Reefal member. The clay content of this facies is very low (approx. 3% insoluble residue content). The insoluble material is concentrated along stylolite planes that commonly cut the rock.

The fossil content ranges between 60-90%. Branching stromatoporoids comprise 95% of the fossil content. The remaining 5% of the fossil content consists of tabulate coral or other stromatoporoid fragments.

Dolomitization and recrystallization have severely altered the rock and consequently it is impossible to identify the branching stromatoporoids as Amphipora or Stachyodes (Plate 5b). They occur as elongated fragments that lie parallel to bedding planes and have a fairly consistent diameter of 3.0 mm. In some specimens a very well developed axial canal was observed, but in others, only an incipient axial canal was noted. Over a 4.0 foot interval there is a general increase in the diameter of the fossils downwards and near the bottom of the interval the number of coral and stromatoporoid fragments increases (Plate 5a). Most of the fossils are replaced by white sparry dolomite. In some flat lying skeletal fragments the top of

the fossil has been dolomitized to a coarse crystalline fabric that contains much dark clay in the intercrystalline voids. The bottom half of the fossil was replaced by sparry dolomite.

Massive Stromatoporoid Facies

The massive stromatoporoid facies consists of black, fine crystalline, argillaceous, fossiliferous, lime wackestone and packstone. The matrix is a black lime mudstone free from any great amounts of silt sized skeletal fragments. The clay content is variable throughout the facies, but seems to be concentrated in shale seams and along stylolites. The fossil content varies from 20-50%. Massive stromatoporoids, including bulbous stromatoporoids, and hemispherical stromatoporoids comprise 90% of the fossil content. The remaining 10% consists of tabulate corals and brachiopod fragments. The various types of massive stromatoporoids could not be identified in drill core and for that reason they are collectively referred to as massive stromatoporoids. In outcrop the larger bulbous stromatoporoids reach 6-8 inches in diameter. Overturned stromatoporoid heads are a common feature of this facies.

Tabulate Coral Facies

The most common facies in the biostrome is the tabulate coral facies. It is comprised of dark grey to black, fossiliferous, lime and dolo-wackestones. The matrix is a black, argillaceous, lime and dolo-mudstone, that contains variable

amounts of silt and sand size skeletal fragments. The total fossil content of the rock ranges from 20-40%. Branching and colonial tabulate corals constitute 60% of the fossil content. Thamnopora is by far the most common species present. Brachiopods comprise 20% of the fossil content and the other 20% is represented by massive and lamellar stromatoporoids and unidentified fossil fragments. Very few crinoids were observed in this facies. Most of the branching tabulate coral fragments lie on their side parallel to bedding, but the colonial tabulate corals nearly always occur in growth position.

In places, this facies has been subjected to intense dolomitization and recrystallization which has resulted in the obliteration of many primary fabrics. The centres of many of the coral fragments have recrystallized. The intensity of the alteration decreases outward into fresh limestone. In many cases, where the fossils have been replaced by white, coarse sparry dolomite, or where vuggy porosity has been plugged by cement, authigenic quartz crystals are found in the centre of the cemented area.

Contacts

The lower contact of the Reefal member is sharp in the sense that it marks the sudden profusion of fossils. The matrix of the rock does not change across the contact. It is interpreted to be conformable. The upper contact is sharp and is marked by the appearance of a nodular

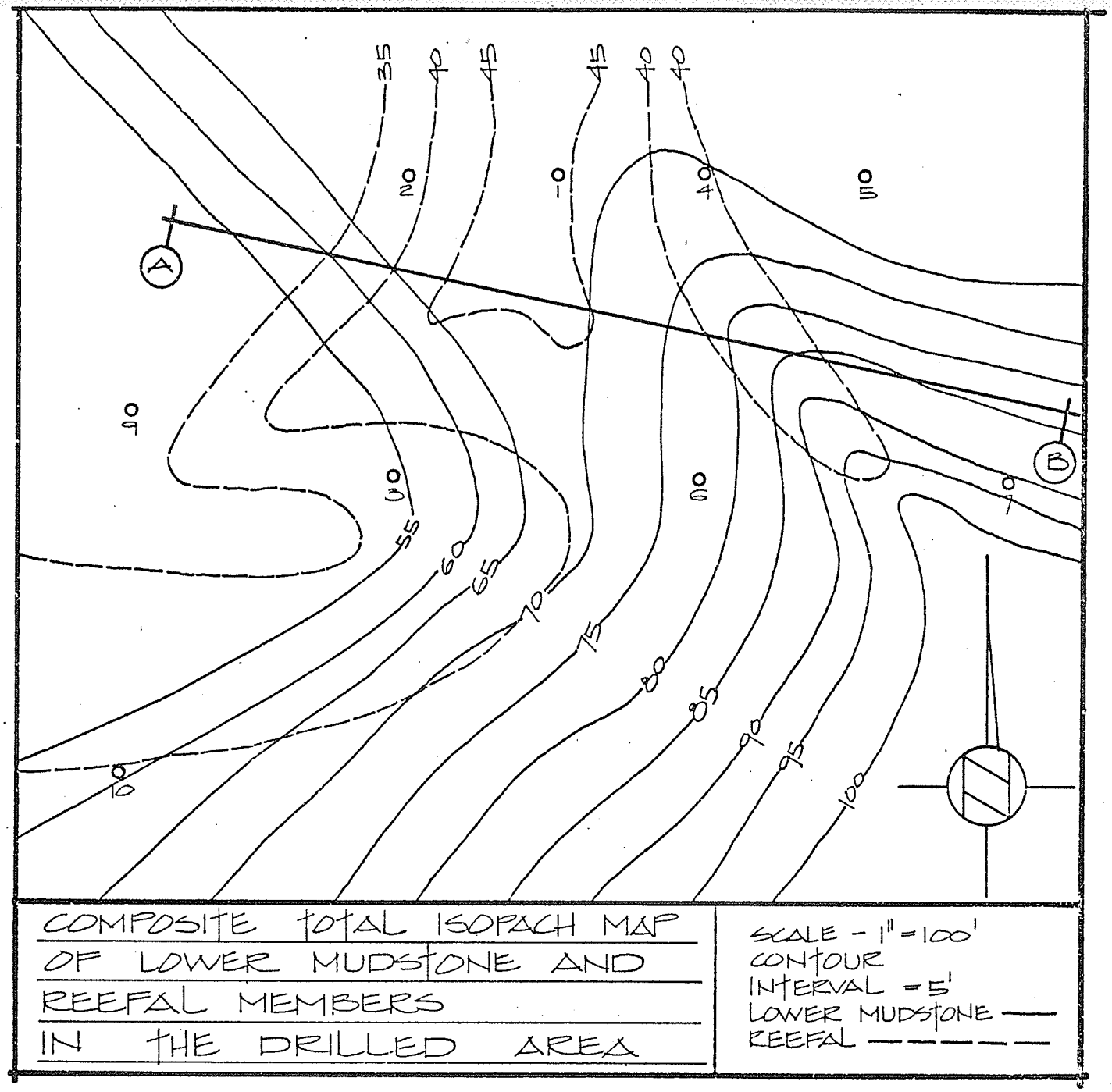
texture in the overlying unit. The crinoid-bearing mudstone lithology persists into the Nodular member across the contact.

Biofacies Distribution

The distribution of the biofacies within the Reefal member was examined in detail in the core recovered from the drilled area (Figure 3). Slope calculations performed with figures derived from a composite total isopach map of the Lower Mudstone and Reefal member (Figure 12) show that the Reefal member was deposited on an approximately 3 degree depositional slope. Within the biostromal unit a zonation of laterally equivalent biofacies was observed. In some places the biofacies distribution showed local reef buildups connected by thin fossiliferous beds overlain by mudstone (Figure 13). A vertical stacking of the banks and associated fossiliferous beds is responsible for the development of the biostromal Reefal member.

Figure 14 illustrates the general vertical zonation of the biofacies. Figures 15, 16, 17, 18 are maps showing the areal distribution of the biofacies at different levels in the Reefal member. The maps are close approximations of time instants because they were constructed at equal levels above a datum (top of the Lower Mudstone member). No feature was found that could be used to define exact time lines. The biofacies distribution maps show a facies migration eastward and illustrate the building of a reef.

FIGURE 12



COMPOSITE TOTAL ISOPACH MAP OF LOWER MUDSTONE AND REEFAL MEMBERS IN THE DRILLED AREA

SCALE - 1" = 100'
CONTOUR INTERVAL = 5'
LOWER MUDSTONE ——
REEFAL — — — —

SECTION A-B

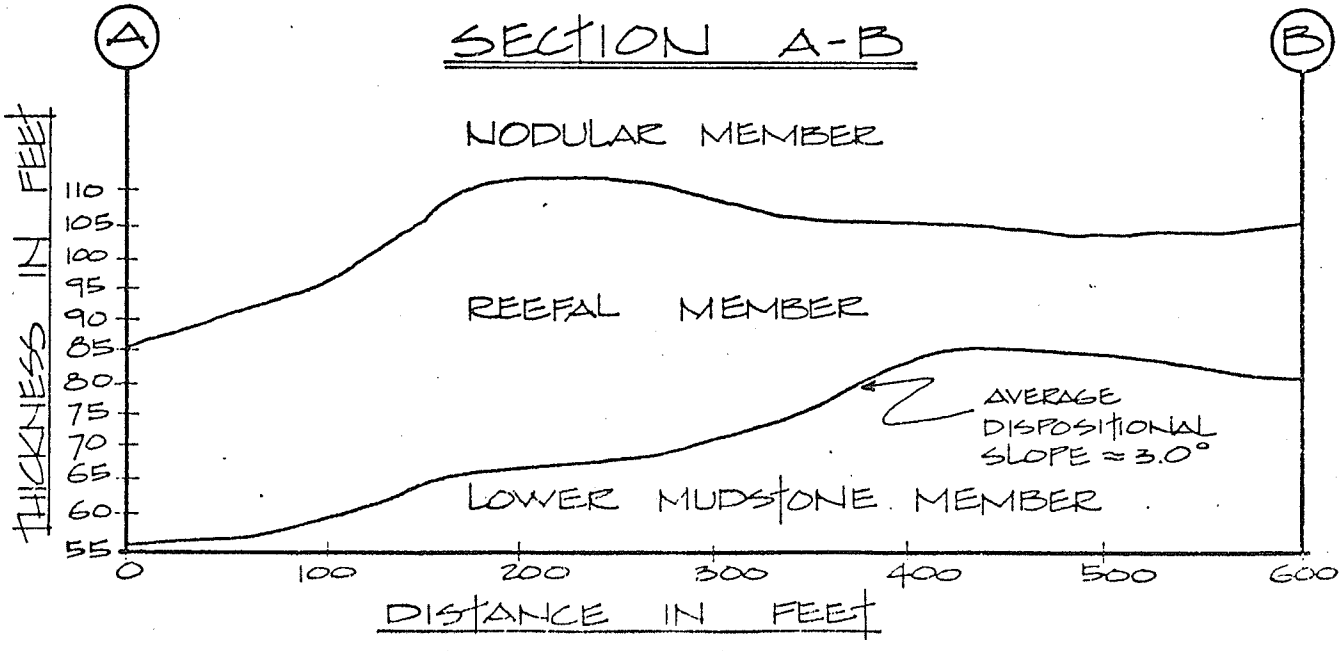


FIGURE 14

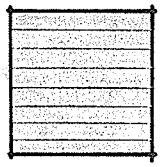
GENERAL VERTICAL ZONATION OF BIOFACIES IN THE REEFAL MEMBER

LITHOLOGY	BIOFACIES	ENERGY
ARGILLACEOUS, LIME MUDSTONES - WACKESTONES	CRINOID BEARING MUDSTONE	LOW
ARGILLACEOUS LIME WACKESTONES / PACK-STONES / LIME WACKESTONES-PACKSTONES	MASSIVE STROMATOPOROIDS / LAMELLAR STROMATOPOROIDS AND/OR TABULATE CORALS	MODERATELY HIGH / MODERATE
ARGILLACEOUS LIME-MUDSTONES WACKESTONES / LIME AND DOLO-WACKESTONES / DOLOMITIC PACKSTONES-WACKESTONES	CRINOID BEARING MUDSTONE / TABULATE CORALS / BRANCHING STROMATOPOROIDS AND TABULATE CORALS	LOW / MODERATELY LOW / MODERATELY HIGH
DOLOMITIC PACKSTONES	BRANCHING STROMATOPOROIDS	MODERATELY HIGH
LIME-WACKESTONES AND PACKSTONES	LAMELLAR STROMATOPOROIDS AND TABULATE CORALS	MODERATE
LIME-WACKESTONES	TABULATE CORALS	MODERATELY LOW
ARGILLACEOUS LIME-MUDSTONES-WACKESTONES	CRINOID BEARING MUDSTONE	LOW
LIME-WACKESTONES	TABULATE CORALS	MODERATELY LOW
LIME WACKESTONES PACKSTONES	LAMELLAR STROMATOPOROIDS	MODERATE

FIGURE 15

LEGEND

BIOFACIES OF REEFAL MEMBER

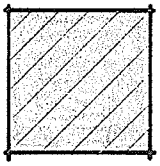


CRINOID-BEARING MUDSTONE FACIES

BLACK, VERY FINE CRYSTALLINE, FOSSILIFEROUS, LIME MUDSTONES-WACKESTONES.
MAIN FOSSILS ARE CRINOIDS, THICK AND THIN SHELLED BRACHIOPODS.

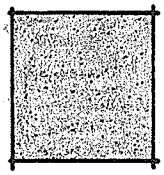
TABULATE CORAL FACIES

DARK GREY TO BLACK, FOSSILIFEROUS, SLIGHTLY ARGILLACEOUS, LIME AND DOLO-WACKESTONES.
MAIN FOSSILS ARE BRANCHING AND COLONIAL TABULATE CORALS, (THAMNOPORA MOST COMMON SPECIES).



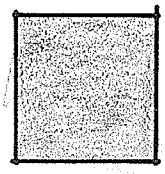
LAMELLAR STROMATOPOROID FACIES

BLACK TO DARK GREY, FOSSILIFEROUS, LIME WACKESTONES AND PACKSTONES.
MAIN FOSSILS ARE LAMELLAR STROMATOPOROIDS AND SILT SIZED ABRADED FOSSIL FRAGMENTS.



BRANCHING STROMATOPOROID FACIES

GREY TO DARK GREY, FOSSILIFEROUS, DOLOMITIC PACKSTONES AND WACKESTONES.
MAIN FOSSILS ARE BRANCHING STROMATOPOROIDS.

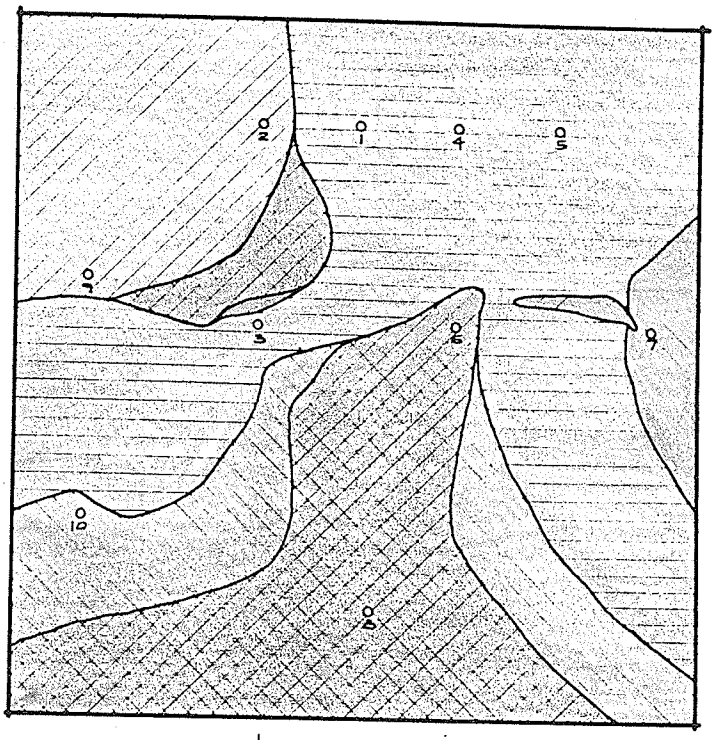


MASSIVE STROMATOPOROID FACIES

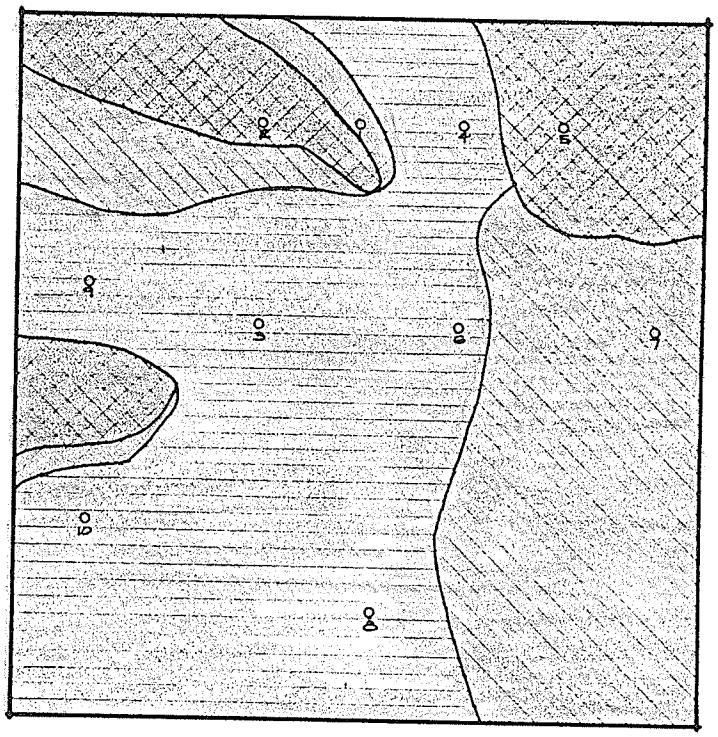
BLACK, FINE CRYSTALLINE, ARGILLACEOUS, FOSSILIFEROUS, LIME WACKESTONES AND PACKSTONES.
MAIN FOSSILS ARE BULBOUS, HEMISPHERICAL AND TABULAR STROMATOPOROIDS.

SCALE - 1" = 100'

FIGURE 16



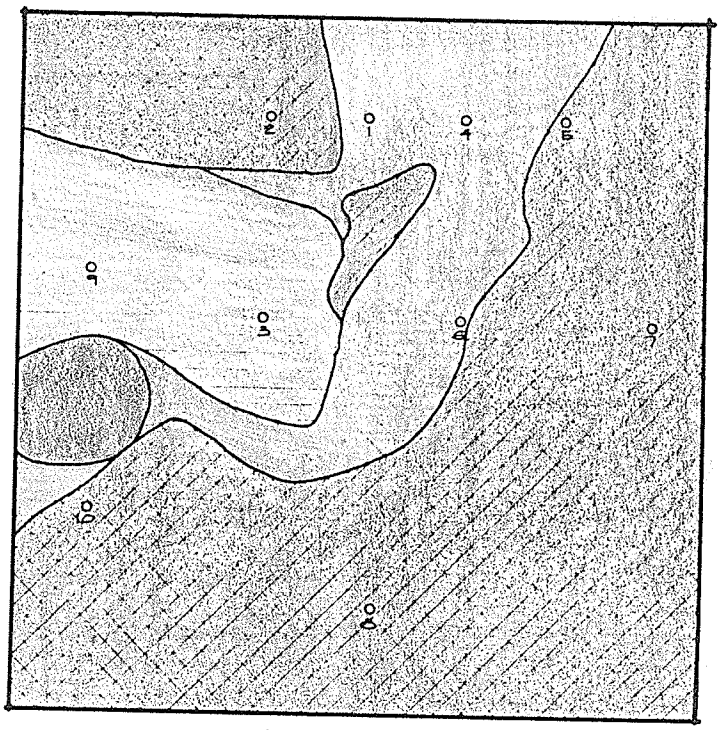
5' LEVEL



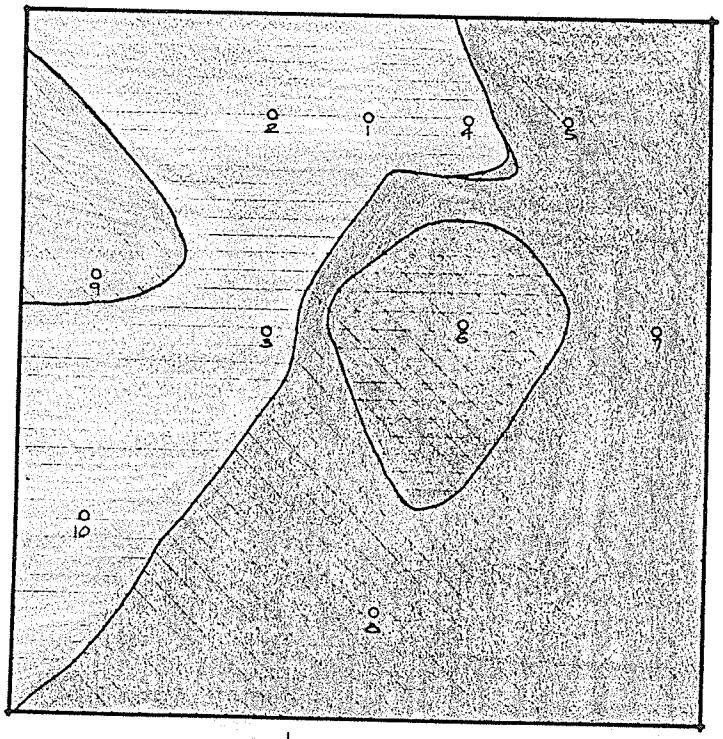
10' LEVEL

100'

FIGURE 17



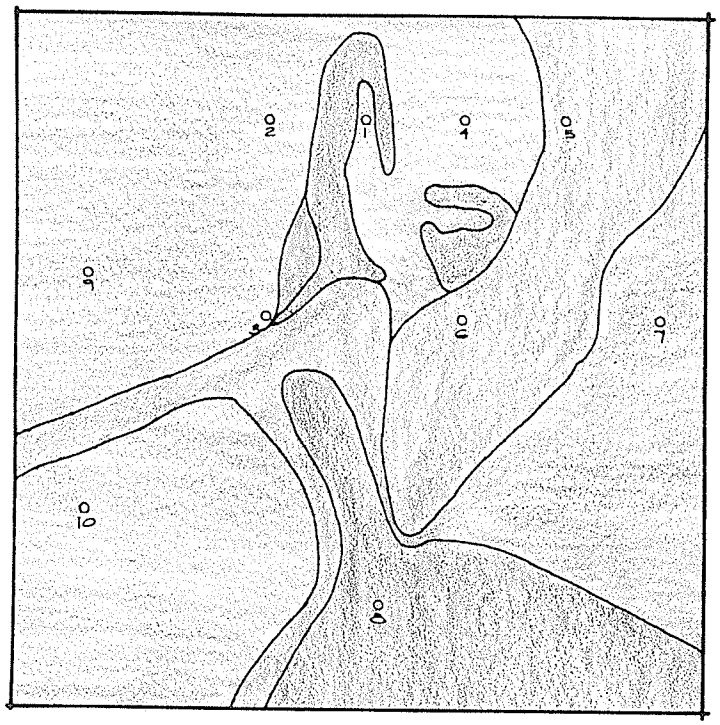
15' LEVEL



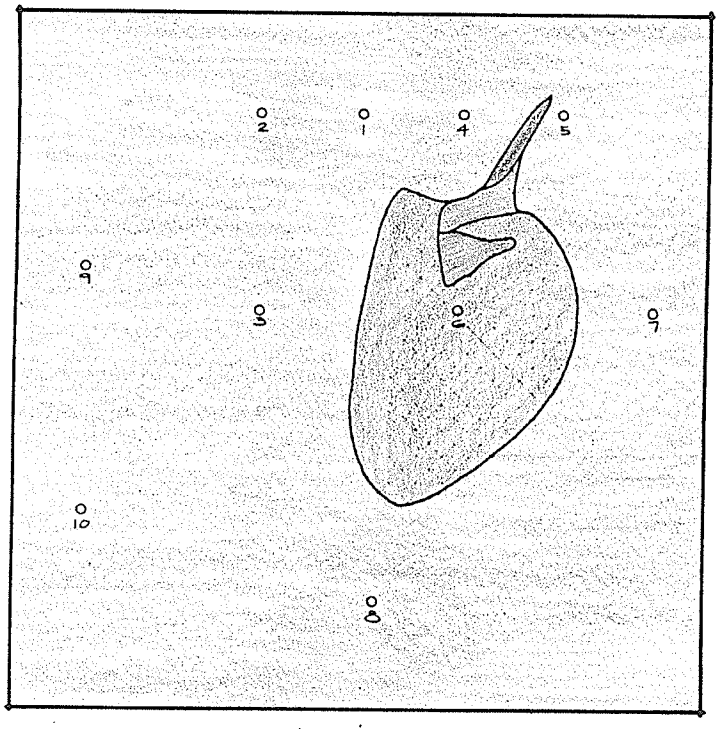
20' LEVEL

100'

FIGURE 18



25' LEVEL



30' LEVEL

100'

The three dimensional distribution of the biofacies has been summarized in Figure 13.

The following zonation pattern emerges from the study of the biofacies distribution. The pioneering organisms were tabulate corals with lamellar stromatoporoids appearing later. In some places it appears that lamellar stromatoporoids were the incipient organisms and the tabulate corals established themselves later. Eventually the tabulate corals superceded the lamellar stromatoporoids. Overlying the basal faunal assemblages are branching stromatoporoid beds that grade upward into units containing branching stromatoporoids and tabulate corals. Commonly the top of the reef is capped by massive stromatoporoids or in rare cases tabulate corals. The crinoid-bearing mudstone overlies the reef and is found in the interreef areas usually overlying fossiliferous beds.

Environmental Interpretation

A comparative study of the lithology and distribution of the biofacies indicates that each facies is representative of different energy conditions. Studies of reef paleoecology by Noble and Ferguson (1971), Klovan (1964) and Lowenstam et al (1956) show that the lithology and fauna present are predominantly energy dependent, with salinity and clarity of the water being secondary factors.

The crinoid-bearing mudstone is interpreted to be a low energy interreef deposit and upper forereef slope

deposit. The muddy nature of the rock and the presence of crinoids as the predominant fauna suggest that crinoid thickets grew below wave base and acted as baffles to trap fine grained sediments which were being shed from the fossiliferous buildups. Occasionally, storm waves destroyed the thickets and this accounts for the deposition of packstone beds composed predominantly of crinoid fragments. Wackestones containing crinoid fragments are interpreted to represent the sediment that accumulated under a normal living thicket, that is accumulation in situ. Mudstones containing crinoid fragments probably represent deeper water areas where the occasional crinoid fragment was washed in. Alternatively, they may represent a deep water environment where only a few crinoids could survive.

The lamellar stromatoporoid facies is thought to represent a subturbulent shoal environment. This environment probably existed landward of the breaking zone of the waves in the shallow area surrounding the reefs. Alternatively, it may have existed in substrate depressions below wave base. Embry and Klovan's (1971) work on the Mercy Bay Member on Banks Island, Northwest Territories suggested that lamellar stromatoporoid facies was representative of a subturbulent or semi-rough water zone that was located below average wave base, but was still within the reach of storm waves.

The branching stromatoporoid facies probably developed in a moderate energy environment. Klovan (1964) suggested

that the branching stromatoporoid facies most commonly developed on the flanks of reefal buildups.

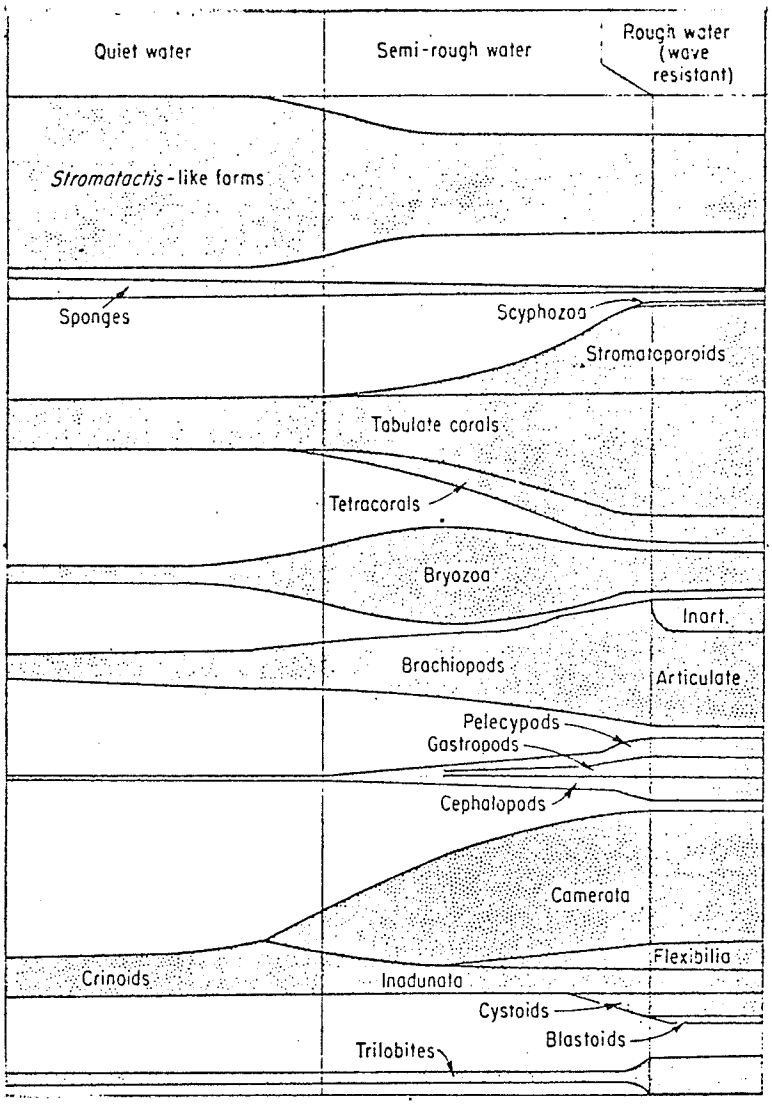
The massive stromatoporoid facies has been interpreted by Laporte (1967), Lecompte (1958), Noble and Ferguson (1971) and Embry and Klovan (1971) to have developed in a high energy, very turbulent environment. In the Nabesche River area this facies consists of argillaceous, lime wackestones and packstones. Because the rock is not a boundstone the energy conditions were probably much lower than what is normally considered high energy in most other studies. The massive stromatoporoid facies undoubtedly represents the highest energy environment present in the Reefal member, but when compared with other studies, it would be considered only moderately high energy. This environment probably occurred just behind the breaking zone.

The tabulate coral facies is representative of a transitional facies between the moderately high energy environment of the massive stromatoporoid facies and the low energy environment of the crinoid-bearing mudstone facies. The moderately low turbulent environment probably was similar to the shoal environment of the lamellar stromatoporoid facies, but slightly lower in energy. This is why the two facies are so commonly associated. However, Embry and Klovan (1971) believed that tabulate coral facies represented a quiet water environment well below the wave base.

Discussion

Generally the same facies-energy relationships have been observed by other authors. Lowenstam et al (1956) established one of the first energy biofacies relationships while working

FIGURE 19



ENERGY – BIOFACIES RELATIONSHIPS IN THE NIAGARAN REEFS IN THE GREAT LAKES AREA

(FROM LOWENSTAM ET AL (1956))

on Silurian rocks in the southern part of the Michigan Basin. They subdivided the energy spectrum into quiet water, semi-rough water and rough water stages (Figure 19). The diagnostic fossils in each stage were tabulate corals, stromatoporoids and tabulate corals respectively. Lecompte (1958) noted six biofacies in his progressive subsidence model for the development of a carbonate-shale transition. The first or highest energy zone, was characterized by the dominance of massive stromatoporoids. The second zone, believed to be representative of the subturbulent environment, was characterized by lamellar stromatoporoids and some branching tabulate corals. The third zone was rich in coral growth and interpreted to represent moderate energy conditions. The fourth zone was dominated by brachiopods and was characteristic of quiet water low energy conditions. The fifth and sixth zones were characteristic of extremely low energy, deep water environments. Noble and Ferguson (1971) completed a detailed paleoecological study of shelf carbonates in the South Nahanni River area. Their work is summarized in Figure 20, which shows the faunal community and its interpreted environment.

Monseur and Pel (1972) described the development of a Givetian reef in Europe. The rocks at the Nabesche River are similar to their unit II which first developed tabulate coral and lamellar stromatoporoid facies on a shallow slope and then extended upwards into the turbulent zone establishing the massive stromatoporoid facies.

Wilson (1974) described three types of carbonate shelf margins. Type I is characterized by a slope varying between

FIGURE 20

COMMUNITY / FAUNAL COMPONENTS	MASSIVE STROMS	BRANCHING STROMS	LAMINAR STROMS	MASSIVE TABULATE CORALS	BRANCHING TABULATE CORALS	LAMINAR TABULATE CORALS	MASSIVE RUGOSE CORALS	FASCICULATE RUGOSE CORALS	SOLITARY RUGOSE CORALS	BRACHIOPODS	CRINOIDS	GASTROPODS	PELECYPODS	TRILOBITES	OSTRACODS	BRYOZOA	CRICOCONARIDS	AMMONOIDS	INTERPRETED ENVIRONMENT
MASSIVE STROM - CORAL	△	△		X	X		X	X	X	X	X	X							OUTER SHELF - SLIGHTLY RESTRICTED
SPINULICOSTA - ATRYPID					X				X	△	X	X		X					OUTER SHELF - SLIGHTLY RESTRICTED
LAMINAR STROM	X		△	△		△	X		X	X	X			X	X				SHELF EDGE
SYRINGOPORA - SPINULICOSTA	X	X			△		X			X	X	X							SHELF EDGE
BRANCHING TABULATE CORAL	X	△		X	△		X		X	X	X	X			X				SHELF EDGE - SHOAL
ATRYPA - BRYOZOA					X					△	X	X				△			SHELF EDGE - SHOAL
WARRENELLA - RYNCHONELLID									X	△	△	X	X	X	X		X		SLOPE - BASIN
EMANUELLA - PELECYPOD										△			△	X	X				SLOPE - BASIN
PELAGIC COMMUNITY										X	X				X		△	△	BASIN

LEGEND
△ MAJOR COMPONENTS
X MINOR COMPONENTS
ABSENT OR RARE

COMPOSITION OF THE PRINCIPAL FAUNAL COMMUNITIES AND THEIR INTERPRETED ENVIRONMENTS. MIDDLE DEVONIAN CARBONATE SHELF IN THE SOUTH NAHANNI RIVER AREA N.W.T. (FROM NOBLE AND FERGUSON (1971))

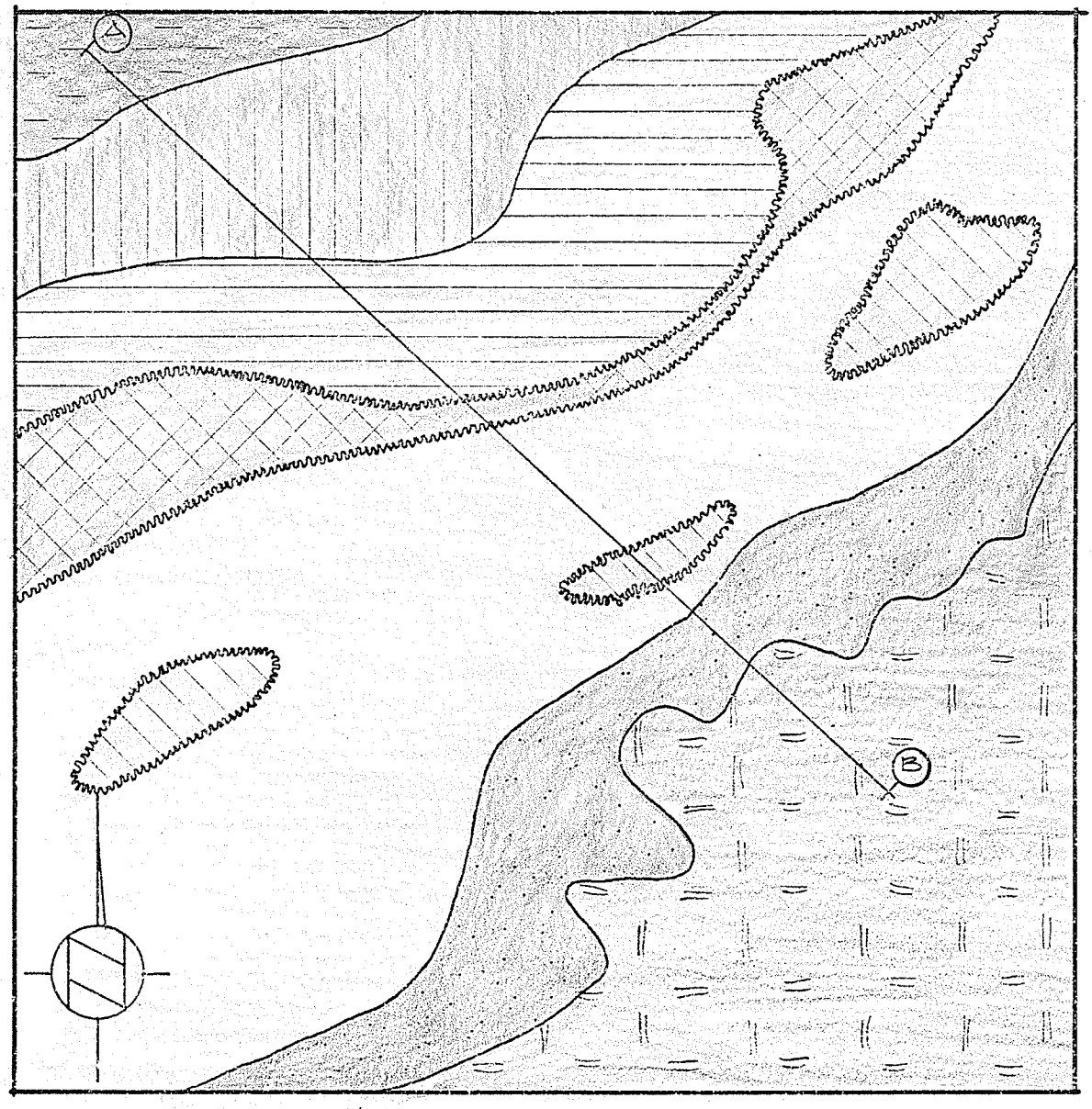
2 and 25 degrees and quiet seas. Type II has a less than 5 degree slope with quiet to moderate seas. Type III is characterized by steep slopes up to 45 degrees or more, foreslope talus blocks and rough seas.

The Slave Point Formation in the Nabesche River area was deposited on Wilson's (1974) Type II shelf margin. The shelf edge exhibits a gentle seaward slope of less than 5 degrees. Linear belts or knoll shaped organic reefs are usually found on the Type II slope of the shelf margin. They were deposited under quiet to moderate energy conditions with mostly sessile and encrusting organisms flourishing below wave base. Upward change in the growth form to massive encrusting frame builders shows that the reef grew and survived just above wave base. In this model the interreef deposits are volumetrically much greater than the reefs and it is not uncommon to find that the reef cores contain lime mud and reef derived debris. Wilson (1974) also pointed out that in times of great organic productivity and moderate subsidence organic buildout resulted in the construction of a gently seaward sloping platform. Figure 21 illustrates the shelf edge position of the Reefal member.

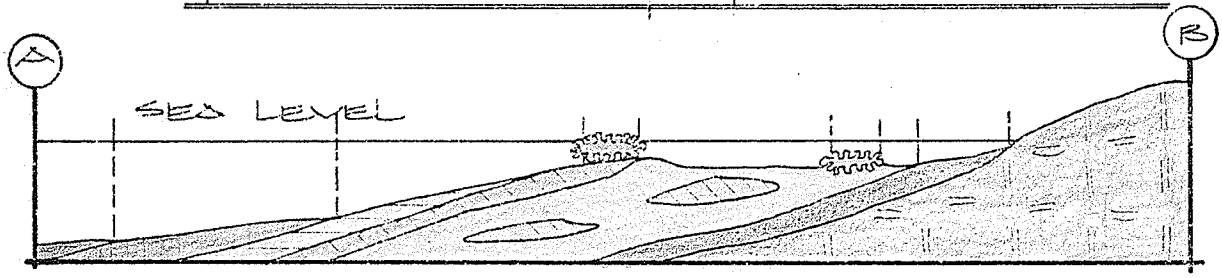
The depositional model envisaged for the development of the Reefal member is very similar to Laporte's (1967) interpretation of the Lower Devonian Manlius Formation in New York state. He documented a biostrome that had developed on a shallow shelf margin slope. Dolphin and Klovan's (1970) work on the Upper Devonian Cairn

FIGURE 21

HYPOTHETICAL DEPOSITIONAL FACIES DISTRIBUTION IN THE SLAVE POINT SEE-NABESCHE RIVER AREA



SCHEMATIC SECTION ILLUSTRATING THE SLAVE POINT TRANSGRESSION



- PEACE RIVER ARCH
- WATT MOUNTAIN FORMATION
- LOWER MUDSTONE MEMBER
- PATCH REEFS
- REEFAL MEMBER
- NODULAR MEMBER
- UPPER MUDSTONE MEMBER
- BESA RIVER FORMATION

HORIZONTAL SCALE - 1" = 3 MILES

Formation in Alberta described how the impingement of waves on a shallow slope is capable of producing the variety of energy niches needed to develop Nabesche River type biostromes.

On the shallow depositional slope the area of breaking waves probably occurred at a considerable distance seaward of the area of the developing biostrome. Only light to moderate surf passed over the areas where lamellar stromatoporoids and tabulate corals flourished. In shallower areas, where subturbulent energy conditions prevailed, lamellar stromatoporoids developed. In other areas, where energy conditions were lower, such as local depressions in the sea bottom, tabulate corals flourished. As the sea transgressed and upward growth of the biostrome continued, higher energy conditions prevailed. Branching stromatoporoid thickets developed in these areas. Tabulate coral growth was able to continue in the lee of these thickets. When the organic growth had reached wave base, massive stromatoporoids grew in the more turbulent environment. On the flanks of the massive stromatoporoid growth, branching stromatoporoids, lamellar stromatoporoids and tabulate corals continued to flourish. Seaward of the reef, and in areas of very low energy within the organic complex, the crinoid-bearing mudstone facies developed. During periods of the biostrome's development, sea level rose faster than the upward growth of the reef in some places. As a result the crinoid-bearing

mudstone facies accumulated in these areas, This explains the interfingering of the crinoid-bearing mudstone facies with the coral-stromatoporoid reefal facies. Ultimately sea level rose faster than shallow water carbonate accumulations and the relatively deeper water crinoid-bearing mudstone facies accumulated over the whole area.

Nodular Member

Lithological Description

The rock of the 48 to 93 foot thick Nodular member exhibits a characteristic nodular or sedimentary boudinage-like structure (Plate 6). This texture is particularly noticeable in drill core. There are three basic components of the fabric: a light grey lime mudstone, a black argillaceous lime mudstone and various allochems. The nodules consist of the light grey lime mudstone and are set in a matrix of black argillaceous lime mudstone. The allochems usually are fossil fragments. The weathered surface has a characteristic recessive, knobby texture.

Nodules

The lithology of the nodules consists of light grey, massive, fine crystalline lime mudstone. Under the binocular microscope the rock exhibits an equigranular texture, but in thin section the rock is micrite. The contact of the nodules may be extremely sharp or very diffuse with all the gradations in between. In many cases one side of the nodule may be defined by a large brachiopod shell (Plates 6b,7a,7b).

The outlines of the nodules are elliptical in shape, but subangular forms are found locally. These commonly occur in places where it appears that the matrix has cut the nodules, splintering them into many pieces. In many cases the nodules will contain patches of highly recrystallized rock. The recrystallization fabric is distinguished by its coarser crystalline nature. In the vicinity of recrystallized patches the lime mudstone is usually very pyrite rich. Some recrystallized patches appear to have been fossiliferous packstones, an observation that is confirmed in thin section (Plates 7b, 7c). Non altered equivalents of the packstone were rarely found. The fabric in the recrystallized patches is coarser crystalline in fossiliferous areas and slightly finer grained in pure lime mudstone.

Often the nodules have conspicuous V-shaped fractures that are healed by white sparry calcite or dolomite. These fractures begin as hairline fractures on one side of the nodule and widen out towards the other side. The widest part of the fracture is commonly filled with dolomite. There seems to be no particular orientation of the fractures, that is, they may be perpendicular or parallel to the long axis of the nodule. In thin section the fractures were found to be perpendicular to the shale seams (Plate 6d). Pyrite is usually found in the vicinity of these fractures. The fractures end sharply at the boundary of the nodule.

Usually the nodules do not contain visible fossils, but in some cases crinoid fragments are found within the nodules. In thin section brachiopods, gastropods, crinoids, and unidentified skeletal fragments were found within the nodules near the edges, but this only occurs in fossiliferous zones of the unit.

Matrix

The lithology of the dark shaly matrix consists of black, very fine crystalline, argillaceous, dolomitic lime mudstone. In most cases the fabric is a fossiliferous wackestone with fossil fragments greater than 0.8 mm in size. The main fossils present are tiny brachiopod or ostracod shells, crinoid fragments or in rare cases coral and stromatoporoid fragments. Up to 20% pyrite occurs in the matrix in the form of fine grains less than 0.1 mm in size. Where the rock becomes very shaly the fabric is finely laminated. The shaly matrix occurs in what appears to be large seams or stylolites that are sinuous and irregularly shaped. They are widely distributed throughout the Nodular member. The seams generally vary from $\frac{1}{4}$"-2" in thickness. In all cases the shaly seams or stylolites are parallel to subparallel to bedding. Usually the larger seams pass laterally into smaller stylolites that commonly cut the nodules. The stylolite fabric of the rock is evident in Plates 6c, 6d.

Compaction structures, such as draping or wraping of the matrix around the nodules and larger fossil fragments

is an outstanding feature of the fabric. No attempt was made to estimate the total compaction within the member.

In some places small dolomite rhombs replace or displace the shaly matrix and commonly the dolomite will be concentrated in patches. The dolomite was found to be iron-rich. In thin section the distribution of the dolomite rhombs was found throughout the argillaceous matrix. In areas of low shale content, where dolomite rhombs are in much closer contact with each other only the intercrystalline voids contain argillaceous material.

Allochems

The allochems present in the rock are predominantly fossil fragments, but in a few places up to 1" subangular to angular clasts (intraclasts ?) occur. Volumetrically, the most important fossil fragments are thick and thin shelled brachiopods, ostracod shells, and crinoid ossicles. Generally the fossils debris tends to be concentrated in the matrix. The shell fragments appear to be more concentrated in the dark matrix and the crinoids occur in the nodules, but in the case of the crinoids there is much overlap and they are often found in the black matrix. It was found that the brachiopod shells were more common near the top of the unit, while crinoid fragments were more abundant near the bottom. Gastropod shells, coral and stromatoporoid fragments were observed, but they are not volumetrically important.

The size of the fossil fragments ranges from submicroscopic to approximately 2 cm in diameter. The elongated fossil fragments, mainly brachiopod shells, usually are aligned with the laminations of the shaly rock. In places where the laminations drape around the more competent nodules, the fragments conform with the laminations. Locally, stretching, breaking, and displacement of shells by the matrix occurred. Potassium ferricyanide and alizarin red S staining of the rocks showed that the fossils are mostly replaced by white iron-poor sparry calcite. Clear, sparry calcite; white, iron-rich, sparry, dolomite or pyrite also replace or rim fossils.

Random pyrite patches occur throughout the rock in both the light and dark lithologies. The patches always have pyrite haloes surrounding them. Generally larger, more concentrated patches of pyrite occur in the nodules. In many places pyrite cubes cut the contact between the light and dark lithologies.

The interrelationships of the light grey lime mudstone nodules, the black argillaceous matrix, and the allochems combine to give the rock a characteristic mottled texture. The general appearance of the rocks is one of light grey coloured nodules floating in a dark matrix (Plates 6b, 6c). The nodular fabric may be described as a mottled, limestone consisting of a series of anastomosing shaly seams enclosing nodules composed mainly of recrystallized limestone.

Contacts

Both the upper and lower contacts of the Nodular member are sharp. They are easy to identify in drill core because of the abrupt disappearance of the nodular texture. Downward the unit passes into a crinoid rich lime mudstone and upward into a shaly lime mudstone. Even though the contacts are sharp, it is believed that there was continuous deposition across both contacts. The change in lithology is only a reflection of an abrupt change in the environment of deposition.

Environmental Interpretation

The presence of lime mudstone and shale indicates that depositional environment of the Nodular member was probably low energy. The uniformly bedded rock and the variable shale content suggest that periodically there was a greater influx of clay material into a carbonate setting. Alternatively, there may have been fluctuations in sea level that caused minor facies shifts.

The faunal assemblage consists predominantly of brachiopods, crinoids, ostracods and gastropods. According to Noble and Ferguson (1971) such an assemblage may represent a low energy deep water slope environment. Locally, stromatoporoid and coral fragments were found (Plate 4c). The fragments probably originated in a higher energy environment and were subsequently transported to their present position.

The combination of the lithology and the faunal

assemblage suggests that the rock was deposited in a low energy environment, probably on the forereef slope (Figure 21). Hopkins' (1972) study of the Upper Devonian Miette reef foreslope in Alberta showed that the reef foreslope may be divided into foreslope, nearslope and basin. The Nodular member probably was deposited in Hopkins' (1972) nearslope environment. According to Wilson's (1970) scheme, the Nodular member would be classified as tidal shelf or toe of the slope facies.

The forereef rubble and exotic mega-breccia blocks described by Srivastava et al (1972) at the margin of the Upper Devonian Ancient Wall carbonate complex were not found in the Nabesche River area. In a few places near the top of the underlying Reefal member a few overturned massive stromatoporoid heads were observed, but these were not considered as forereef rubble. The absence of a forereef mega-breccia is probably caused by the lack of any appreciable relief developed by the reef, because of its biostromal nature.

The Origin of the Nodular Fabric

A nodular texture in carbonates may be developed by several processes. A distinct nodular, mottled fabric is commonly the result of burrowing by organisms (Winder (1968)), but when no evidence of burrowing may be found and the composition of the rock is quite argillaceous

three other possibilities present themselves. The origin of a nodular fabric may be achieved by compaction, selective recrystallization or pressure solution.

McCrossan (1958) described a nodular texture in the Ireton Formation and proposed an origin for the structure. He suggested that lime muds and clays were deposited in varying proportions on a gently undulating bottom. As the laterally unconfined sediments became compacted they spread plastically to lower areas in the basin. The more plastic, shaly rock spread faster than the more competant lime mudstone creating drag along the contacts. Eventually the lime mudstone beds thinned, became elongated, and at points of weakness ruptured into separate lenses. As the process continued the separate lenses interfered with each other causing a draping over and a squeezing of each other. The resultant texture was limy lenses scattered randomly in more argillaceous rock. In effect, McCrossan (1958) suggested a sedimentary boudinage process for the development of the nodular texture.

Hopkins (1972) also described a nodular, clayey limestone, containing brachiopod and echinoderm fragments, peloids and thin shelled pelagic organisms in the Mount Hawk Formation. He suggested that in the absence of direct evidence for burrowing the nodular fabric was formed by selective recrystallization. That is, the recrystallization affected only the carbonate mud and not the allochems. Williams et al (1955) pointed out that clay inhibits the

formation of sparry calcite. Therefore recrystallization did not occur in the more argillaceous areas of the rock and proceeded in the lime mud. The resultant texture would be similar to that of the Nodular member.

Mossop (1972) showed how pressure solution could produce a nodular texture. Many authors agree that stylolite and residual shale seams are a result of pressure solution. Stylolites tend to develop in areas of inhomogeneity in the rock, such as near the contact of lime mudstone and argillaceous mudstone. If the rock is under pressure for a great length of time many stylolites will form. Often they coalesce in what Mossop (1972) called "Horsetail Groups". A horsetail group looks very much like a sheaf of wheat with each individual stalk of wheat representing a stylolite. A great many of these horsetail features stacked one on top of the other and arranged laterally give the appearance of a nodular texture.

Bathurst (1971) showed that stylolites very commonly will start in a fossiliferous bed, especially along a bedding plane. Hypothetically, if one were to begin with a rock composed of 60% argillaceous lime mud and 40% fossil fragments and then stress it such that pressure solution processes could operate, probably the majority of the lime mud would be dissolved and the resultant rock would be one of approximately 80% fossil fragments and 20% insoluble residue. The residual rock would be representative of a significant loss in volume. This process is en-

visaged for the development of the fossiliferous shaly matrix found in the Nodular member. In the non nodular sections of the member the rock consists of approximately 60% argillaceous lime muds and 40% fossil fragments. This lithology commonly is overlain by thick, argillaceous, fossil rich seams composed of 80% fossil fragments and 20% shaly matrix.

Bathurst (1958) pointed out that a great volume of calcium carbonate may be released during the formation of a stylolite. Much of this calcium carbonate is precipitated in the voids adjacent to the stylolite. The cementation of the porosity in the lime mud near the shaly seams is probably a result of this process. The V-shaped fractures in the nodules, probably tension fractures caused by lateral stretching on the rock, are healed by calcium carbonate presumably made available by pressure solution.

No one particular process is considered to have caused the nodular texture in the Nodular member of the Slave Point Formation. All three processes may have been instrumental at some time in the history of the rock. The lenticular morphology of the nodules and the presence of V-shaped fractures suggests that the rock underwent compaction. The recrystallized fabric of the nodules in the non altered shaly matrix shows that selective recrystallization has taken place. The presence of a large number of stylolites and shaly seams indicates that pressure solution has occurred in the rock. The closely associated processes of compaction and pressure solution are probably most

responsible for the development of the nodular texture. The larger nodules may have been formed by sedimentary boudinage. The smaller more irregularly shaped nodules probably were produced by stylolite formation as the result of pressure solution. The entire fabric was modified and made more distinctive by selective recrystallization and cementation, which again are related to pressure solution.

Hopkins (1972), Wilson (1970) and McCrossan (1958) agree that nodular rock may form in the forereef slope environment. Hopkins (1972), Mossop (1972) and Bathurst (1971) implied that a nodular fabric probably is a product of diagenesis and volume reduction in the rock.

Upper Mudstone Member

Lithological Description

The 60 to 102+ foot thick Upper Mudstone member consists predominantly of thin bedded (individual beds less than 1 foot thick), black to brown, fine crystalline, very argillaceous, lime mudstone. The beds usually contain $\frac{1}{4}$"-$\frac{1}{2}$" laminations. Scattered throughout the rock are small vugs that are filled with a brown sandy soil. Outcrop exposure of this unit is poor, therefore it is difficult to determine if the sandy soil in the vugs is Middle Devonian in age or post Laramide. No fossils were found in the samples collected.

The rock weathers grey-brown, has an earthy texture and is extremely recessive. In outcrop a very pronounced cleavage was observed with an attitude of 96°/44° S.

Contacts

The lower contact is placed at the top of the last fossil bearing bed in the Nodular member. In drill core this generally coincides with the disappearance of the nodular fabric. The contact is sharp in the sense that the disappearance of fossils is abrupt, but the characteristics of the matrix do not change across the contact. Insoluble residue data show that the average amount of clay in the rock increases gradually across the contact from about 10% to about 20%. In this respect the contact is gradational. The contact is interpreted to be conformable.

The position and nature of the upper contact is a matter of controversy and because it is the upper contact of the Slave Point Formation it has been discussed in detail elsewhere in this paper (Chapter III p. 29). The contact in the field is transitional from an argillaceous limestone to a calcareous shale. For the purposes of this study the contact was placed where the insoluble residue content of the rock first became greater than 50% of the rock.

Environmental Interpretation

The composition and fine grained nature of the argillaceous lime mudstone are indicative of a very low energy environment. The thin bedded character of the rock and the laminated beds show that the nature of the supply

of sediments was episodic. The apparent absence of fossils indicates that the water depth may have been greater than the depth of the photic zone, thereby inhibiting the growth of benthic organisms.

The presence of a large amount of clay, the laminated bedding and the absence of fossils would indicate that the rock of the Upper Mudstone member was deposited in a deep water open marine environment (Figure 21). According to Wilson's (1970) classification the Upper Mudstone member would be called basin facies.

Geological History

Griffin (1965), McCamis and Griffith (1967) and Belyea (1971) have described the regional geological history of the Slave Point Formation in northeastern British Columbia, Zama area and northern Alberta respectively. The Slave Point Formation represents the spread of normal open marine conditions eastward over the area, after a period of fluctuating sea-levels. During the period of unstable conditions the Sulphur Point and Watt Mountain Formations were deposited. The return of more stable conditions permitted the growth of carbonate complexes and the accumulation of the associated shelf-type sediments. A barrier reef developed in a north and northeasterly trend along the edge of the carbonate platform. The major framework builders of the barrier reef were stromatoporoids. The reef was not of uniform thickness along the length of the front

(Douglas et al, 1970). Biostromal beds lay between areas of maximum reef growth. The Nabesche River area is an illustration of such a biostromal buildup. Westward and northward the barrier reef facies passes abruptly into shale (Douglas et al, 1970). Behind the barrier reef, southward and eastward, an immense, clear, warm, shallow water lagoon existed. In many places throughout this environment patch reef and carbonate mud banks developed and it is not inconceivable that near the eastern limit of the lagoon an evaporitic environment existed (Figure 8). Near the end of Slave Point deposition, the area experienced an increased rate of subsidence allowing the argillaceous marine basin facies to spread eastwards. The greater amount of clay and mud prevented the further growth of reef building organisms and they were replaced by brachiopods and bottom dwellers that could survive in the turbid environment. Slave Point deposition was brought to a close by the deposition of the Besa River shale. According to Griffin (1965), at the end of Beaverhill Lake time, uplift took place and erosion exposed the Slave Point Formation north of latitude 58°30'N. Upon submergence, the Muskwa shale and Fort Simpson shale were deposited on the eroded Slave Point surface.

Summary of the Geology of the Slave Point Formation inthe Nabesche River Area

The 55 to 70 foot thick basal member, the Lower Mudstone member, consists of two facies: a reefal facies that is

characterized by black, fossiliferous, lime wackestones and mudstones and an overlying mudstone facies consisting of black lime mudstones containing scattered fossil fragments.

The 40 to 46 foot thick conformably overlying Reefal member is a biostrome composed of five biofacies: the dark, crinoid bearing mudstone facies, the lamellar stromatoporoid facies consisting of black, fossiliferous wackestones and packstones, the branching stromatoporoid facies characterized by dark grey fossiliferous dolomitic packstones, the massive stromatoporoid facies represented by black, shaly, fossiliferous wackestones and the tabulate coral facies consisting of dark grey to black fossiliferous wackestones and packstones.

The Reefal member is overlain conformably by the 48 to 93 foot thick Nodular member. The nodular fabric of this unit is very distinctive in drill core. The distinctive texture is composed of three elements: a black argillaceous lime mudstone matrix, grey lime mudstone nodules and scattered fossil fragments. The fabric gives the appearance of grey nodules floating in a black matrix with fossils scattered throughout.

Conformably overlying the Nodular member is the 60 to 102+ foot thick Upper Mudstone member that consists of a monotonous black to brown argillaceous lime mudstone.

The lower contact of the Slave Point Formation with the Watt Mountain Formation was found to be gradational and interpreted to be conformable. The upper contact with

the Besa River Formation was never directly observed, but on the basis of insoluble residue data and limited sampling of the rocks spanning the contact, it is suspected to be gradational and probably conformable.

The Slave Point Formation was deposited on a very slightly northward dipping platform. Each member within the formation is representative of a facies in the depositional model devised for carbonate environments by Wilson (1970, 1974). The vertical succession of the facies is a result of onlap by the late Givetian southeastward transgression. Figure 21 illustrates the hypothetical distribution of depositional facies in the Slave Point sea. Section A-B indicates the path of movement of depositional facies across the Nabesche River area. The Lower Mudstone member is shown as a back-reef lagoon environment where patch reefs and organic banks flourished and were separated by areas of lime mud deposition. The Reefal member is interpreted to be a biostromal unit that existed between larger biohermal buildups at the shelf edge. Collectively, the biostromes and bioherms represent the regional barrier facies of the Slave Point Formation. The Nodular member was deposited on a gently dipping forereef slope. The Upper Mudstone member, a transitional facies between carbonates and shales, probably accumulated near the bottom of the reef foreslope.

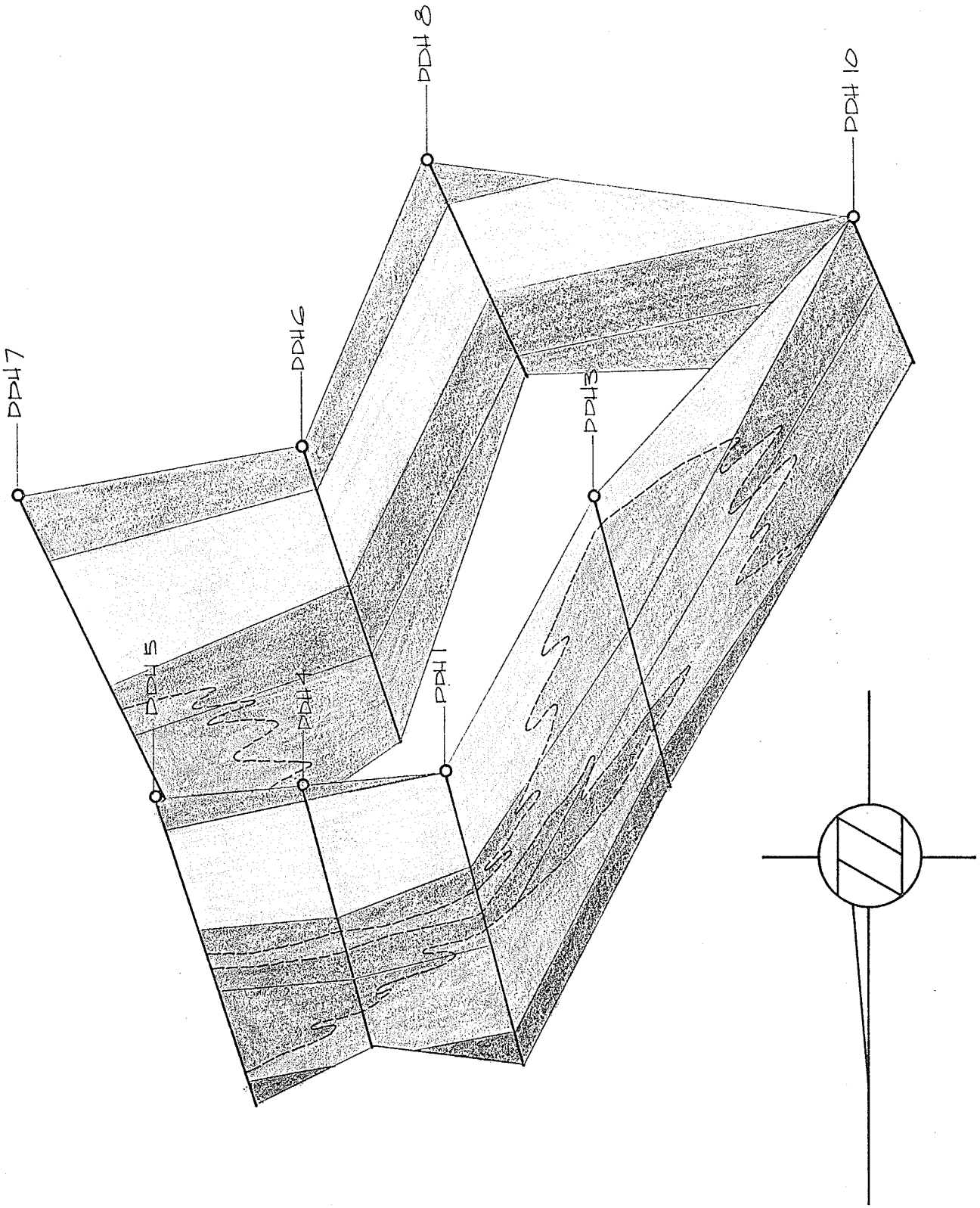
CHAPTER FOUR - DIAGENESIS AND MINERALIZATION IN THE SLAVE POINT FORMATION

Dolomitization

Within the Slave Point Formation of the Nabesche River area there are large volumes of dolomitized rock. They are distributed mainly throughout the Lower Mudstone member and in the branching stromatoporoid facies of the Reefal member (Figure 22). The Nodular member was rarely dolomitized and the Upper Mudstone member apparently was not dolomitized.

Two types of dolomite were observed within the altered zones. One of these, a light grey to dark grey, fine to coarse crystalline dolomite comprising the host rock in the altered zones, was termed macrodolomite by Macqueen and Taylor (1974). The fabric is composed of a mosaic of small dolomite rhombs. Commonly the individual rhombs average about 40 microns in size. The intercrystalline voids are often filled with black shale giving the rock a checkerboard appearance. The amount of argillaceous material present may vary from zero, in rocks which have an interlocking crystal mosaic, to over 50%, in which case the crystals are supported by the argillaceous matrix (Plate 8a). Variation in the size of the dolomite crystals from several microns to a millimeter in diameter occur locally. Mutually exclusive patches of finer and coarser crystalline material result in a texture that has a breccia-like appearance (Plate 8b). Staining showed that the individual rhombs are composed of iron-rich dolomite. Many rhombs are zoned with an iron-poor

FIGURE 22



FENCE DIAGRAM SHOWING STRATIGRAPHY OF THE SLAVE POINT FORMATION IN THE DRILLED AREA - NABESCHE RIVER AREA

- WATT MOUNTAIN FORMATION
- LOWER MUDSTONE MEMBER
- REEFAL MEMBER
- NODULAR MEMBER
- UPPER MUDSTONE MEMBER
- ALTERED ZONE

SCALE - 1" = 100'

centre and an iron-rich outer margin. The zoned crystals occur most commonly in areas of high argillaceous content, but not exclusively. Original fabric features are rarely preserved. In a few cases ghosts of veinlets and fossils are seen in the mosaic. Large fossils and sedimentary structures are preserved.

The second type of dolomite that occurs is white and coarse to very coarse crystalline. Macqueen and Taylor (1974) called this dolomite Presqu'ile type. Beales (1971) refers to the same type of dolomite as white sparry dolomite cement. The problem with this type of dolomite lies in how much of it originated as void or fracture filling and how much originated as an in situ replacement.

Dunsmore (1973) described a process that shows how the Presqu'ile type dolomite could have developed. The original rock was probably a fossiliferous limestone. The process was initiated by fracturing of the limestone and filling of the fractures by white sparry dolomite cement. The dolomite grew outwards from the fractures and replaced the limestone on either side of the fractures. This process continued until only scattered pockets of limestone remained. The remaining limestone was dissolved, forming a vug lined by white sparry dolomite. Further growth into the void may have occurred at a later time.

Dunsmore (1973) suggested that the corrosive fluid that dissolved the limestone originated from the exothermic reduction of sulfate ions from anhydrite in the presence of

hydrocarbons. The suggested products of this reaction could be hydrogen sulfide, carbon dioxide, water and heat. A fluid with these components would be highly corrosive to limestone. Although this process could account for large scale replacement of limestone, it seems less likely to explain the large volumes of Presqu'ile type dolomite which occur in macrodolomite.

The nature and the distribution of both types of dolomite within the altered zones of the Slave Point Formation indicate that they are of secondary origin. No dolomite of possible penecontemperaneous (i.e. sabkha-type) origin was observed within the Slave Point Formation.

C e m e n t a t i o n

Four types of carbonate cement were found in the rocks of the Slave Point Formation: iron-poor calcite and dolomite and iron-rich calcite and dolomite. The distribution of the cements was not mapped in detail, but the iron-poor calcite and dolomite commonly were found in the limestone and dolomite host rocks respectively. The iron-rich calcite and dolomite usually occur as fracture fillings which randomly cut all lithologies.

The iron-poor white sparry calcite is the most important cement volumetrically. It fills fossil molds and irregular fractures. The calcite filling fossil molds is fine to medium crystalline with most crystals measuring in the order of 50 to 100 microns. The cement in the fractures

is generally coarser crystalline with crystals varying in size from 0.1-0.5 mm. The volume of iron-poor calcite cement increases in the vicinity of many shaly seams and stylolites. Some unidentified fossils or grains were found to be rim cemented with elongated sparry crystals. Rarely, syntaxial overgrowths of iron-poor cement on crinoid fragments were found. There appear to be two generations of iron-poor calcite cement. The early cement fills fossil molds and plugs host rock porosity, whereas later cement fills vuggy secondary porosity. The later cement commonly cuts cement filled fossil molds. Very coarse crystalline iron-poor calcite cement occurs in the centre of many dolomite veinlets. It is not known if this is a third generation or if it is part of the second generation.

Iron-poor white sparry dolomite occurs as void filling cement. The cement is generally coarse crystalline with crystal sizes varying from 0.1-2.5 mm. The largest crystals occur as single crystal replacements of crinoid fragments and as coarse crystalline cement lining open voids. Several generations of the cement may be present. Since the Presqu'ile type dolomite (Macqueen and Taylor (1974)) is present much of the cement described above may in fact be Presqu'ile type dolomite.

Iron-rich calcite cement is rare, but some was found in a few 2.0-3.0 cm thick veinlets that cut all previous fabrics.

Iron-rich white sparry dolomite cement was only found filling small hairline fractures and rimming older iron-poor dolomite crystals. The iron-rich margin may not be a separate cementation event. Oldershaw (1971) suggested that many cement crystals may have an iron-rich outer margin because through the crystallization process the iron is preferentially concentrated in the last crystallizing phase of the solution. In some places an iron-rich dolomite cement occurs within central regions of a cemented void. This could be the result of the iron-rich dolomite filling the void created by the dissolution of limestone in the process described by Dunsmore (1973).

S i l i c i f i c a t i o n

Diagenetic silica is present in the rock in three modes: as doubly terminated, euhedral, authigenic quartz crystals, as bladed or lamellar quartz, and as a fine aggregate of subhedral to euhedral quartz crystals. Silicification apparently is restricted to areas that have been dolomitized.

Authigenic Quartz Crystals

The euhedral authigenic quartz crystals are closely associated with the coarse sparry dolomite cement that fills fractures. Crystals varying from 20 microns to several centimeters in length are found occupying the central regions of larger dolomite veins or cement filled voids. The larger quartz crystals are quite conspicuous in outcrops.

In thin section the crystals are ubiquitous within the dolomite, comprising about 10% of the dolomite zones. Commonly they are found enclosed by a single dolomite crystal in poikilitic fashion. There is a random distribution of quartz crystals throughout the dolomite cement. This suggests that the quartz may have crystallized from the dolomite bearing solutions.

Bladed Quartz

Bladed or lamellar quartz is rare. It is found exclusively in association with sphalerite or pyrite mineralization. The quartz has crystallized in an elongated and twisted bladed form and is arranged in linear arrays. The appearance of the fabric under crossed nicols is illustrated in Plate 9a. The elongation of the quartz in any one thin section is always oriented in the same direction and its habitat is always at the extremities of elongated sphalerite and pyrite grains (Plates 9b, 9c). The habitat and peculiar form of the bladed quartz suggests that it may have crystallized under pressure and developed in the direction of minimum stress. The close association with sphalerite and pyrite suggests that the quartz was introduced with the mineralizing solutions.

Aggregates of Subhedral Quartz Crystals

The fine aggregates of quartz crystals represent replacement of the host rock by silica. In thin section various stages of the replacement process may be observed.

The silicification process attacks the host rock and sparry dolomite indiscriminantly and replaces both (Plate 10). The fine aggregate has a felted texture. The majority of the subhedral to euhedral quartz crystals comprising the felted fabric are less than 20 microns in length and approximately 5 microns in width. Random orientation of the crystal needles results in the felted appearance of the fabric. Commonly, opaque material is associated with the silicification texture. It is prevalent in intercrystalline void spaces and in some areas of high argillaceous content it acts as a mud supporting matrix for the quartz crystals. The silicification process did not affect the argillaceous material, but it replaced any dolomite in the rock. The relative timing of the silicification is difficult to determine, but it certainly was later than the sparry dolomite because the dolomite is partly replaced by the felted quartz fabric.

B r e c c i a

Breccias resulting from tectonic adjustments occur very rarely in rocks of the Slave Point Formation. Tectonic breccia is characterized by a variety of sizes of angular and subangular fragments of the host rock. Features that are usually diagnostic of tectonic breccia are the rotation of fragments, a preferred orientation of the fragments relative to the stress field and a very disordered packing of the broken and ground up fragments.

These features were observed locally in some breccias within the study area. Commonly tectonic breccias occur in elongated breccia pipes that probably indicate the position of old faults. One of the problems in recognizing the true tectonic breccias is that many of the fractured areas have been cemented by iron-rich sparry calcite and in outcrop look very similar to pseudobreccia.

P s e u d o b r e c c i a

Pseudobreccias are very common within the rocks of the Slave Point Formation. The pseudobreccia fabric is formed by diagenetic alteration of the rock. Two types of pseudobreccia were identified: one that results from the preferential dolomitization of the rock and one that is directly related to the formation of Presqu'ile type dolomite.

Fabric selective dolomitization produces a very distinct pseudobreccia. In many carbonate beds with variable shale content a pseudobreccia texture occurs because dolomitization has proceeded more completely in the less argillaceous areas. The resulting texture is one of argillaceous dolomitic limestone patches set in a dolomite matrix. In many places, especially within the Lower Mudstone member, where the limestone fabric contained lithoclasts or intraclasts, dolomitization proceeded within the matrix and did not appreciably affect the clasts. The resulting pseudobreccia fabric is then only an accentuation

of the heterogeneous nature of the pre-existing lithology (Plate 11a).

The formation of Presqu'ile type dolomite produced the most striking pseudobreccia textures. Commonly a crisscrossing system of veinlets outlines many pseudobreccia fragments (Plate 11b). Ordinarily, fragments within larger dolomite filled fractures have been separated from the wall rock by white sparry dolomite. Features such as small veinlets and larger fossil fragments comprising the fabric of the host rock have been cut and the pieces are separated by Presqu'ile type dolomite. There are areas where the original fabric could be reconstructed by the removal of the white sparry dolomite because no rotation of fragments has occurred. In one instance the replacement of host rock by Presqu'ile type dolomite outlined small blocks. The resulting fabric is illustrated in Plate 11c.

The fabrics and minerals found in the pseudobrecciated rocks of the Slave Point Formation strongly suggest that Dunsmore's (1973) process was operative. One prerequisite for the formation of Presqu'ile type dolomite, as visualized by Dunsmore (1973), was that the host rock should be limestone. In the Nabesche River area where Presqu'ile type dolomite occurs in the Slave Point Formation the host rock is dolomite. Therefore, the process must have been preceeded by the recrystallization of the host rock to macrodolomite. Alternatively, the limestone may have been replaced by the macrodolomite at the same time the Presqu'ile type

dolomite was forming.

Porosity

Generally porosity in the rocks of the Slave Point Formation is less than 2% (visual estimate). Locally there are porous zones in the rock where porosity may comprise up to 30% (visual estimate) of the rock. Megapores (Choquette and Pray, 1970) in the form of non fabric selective vugs account for the porosity in these zones (Plates 12d, 13b). The straight walled, but polygonally shaped voids are rarely interconnected and are usually lined with a diaphanous, very fine, crystalline, dolomite cement. Commonly, the vugs may contain a very delicate dolomite boxwork structure. The vug porosity probably was formed in the telogenetic zone associated with the present day weathering surface, because it was only observed in surface samples. The voids originated by the leaching of sphalerite crystals (Plates 12c, 12d, 13b).

The macrodolomite found in the Slave Point Formation may locally contain some intercrystal porosity (Macqueen and Taylor, 1974). In thin section no significant porosity was observed.

Mineralization

Pyrite and sphalerite comprise the sulfide mineralization found in the Slave Point Formation in the Nabesche River area. Pyrite is a common mineral, but it is not volumetrically or economically important. Only sphalerite mineralization will be discussed here.

Mode of Occurrence

Sphalerite mineralization detected to date is not extensive in the Slave Point Formation in the Nabesche River area. Sphalerite occurs as rare blebs or well terminated euhedral crystals 0.5-4.0 cm in diameter. Usually each occurrence is a crystal or patch of sphalerite. The sphalerite is red to dark brown in colour and is laced with hair-sized veinlets of dolomite cement. On weathered surfaces the mineralization is highly leached and altered (Plate 13a). The gossan is ochre yellow to orange and the surrounding host rock is stained with a bluish-white zinc bloom. Minerals present in the gossan are smithsonite, sphalerite, hydrozincite and possibly other zinc oxides. In many places the appearance of the hydrozincite (zinc bloom) is the only indication that the rock below the weathered surface contains sphalerite, because the dolomite host rock is otherwise unaltered. In regions where the sphalerite has been leached there remains a delicate dolomite boxwork structure. Often it is stained with hydrozincite (Plate 13b).

The sphalerite occurs in association with sparry dolomite and bladed silica (Plates 9b, 9c, 12a). Some sphalerite crystals locally occur in angular voids that are partly line by bladed quartz. There is much open space between the sphalerite and the host rock and contact between the two is minimal (Plate 12c). Probably

the open voids are the result of the incomplete leaching of sphalerite associated with the present weathering surface. This feature was only noted in thin sections cut from surface samples.

All the sphalerite crystals observed were cut by fractures filled with white dolomite cement. In many places the fracture pattern was a rectilinear mesh cutting the grain, indicating that the dolomite boxwork structure found in surface samples indeed was the result of the leaching of sphalerite (Plates 12b, 13b). In some places the sphalerite is completely enclosed by coarser sparry dolomite cement crystals, but in most cases bladed quartz is in contact with the sphalerite crystal at its extremities and a medium to coarse grained dolomite cement is in contact with it elsewhere (Plates 9c, 12a). Rarely is the sphalerite in direct contact with its host rock. Within the larger masses of sphalerite there are inclusions of dolomite that measure 20-50 microns in diameter. The close spatial relationship of sphalerite and silica suggests that the sphalerite mineralization and silica crystallized from the same solution. R.W. Macqueen (1974, personal communication) suggested that on the basis of meagre chemical data the bulk of the white sparry dolomite within the underlying Pine Point Formation may not be related to the mineralization. The white dolomite appears to be the product of Dunsmore's (1973) process.

Distribution and Relationship to Rock Type

The sphalerite mineralization is found only in the dolomitized areas of the Slave Point Formation, particularly within the crinoid bearing mudstone facies of the Reefal member. Rare scattered occurrences were found in the Nodular member and the Lower Mudstone member. Detailed study revealed that the mineralization occurred only within the dolomitized mudstone facies of the above named members. Presumably this lithology was most favourable because it was permeable enough to allow the mineralizing solutions to pass through it and at the same time it was a reducing environment with a high content of hydrogen sulfide.

Origin of the Sphalerite Mineralization

Jackson and Beales (1967) presented a comprehensive model for a diagenetic origin of the Pine Point lead-zinc ore deposit in the Northwest Territories. They suggested that metals carried in high salinity brines were precipitated as sulfides in dolomitized carbonate rock found at the carbonate shale facies front.

Many writers have supported the conclusion that diagenetic processes are responsible for the concentration of lead and zinc mineralization at carbonate-shale facies fronts. Snyder (1967), Beales and Jackson (1968), Billings et al (1969), Boyle and Lynch (1968) and Roedder (1968) suggested that the metals were leached from the basin sediments during dewatering due to compaction. Basin solutions

then carried the metals along permeable zones to the site of deposition.

Roedder (1968), Sawkins (1966) and Davidson (1966) showed on the basis of fluid inclusion work that the transporting solutions were probably chloride brines and that the metals were carried as chloride complexes. Billings et al (1969) suggested that the solutions were similar to formation waters found in subsurface rocks today. In fact these authors calculated that the amount of zinc present in the Western Canadian Sedimentary Basin could potentially have formed several Pine Point-type ore deposits.

The metals were deposited as sulfides wherever they encountered sulfur ions. Jackson and Beales (1967) proposed that sulfur ions were made available by bacterial reduction of sulfate ions. Starkey (1968) suggested that microbiological processes might reduce sulfate ions to sulfide ions. Trudinger et al (1972) reported that biological processes could be responsible for the production of a reducing agent for sulfide ores. Dunsmore (1973) showed that a chemical reaction between anhydrite and hydrocarbons could produce hydrogen sulfide. Therefore a mechanism to provide a reducing agent for the metals being carried in solution does not appear to be a problem.

Sulfur isotope studies conducted by Pinckney and Rafter (1972), Sasaki and Krause (1969), Jensen and Dessau (1967) and Soloman et al (1971) indicated that the isotopic composition of the sulfur in the sulfides of the Pine Point-

type deposits are more compatible with sea water than with sulfur that originated with magmatic deposits.

Geothermometry work done by Roedder (1972, 1968) and Miller (1969) showed that most Pine Point-type ore formed at low temperatures, generally between 50° and 200° C. This temperature range is compatible with subsurface basin temperatures observed today. The low temperatures of ore formation would further strengthen the idea that the mineral deposits were formed by diagenetic processes.

In light of the above mentioned work it may be postulated that any sedimentary basin has the potential to produce a lead-zinc deposit. Within the basin there is the source of metals, the solutions needed to transport the metals to the site of deposition, the plumbing system to the site of deposition, the site of deposition and a low temperature mechanism for the precipitation of the metals from the solution as sulfide ore. If any one of these factors is missing in a given basin an ore deposit will not form.

In the Nabesche River area traces of sphalerite mineralization have been found in the dolomitized mudstone facies of a carbonate complex at a carbonate-shale facies front. The fact that an ore deposit does not appear to have been formed, may be related to an insufficient supply of sulfur ions present at the time that the ore bearing solutions passed through the rock. This is not surprising, because it is unlikely that there was sulfur

locally available in the predominantly "dirty" carbonate basin.

Beales and Jackson (1968) showed that at Pine Point there was a large supply of sulfur available from the adjacent evaporite basin. Dunsmore (1973) noted that the Middle Devonian rocks in general and the Pine Point Formation in particular could be designated as a sulfur province. Therefore the supply of sulfide ions was no problem in the Pine Point area.

Another major difference between the Nabesche River sphalerite mineralization and the Pine Point ore deposit is the close spatial relationship of silica and sphalerite in the Nabesche River mineral occurrence.

Blatt et al (1972, p.390) estimated that the quartz content of most shales was approximately 31%. Therefore a ready source of silica exists in the Nabesche River area in the form of the adjacent shale basin. Trowe (1962) suggested that silica may be dissolved out of clay minerals and carried in water squeezed out of shales during loading and compaction of the basin. Jackson and Beales (1967) and Boyle and Lynch (1968) as noted above, indicated that the source of the metals forming the ore deposits probably was shale. Therefore, it is not unreasonable to suggest that the solutions that carried metal ions from the shale basin may have also carried silica.

Much work is yet to be done on the origin of zinc mineralization in the Nabesche River area, and on the

chemical nature of solutions that can carry zinc and silica. Macqueen and Taylor (1974) noted:

> "...any theory of the origin of zinc-lead mineralization in the area will have to include the apparent close association of ore minerals with quartz as well as dolomite and the probable absence of solution breccia on any appreciable scale - breccia which is apparently very common in the classical Pine Point orebodies on the south shore of Great Slave Lake (see Beales and Jackson, 1968; and others)".

Summary of the Diagenetic History

The diagenetic history of the area was not studied in detail. However, some relative time relationships were established. The development of the nodular texture and the cementation of the rock by iron-poor calcite happened relatively early in the diagenetic history of the rock. The formation of macrodolomite occurred where permeable sections of the host rock were exposed to the dolomitizing solutions. Presqu'ile type dolomite probably formed near the end of the dolomitization phase. Many of the voids created by the Presqu'ile type dolomite were then filled by iron-rich dolomite cement, authigenic quartz crystals and in a few places bladed silica and sphalerite. The silicification of the dolomite host rock probably occurred at the same time as the emplacement of the mineralization.

The paragenetic sequence in the mineralized areas appears to be as follows: the formation of the iron-poor

Presqu'ile type dolomite, the growth of authigenic quartz crystals, the precipitation of the iron-rich dolomite cement, the silicification of the host rock and the precipitation of the sphalerite.

Late iron-poor calcite cement filled veinlets were found cutting all previous diagenetic fabrics. In a few places iron-rich calcite cemented fractures were found cutting the iron-poor calcite cement indicating that it was the last apparent diagenetic change in the rock before present day weathering.

CHAPTER FIVE - SUMMARY AND CONCLUSIONS

S u m m a r y

The Nabesche River study area lies within a thrust sheet bound by the Nabesche Fault to the north and the Mount Burden Fault to the south.

The Middle Devonian section in the area is approximately 2100 feet thick. It is composed predominantly of marine shelf carbonate rocks. The section is unconformably underlain by the Lower Devonian Muncho McConnell Formation and conformably overlain by the Upper Devonian Besa River Formation.

The Middle Devonian sequence has been subdivided by Taylor and Bamber (1970) into the Stone Formation, Pine Point Formation, Sulphur Point Formation, Watt Mountain Formation and the Slave Point Formation. The section is representative of a major marine transgression that occurred in the Middle Devonian. However, the transgression was not continuous and unconformities are found within the section. Major periods of biostrome or carbonate bank development occurred in the middle of the Pine Point and Slave Point Formations.

The Slave Point Formation which is the focus of this study was deposited in the final transgression of the Middle Devonian sea. A complete gradation from shallow water lagoonal facies to deep water carbonate-shale transitional facies may be observed within the formation. The Slave Point Formation can be subdivided into four informal members on the basis of lithology: a Lower Mudstone member

that represents the lagoonal facies, a Reefal member that marks the biostrome growth, a Nodular member that represents the base of the slope carbonate-shale transitional facies and an Upper Mudstone member that represents the deep water basinal facies. Thus in vertical sequence the four members represent progressively deeper water environments.

The general lithology of the Slave Point Formation consists predominantly of black, argillaceous, lime mudstones, and fossiliferous, lime wackestones and packstones. The main fossils present are stromatoporoids and brachiopods. Large patches of dolomitized rock that occur randomly distributed throughout the unit have been silicified and cemented by several generations of calcite and dolomite cement. Sphalerite mineralization occurs sporadically within the Presqu'ile type dolomitized zones and it was found to be closely associated with quartz.

C o n c l u s i o n s

Three conclusions may be drawn in response to the outlined objectives of this study:

1. The depositional environments present in the Slave Point Formation indicate a deepening of the water as one progresses upward in the section.
2. The mineralization in the study area is exclusively found within the dolomitized mudstone lithology of the Slave Point Formation and is particularly concentrated in the dolomitized crinoid-bearing mudstone facies of the Reefal member.

3. The sphalerite mineralization is closely associated spatially with bladed silica.

REFERENCES

Bathurst, R.G., 1958, Diagenetic fabrics in some Dinantian limestones: Liverpool Manchester Geol. Jour., v.2, p. 11-36.

_____, 1971, Carbonate Sediments and Their Diagenesis: Amsterdam, Elsevier, 620 p.

Beales, F.W., 1971, Cementation by white sparry dolomite; in Bricker, O.P. (Ed.), Carbonate Cements: Baltimore and London, John Hopkins Press.

_____, and Jackson, S.A., 1968, Pine Point - A stratigraphical approach: Can. Min. Met. Bull., v. 61, p. 867-878.

Belyea, H.R., 1952, Notes on the Devonian System of the northcentral plains of Alberta: Geol. Surv. Can. Paper 52-27.

_____, 1961, Personal communication to A.W. Norris, 1965, Stratigraphy of Middle Devonian and older Paleozoic rocks of the Great Slave Lake region, N.W.T.: Geol. Surv. Can. Mem. 322.

_____, 1971, Middle Devonian tectonic history of the Tathlina Uplift, southern District of Mackenzie and northern Alberta, Canada: Geol. Surv. Can. Paper 70-14.

_____, and Norris, A.W., 1962, Middle Devonian and older Paleozoic formations of southern District of Mackenzie and adjacent areas: Geol. Surv. Can. Paper 62-15.

Billings, G.K., Kesler, S.E., and Jackson, S.A., 1969, Relation of zinc rich formation waters of northern Alberta to the Pine Point ore deposits: Econ. Geol., v. 64, no. 4, p.385.

Blatt, H., Middleton, G.V., and Murray, R.C., 1972, Origin of Sedimentary Rocks: Englewood Cliffs, New Jersey, Prentice-Hall Inc., 609 p.

Boyle, R.W., and Lynch, J.J., 1968, Speculation on the source of zinc, cadmium, lead, copper and sulfur in Mississippi Valley, and similar type of lead-zinc deposits: Econ. Geol.,v. 63, no. 4, p. 421.

Cameron, A.E., 1918, Explorations in the vicinity of Great Slave Lake: Geol Surv. Can. Sum. Rept., 1917, pt. C, p. 21-28.

Campbell, N., 1950, The Middle Devonian in the Pine Point area, N.W.T.: Proc. Geol. Assoc. Can., v.3, p.87-96.

_____, 1957, Stratigraphy and structure of the Pine Point area, N.W.T.; in Structural Geology Canadian Ore Deposits, v.II, Sixth Commonwealth Min. and Met. Congr., Canada, p. 161-174.

Choquette, P.W., and Pray, L.C., 1970, Geologic nomenclature and classification of porosity in sedimentary carbonates: Am. Assoc. Petroleum Geologists Bull., v.54, no.2, p. 207-250.

Committee on Slave Point and Beaverhill Lake Formations, 1965, Upper Devonian; in McCrossan et al (Eds.), Geological History of Western Canada: Alberta Soc. Petrol. Geol. Spec. Publ., Chpt. 6, pt. 1, p. 60-66 (1964).

Crickmay, C.H., 1957, Elucidation of some Western Canada Devonian formations: Calgary, Imperial Oil Ltd., published by the author.

Davidson, C.F., 1966, Some genetic relationships between ore deposits and evaporites: Trans. Instn. Min. Metall. (sec. B: Appl. earth Sci.), v.75, B216-225.

Dolphin, D.R., and Klovan, J.E., 1970, Stratigraphy and paleoecology of an Upper Devonian carbonate bank, Saskatchewan River crossing, Alberta: Bull. Can. Pet. Geol., v. 18, no. 3, p. 289-331.

Douglas, R.J.W., Gabriesle, H., Wheeler, J.O., Stott, D.F., and Belyea, H.R., 1970, Geology of Western Canada; in Douglas, R.J.W. (Ed.), Geology and Economic Minerals of Canada; Geol. Surv. Can Rept. 1, p. 366-488.

Dunsmore, H.E., 1973, Diagenetic processes of lead-zinc emplacement in carbonates: Trans. Instn. Min. Metall. (sec. B: Appl. earth Sci.), v.82, B168-173.

Embry, A., and Klovan, J.E., 1971, A Late Devonian reef tract on northeastern Banks Island, N.W.T.: Bull. Can. Petrol. Geol., v. 19, no.4, p. 730-781.

Fitzgerald, E.L., and Braun, L.T., 1965, Disharmonic folds in the Besa River Formation, Canada: Am. Assoc. Petrol. Geol. Bull., v. 49, no.4, p. 418.

Gabriesle, H., 1967, Tectonic evolution of the northern Canadian cordillera: Can Jour. Earth Sci., v.4, p.271-298.

Gabriesle, H., and Wheeler, J.O., 1961, Tectonic framework of the southern Yukon and northwestern British Columbia: Geol. Surv. Can. Paper 60-24.

Gray, F.F., and Kassube, J.R., 1963, Geology and stratigraphy of the Clarke Lake gas field, northeastern British Columbia: Am. Assoc. Petrol. Geol. Bull., v. 47, no. 3, p. 467-483.

Grayston, L.D., Sherwin, D.F., and Allan, J.F., 1965, Middle Devonian; in McCrossan et al (Eds.), Geological History of Western Canada: Alberta Soc. Petrol. Geol. Spec. Publ., Chapt. 5, p. 49-59.

Griffin, D.L., 1965, The Devonian Slave Point, Beaverhill Lake and Muskwa Formations of northeastern British Columbia and adjacent areas: British Columbia Dept. Mines and Petrol. Res. Bull. 50.

_____, 1967, Devonian of northeastern British Columbia; in Oswald, D.S. (Ed.), International Symposium on the Devonian System; vol. 1, Calgary, Alberta Soc. Petrol. Geol., p. 803-826.

Hopkins, J.C., 1972, Petrography, distribution and diagenesis of foreslope, nearslope and basin sediments, Miette and Ancient Wall carbonate complexes (Devonian) Alberta: Unpubl. Ph. D. thesis, McGill University, 234 p.

Hriskevich, M.E., 1970, Middle Devonian production, Rainbow area, Alberta, Canada: Am. Assoc. Petrol. Geol. Bull., v.54, no.12, p.2260.

Irish, E.J.W., 1970, Halfway River map-area, British Columbia: Geol. Surv. Can. Paper 69-11.

Jackson, S.A., and Beales, F.W., 1967, An aspect of sedimentary basin evolution: The conception of Mississippi Valley-type ores during late stages of diagenesis: Bull. Can. Petrol. Geol., v. 15, no. 4, p. 383-433.

Jensen, M.L., and Dessau, G., 1967, The bearing of sulfur isotopes on the origin of Mississippi Valley type deposits; in Brown, J.S. (Ed.), Genesis of Stratiform Lead-zinc-barite-fluorite Deposits: Econ. Geol. Monograph 3, p.400-408.

Kidd, F.A., 1963, The Besa River Formation: Bull. Can. Pet. Geol. Bull., v.11, no. 4, p.369.

Klovan, J.E., 1964, Facies analysis of the Redwater reef complex, Alberta, Canada: Bull. Can. Pet. Geol., v.12, p.1-100.

Laporte, L.F., 1967, Carbonate deposition near mean sea-level and the resultant facies mosaic: Manlius Formation (Lower Devonian) of New York state: Am. Assoc. Petrol. Geol. Bull., v. 51, no. 1, p. 77-100.

Law, J., 1955, Geology of northwestern Alberta and adjacent areas: Am. Assoc. Petrol. Geol. Bull., v. 39, p.1927-1978.

Lecompte M., 1958, Les recif paleozique en Belgique: Geol. Rundschau, v. 47, p. 384-401.

Lowenstam, H.A., Willman, H.B., and Swann, D.H., 1956, The Niagran Reef at Thornton, Illinois: Guidebook Am. Assoc. Petrol. Geol. and Soc. Econ. Paleon. Min., Urbana, Ill., p. 1-19.

Macqueen, R.W., and Taylor, G.C., 1974, Devonian stratigraphy, facies changes and zinc-lead mineralization, southwestern Halfway River area (94B), northeastern British Columbia: Geol. Surv. Can. Paper 74-1 pt. A., p.327-331.

McCamis, J G., and Griffith, L.S., 1967, Middle Devonian facies relationships, Zama area, Alberta: Bull. Can. Pet. Geol., v.15, no. 4, p. 434-467.

McCrossan, R.G., 1958, Sedimentary "boudinage" structures in the Upper Devonian Ireton Formation of Alberta: Jour. Sed. Pet., v. 28, no. 3, p.316-320.

Miller, J.O., 1969, Fluid inclusion temperature measurements in east Tennessee zinc district: Econ. Geol., v. 64, no. 1, p. 109.

Monger, J.W.H., Southier, J.G., and Gabriesle, H., 1972, Evolution of the Canadian cordillera: A plate tectonic model: Am. Jour. Sci., v. 272, p. 577-602.

Monseur, G., and Pel, S., 1972, Reef facies, dolomitization and stratified mineralization: Min. Deposita, (Berl.), v. 7, p.89.

Mossop, G.D., 1972, Origin of the peripheral rim Redwater reef Alberta: Bull. Can. Pet. Geol., v. 20, no. 2, p.238.

Noble, J.P.A., and Ferguson, R.D., 1971, Facies and faunal relations at the edge of an early Middle Devonian carbonate shelf, South Nahanni River area, N.W.T.: Bull. Can. Pet. Geol., v. 19, no. 3, p. 510.

Norris, A.W., 1963, Devonian stratigraphy of northeastern Alberta and northwestern Saskatchewan: Geol. Surv. Can., Mem. 313.

Norris, A.W., 1965, Stratigraphy of Middle Devonian and older Paleozoic rocks of the Great Slave Lake region, N.W.T.: Geol. Surv. Can. Mem. 322.

Oldershaw, A.E., 1971, The significance of ferroan and non-ferroan calcite cements in the Halkin and Wenlock Limestones (Great Britain): in Bricker, O.P. (Ed.), Carbonate Cements: Baltimore and London, John Hopkins Press.

Pinckney, D.M., and Rafter, T.A., 1972, Fractionation of sulfur isotopes during ore deposition in Upper Mississippi Valley zinc-lead districts: Econ. Geol., v. 67, no.3, p.315.

Roedder, E., 1968, Temperature, salinity and origin of the ore forming fluids at Pine Point N.W.T., Canada from inclusion studies: Econ. Geol. v. 63, no. 5, p. 439.

_____, 1972, Barite fluid inclusion geothermometry, Cartersville Mining District N.W. Georgia: Econ. Geol. v.67, no. 6, p. 821.

Sasaki, A., and Krouse, H.R., 1969, Sulfur isotopes and the Pine Point lead-zinc mineralization: Econ. Geol., v. 64, no.7, p.718.

Sawkins, F.J., 1966, Ore genesis in the north Pennine ore field in light of fluid inclusion studies: Econ. Geol. v. 61, no. 2, p. 385.

Snyder, F.G., 1967, Criteria for origin of stratiform ore bodies with application to southeast Missouri; in Brown, J.S. (Ed.), Genesis of Stratiform Lead-zinc-barite-fluorite Deposits: Econ. Geol. Monograph 3, p. 1-12.

Soloman, M., Rafter, T.A., and Dunham, K.C., 1971, Sulfur and oxygen isotope studies in the northern Pennines in relation to ore genesis: Trans. Instn. Min. Metall. (sec. B: Appl. earth Sci.), v. 80, B259-275.

Srivastava, P.V., Stearn, C.W., and Mountjoy, E.W., 1972, A Devonian mega-breccia at the margin of the Ancient Wall carbonate complex, Alberta: Bull. Can. Pet. Geol., v. 20, no. 2, p. 412-438.

Starkey, R.L., 1968, Microbiological processes in the formation of sulfur deposits, M.V. Ivanov: Econ. Geol., v. 63, no. 6, p. 708.

Taylor, G.C., 1969, Devonian stratigraphy, northeastern British Columbia (94B); in Rept. of Activities, Pt. A, Apr. to Oct., 1968: Geol. Surv. Can. Paper 69-1, p. 246.

Taylor, G.C., and Bamber, E.W., 1970, Paleozoic stratigraphy of Pine Pass, northeastern British Columbia: Edmonton Geol. Soc., Guide Book, Peace River, Pine Pass, and Yellowhead areas, p. 46-57.

_____, and MacKenzie, W.S., 1970, Devonian stratigraphy of northeastern British Columbia: Geol. Surv. Can. Bull., 186.

_____, and Stott, D.F., 1973, Tuchodi Lakes map-area, British Columbia: Geol. Surv. Can. Mem. 373.

Trowe, K.M., 1962, Clay mineral diagenesis as a possible source of silica cement in sedimentary rocks: Jour. Sed. Pet., v. 23, p. 26-28.

Trudinger, P.A., Lambert, I.B., and Skyring, G.W., 1972, Biogenic sulfide ores; a feasibility study: Econ. Geol., v. 67, no. 8, p. 1114.

Williams, H., Turner, F.J., and Gilbert, C.M., 1955, Petrography - An Introduction to the Study of Rocks in Thin Section: San Francisco, Freeman and Co., 406 p.

Wilson, J.L., 1970, Deposition facies across carbonate shelf margins: Gulf Coast Assoc. Geol. Socs., Trans., v. 20, p. 229-233.

Wilson, J.L., 1974, Characteristics of carbonate-platform margins: Am. Assoc. Petrol. Geol. Bull., v. 58, no. 5, p. 810-824.

Winder, C.G., 1968, Carbonate diagenesis by burrowing organisms; in Internat. Geol. Cong., 23d., Prague, Proc., Sec. 8, Genesis and classification of sedimentary rocks: Prague, Academia, p. 173-183.

PLATES

PLATE 1

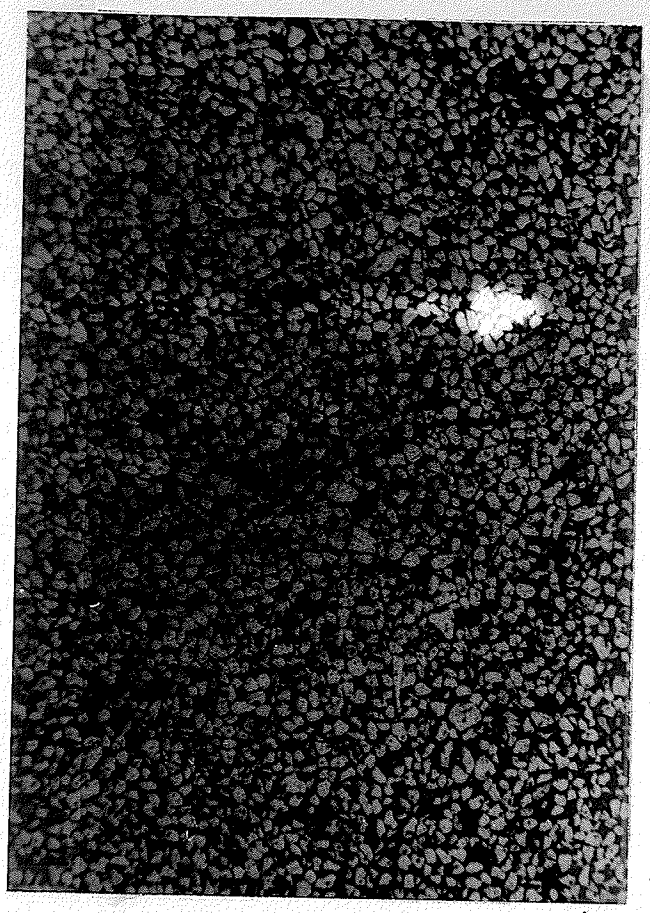
The gradational nature of the contact between the Watt Mountain Formation and the Lower Mudstone member of the Slave Point Formation.

Plate 1a. Watt Mountain Formation. Well sorted, rounded, quartz grains with minor argillaceous content comprise the fabric near the base of the unit. (Photomicrograph - plane light).

Plate 1b. Watt Mountain Formation. Within the upper part of the unit the degree of sorting decreases and the argillaceous content increases near the contact with the Slave Point Formation (Photomicrograph - plane light).

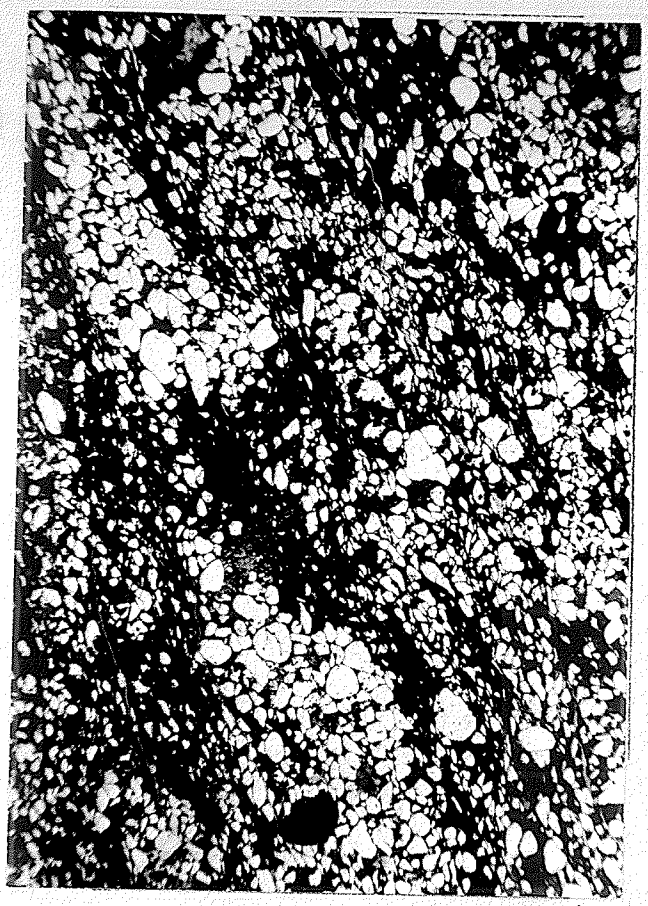
Plate 1c. Slave Point Formation, Lower Mudstone member. The dolomitic-lime mudstone matrix contains subrounded quartz grains (white grains) and fossiliferous lithoclasts (wackestone). This fabric is characteristic of the basal beds in the Lower Mudstone member. (Photomicrograph - plane light).

Plate 1d. Slave Point Formation, Lower Mudstone member. The lime wackestone of the fossiliferous beds near the bottom of the Lower Mudstone member contains many small rounded to angular quartz grains (small white grains). (Photomicrograph - plane light).



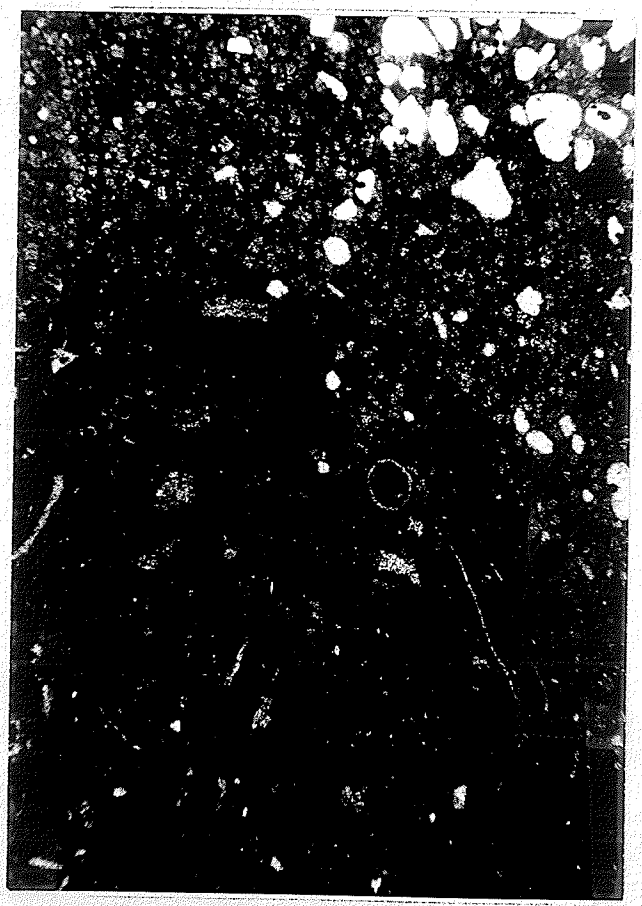
1 mm

1a



1 mm

1b



1 mm

1c

1 mm

1d

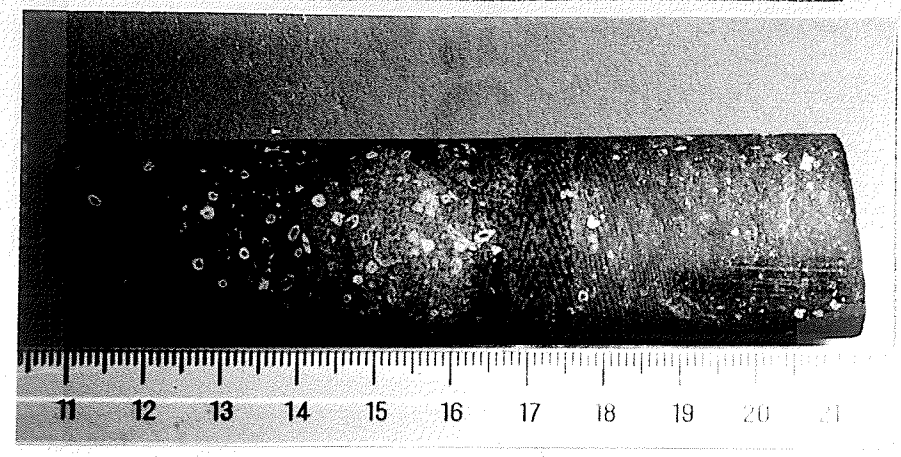
PLATE 2

An illustration of auloporid corals found in the Reefal member

Plate 2a. A drill core showing auloporid corals in an argillaceous lime mudstone matrix. The auloporid corals were commonly found in the crinoid-bearing mudstone facies of the Reefal member.

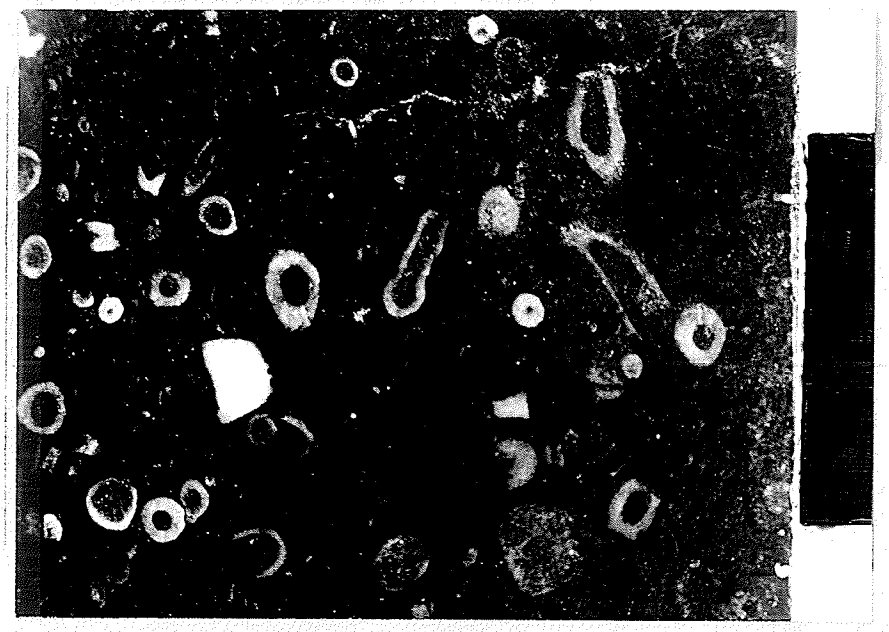
Plate 2b. Auloporid corals in an argillaceous lime mudstone matrix. Note the characteristic trumpet shape of the corals

Plate 2c. A thin section view of auloporid corals in an argillaceous lime mudstone matrix. (Photomicrograph - plane light).



scale is in centimeters

2a



bar scale is 1 cm

2b

1 mm

2c

PLATE 3

Lamellar stromatoporoid wackestone fabrics of the Reefal member

Plate 3a. Lamellar stromatoporoids and some Thamnopora fragments in a slightly argillaceous lime mudstone matrix. Note how some of the lamellar stromatoporoids are encrusting the Thamnopora fragments.

Plate 3b. Lamellar stromatoporoids binding a skeletal silt wackestone-mudstone. The lamellar stromatoporoids grew on a muddy substrate in the absence of any fragments which they could have otherwise encrusted. (Photomicrograph - plane light).

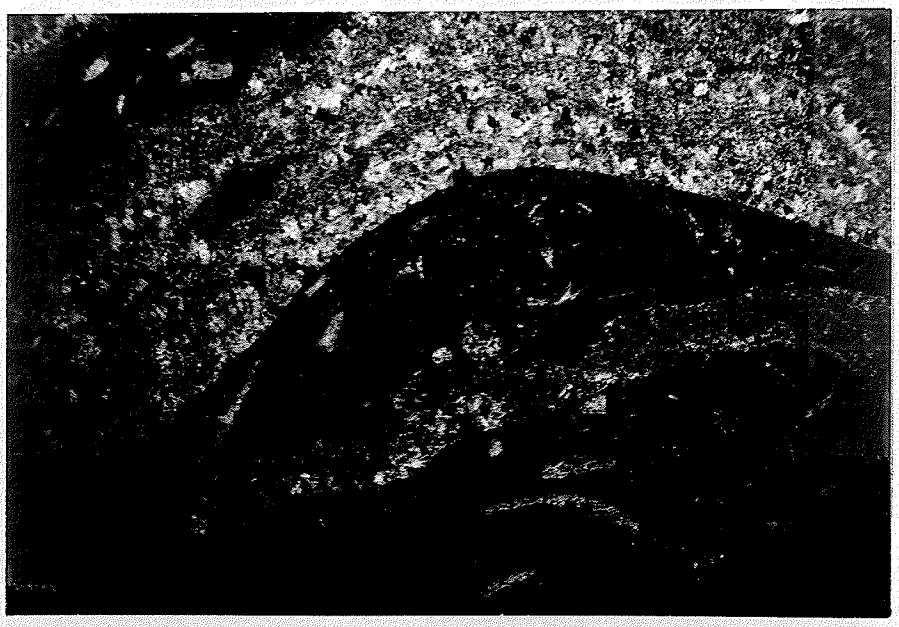
Plate 3c. Lamellar stromatoporoids binding a skeletal silt wackestone. Note that the thickness of the lamellar stromatoporoids is not uniform, indicating variable growth conditions. (Photomicrograph - plane light).

bar scale
is 1 cm

3a

1 mm

3b



1 mm

3c

PLATE 4

Some rock fabrics found in the Slave Point Formation

Plate 4a. Massive stromatoporoid facies of the Reefal member. Massive stromatoporoids and branching tabulate corals in a lime mudstone matrix. This fabric represents the barrier facies of the Slave Point Formation.

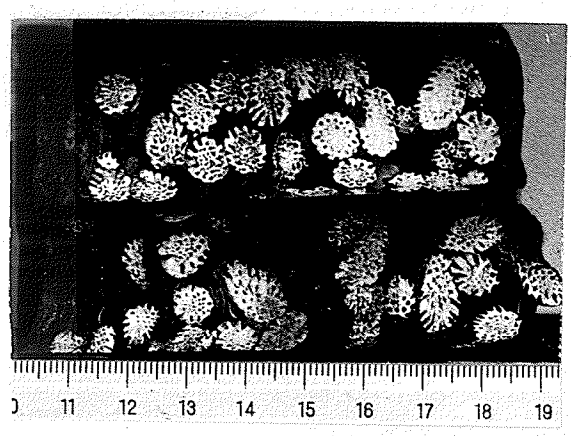
Plate 4b. Tabulate coral facies of the Lower Mudstone member. Thamnopora set in an extremely argillaceous lime mudstone matrix. This unit proved to be a valuable marker horizon in the Lower Mudstone member. The tabulate coral facies of the Reefal member is similar in appearance, but less argillaceous and with a high skeletal silt content.

Plate 4c. Lime wackestone of the Nodular member. The fabric is composed of skeletal debris, notably branching stromatoporoid and brachiopod fragments. It occurs only locally. (Photomicrograph - plane light).

Plate 4d. Crinoid bearing mudstone facies of the Reefal member. The rock consists of crinoid and brachiopod fragments set in an argillaceous lime mudstone matrix. Note the lithoclast composed of lime wackestone in the lower right hand corner of the plate. (Photomicrograph - plane light).

4a

scale is in centimeters



4b

scale is in centimeters

1 mm

4c

1 mm

4d

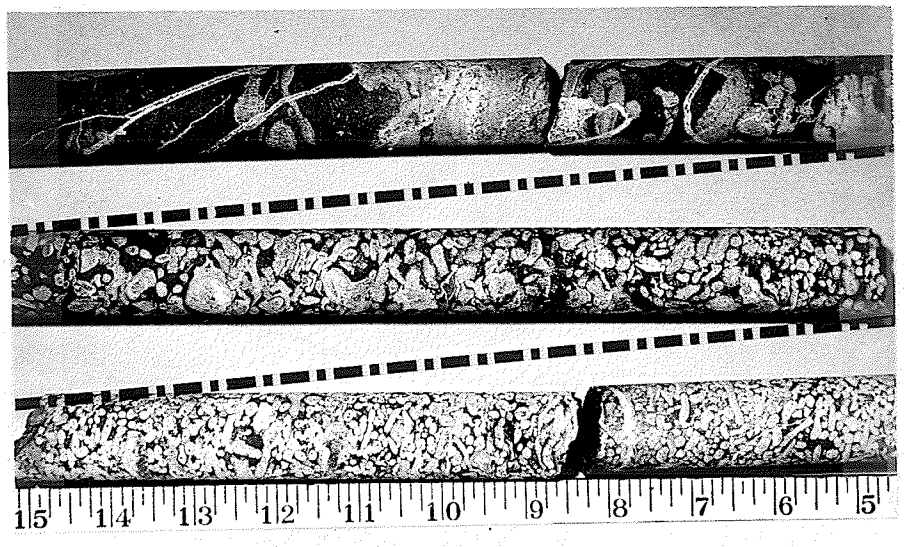
PLATE 5

Branching stromatoporoid facies of the Reefal member

Plate 5a. Branching stromatoporoid facies of the Reefal member. Note the upward decrease in the fossil size. The lower part of the interval consists of tabulate corals and lamellar stromatoporoids. The upper part of the interval consists of branching stromatoporoid and a few tabulate coral fragments. This bed is the best marker unit found in the Slave Point Formation in the Nabesche River area.

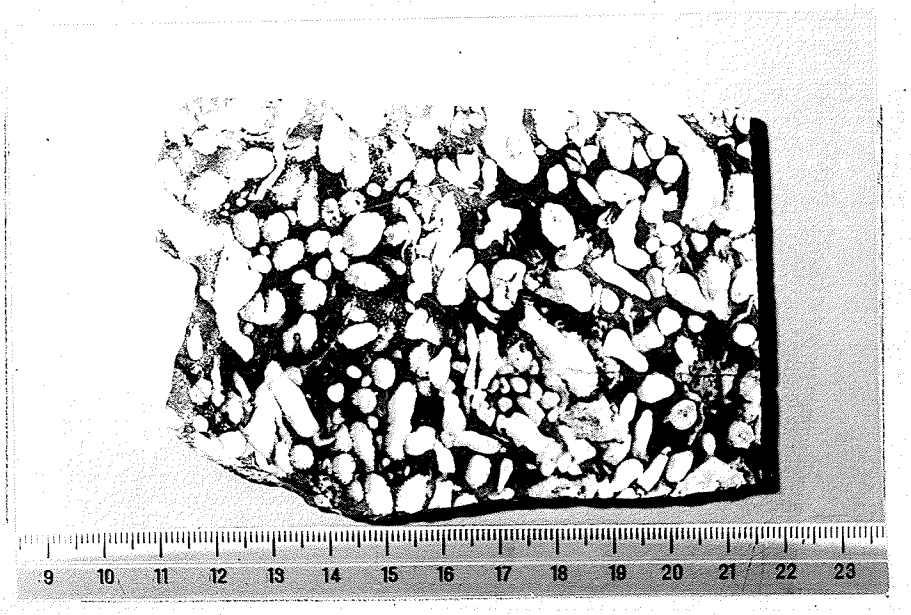
Plate 5b. Branching stromatoporoid facies. Lime packstone consisting of branching stromatoporoids and tabulate coral fragments. Note the severe recrystallization that occurs in the centre of some of the larger fossils.

Top



5a

scale is in inches



5b

scale is in centimeters

PLATE 6

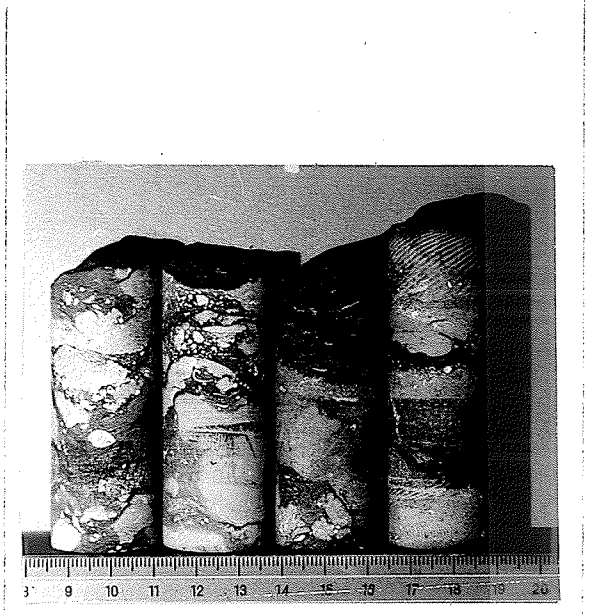
Representative fabrics of the Nodular member

Plate 6a. Drill core illustrating the nodular fabric of the Nodular member. Note the three components of the fabric: the light grey lime mudstone nodules, the dark grey to black argillaceous matrix and the allochems consisting predominantly of fossil fragments.

Plate 6b. The nodule located in the lower centre of the plate is outlined by a large brachiopod shell. Note the diffuse contact between nodules and matrix in the upper centre of the plate.

Plate 6c. This plate shows the appearance of nodules "floating" in the dark matrix. Stylolites commonly are found on the edges of the nodules and throughout the argillaceous matrix.

Plate 6d. The white carbonate filled fractures end abruptly at the shale seam cutting the nodule. Note the V-shape of the fracture in the upper part of the plate. (Photomicrograph - plane light).



6a

scale is in centimeters

scale is in centi-meters

6b

6c

bar scale is 1 cm

1 mm

6d

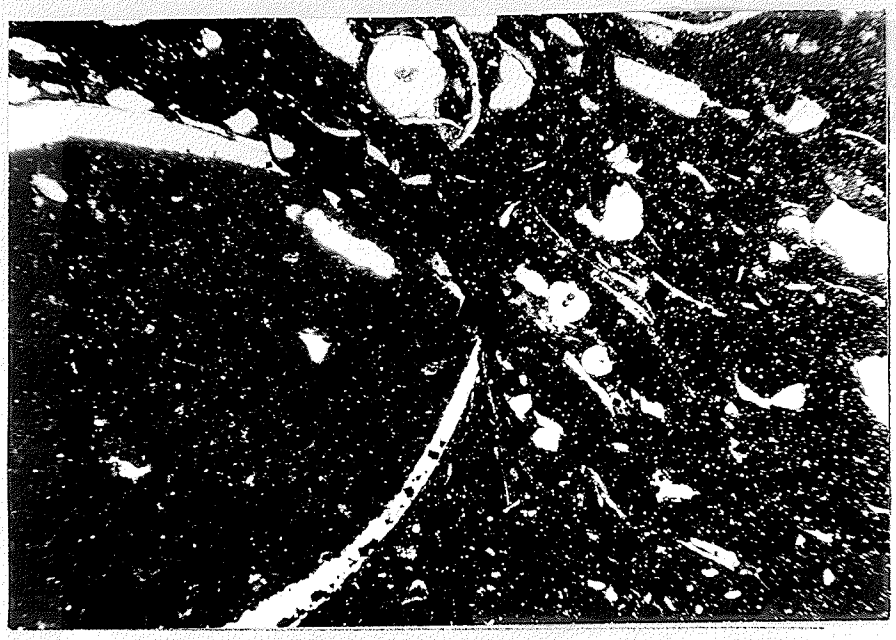
PLATE 7

Representative fabrics of the Nodular member in thin section

Plate 7a. A large brachiopod shell outlines a nodule on the left side of the plate. Note how the skeletal fragments and the matrix drape around the nodule. This is a good indication that differential compaction has occurred in the rock. (Photomicrograph - plane light).

Plate 7b. A large brachiopod shell separates the nodule composed of fossiliferous packstone from the argillaceous matrix. (Photomicrograph - plane light).

Plate 7c. Nodules consisting of recrystallized fossiliferous lime packstone are separated by a dark argillaceous matrix. (Photomicrograph - plane light).



1 mm

7a

1 mm

7b

1 mm

7c

PLATE 8

Macrodolomite fabrics

Plate 8a. Dolomite rhombs supported by an argillaceous matrix. Note the zoning of the dolomite crystals. (Photomicrograph - crossed nicols).

Plate 8b. Variations in crystal size result in a texture that has a breccia-like appearance. The areas of the smaller crystal size are typical of the macrodolomite fabric.

8a

0.2 mm

8b

bar scale is 1 cm

PLATE 9

The relationship of
bladed quartz and sphalerite mineralization

Plate 9a. This plate produced under crossed nicols illustrates the linear arrays of the elongated, twisted, bladed form of the quartz that is associated with sphalerite mineralization. (Photomicrograph - crossed nicols).

Plate 9b. All occurrences of the bladed quartz are oriented in the same direction in a given thin section. Note the preferred locality of the quartz at the extremities of the sphalerite crystals (black areas). (Photomicrograph - crossed nicols).

Plate 9c. Sphalerite crystals (black areas) are surrounded by sparry dolomite and bladed quartz (only at the extremities of the crystals). Note the parallel orientation of bladed quartz occurrences. No bladed quartz occurs away from the sphalerite crystals. (Photomicrograph - crossed nicols).

0.2 mm

9a

0.5 mm

9b

1 mm

9c

PLATE 10

The silicification of dolomite

Note that the felted quartz fabric replaces Presqu'ile type dolomite and macrodolomite indiscriminately.

Plate 10a. Incipient replacement of Presqu'ile type dolomite by silica. (Photomicrograph - crossed nicols).

Plate 10b. Complete replacement of Presqu'ile type dolomite by silica. (Photomicrograph - crossed nicols).

Plate 10c. The silicification of macrodolomite. The small white specks are quartz crystals. (Photomicrograph - crossed nicols).

Plate 10d. The silicification of macrodolomite. Note the crisscrossing random orientation of the quartz crystals producing the felted texture. (Photomicrograph - crossed nicols).

1 mm

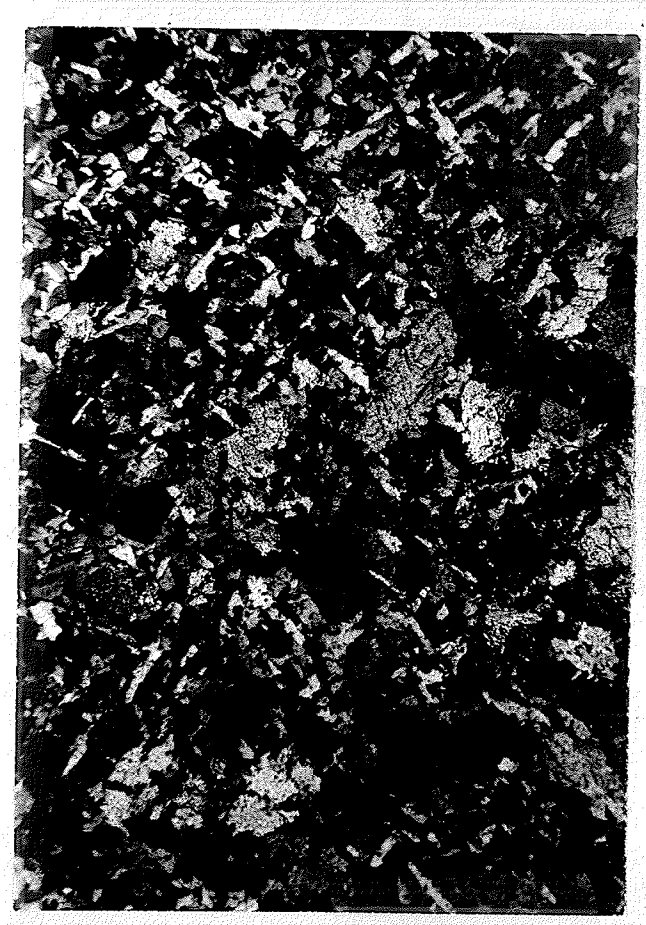
10a

1 mm

10b

1 mm

10c



1 mm

10d

PLATE 11

Pseudobreccia fabrics

Plate 11a. This pseudobreccia was produced by fabric selective dolomitization. The light coloured and white areas are original matrix areas and the darker areas particularly in the centre of the plate are original clasts. Dolomitization affected the original matrix more severely than the original clasts.

Plate 11b. The formation of Presqu'ile type dolomite produces a distinctive pseudobreccia. This fabric is commonly known as crackle breccia.

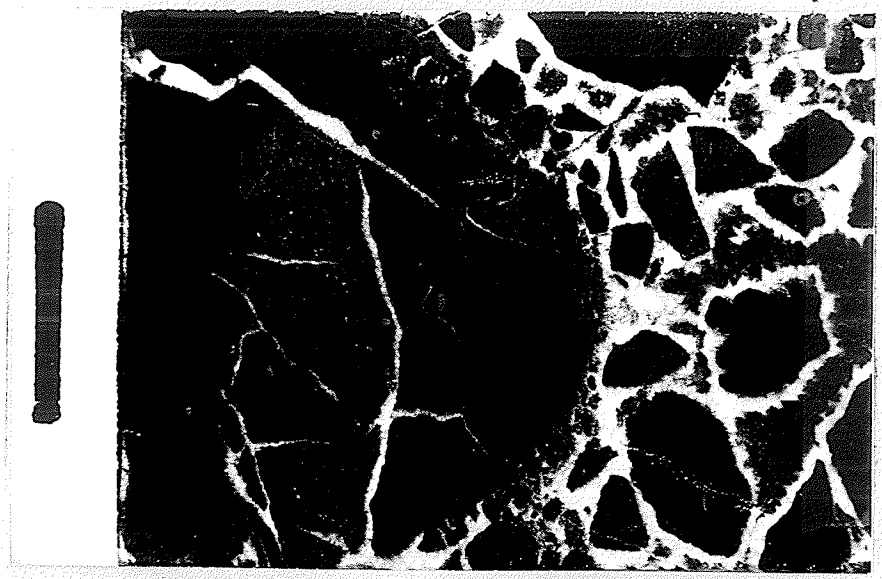
Plate 11c. Presqu'ile type dolomite surrounds small dolomite blocks producing a pseudobreccia texture.

bar scale is
is 1 cm

11a

bar scale
is 1 cm

11b



bar scale
is 1 cm

11c

PLATE 12

Sphalerite mineralization in thin section

This plate illustrates the progressive leaching of sphalerite that produces up to 30% porosity (visual estimate) in surface and near-surface samples of the crinoid-bearing mudstone facies of the Reefal member.

Plate 12a. Unaltered sphalerite surrounded by sparry dolomite. Only in rare cases is the sphalerite in direct contact with macrodolomite. (Photomicrograph - crossed nicols).

Plate 12b. A fracture pattern in sphalerite that has been healed by dolomite. (Photomicrograph - crossed nicols).

Plate 12c. The bright white areas are zones where sphalerite has been removed by leaching. Note that sphalerite and host rock contact is minimal. (Photomicrograph - plane light).

Plate 12d. In areas where sphalerite has been removed a vuggy porosity remains. (Photomicrograph - plane light).

12a

1 mm

12b

1 mm

12c

1 mm

12d

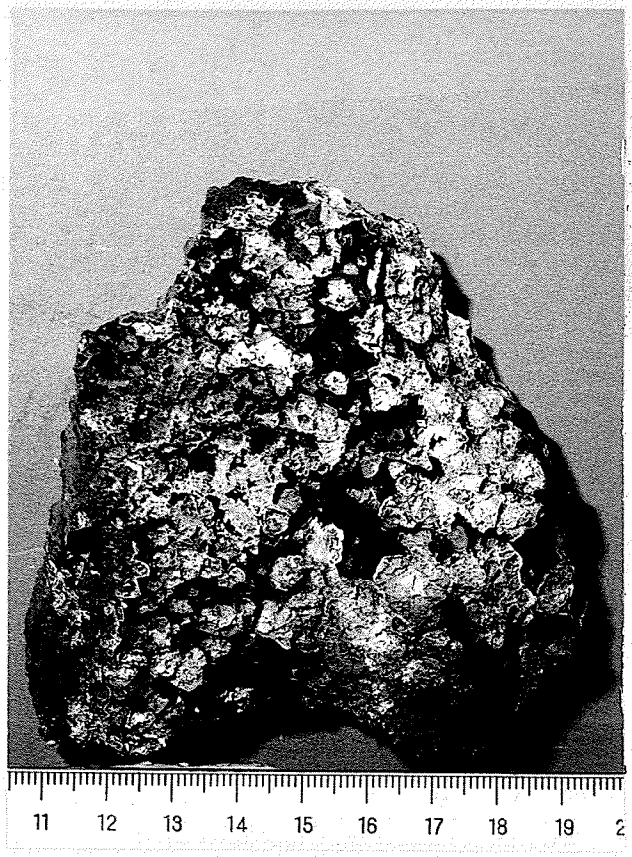
1 mm

PLATE 13

Sphalerite mineralization in surface samples from crinoid-bearing mudstone facies of the Reefal member

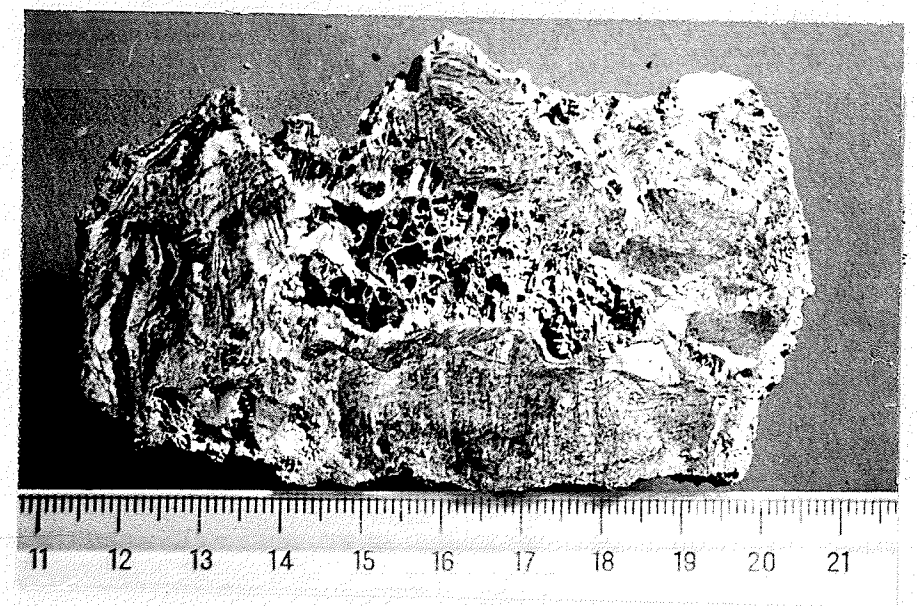
Plate 13a. A surface sample of sphalerite mineralization showing its highly weathered nature. The gossan is ochre yellow to orange. Note the delicate boxwork structure in some of the lighter weathered patches.

Plate 13b. A delicate boxwork composed of dolomite remains after sphalerite is removed by weathering. Commonly the boxwork is coated with hydrozincite.



13a

scale is in centimeters



13b

scale is in centimeters

APPENDIX - 1

S t a i n i n g M e t h o d

The following staining method was used to identify the presence of ferroan calcite or dolomite.

A 100.0 cc volume of stain was prepared in the following manner:

98.6 cc of H_2O
1.0 gm of potassium ferricyanide
0.2 gm of alizarin red S
0.2 cc of HCl

total 100.0 cc of staining solution

The rock slab or thin section was immersed in the solution for about 1.5 to 2.0 minutes. This amount of time gave the best results. If a specimen was left in the solution for longer than this time it was found that everything in the rock turned to a uniform violet colour. Also it is preferable to use a fresh solution for each staining session because the solution loses its strength with time and the unused portion breaks down chemically.

The following colour identification scheme was used:

red = iron poor calcite
purple or dark blue = iron rich calcite
no stain = iron poor dolomite
bluish-green (turquoise) = iron rich dolomite

This method of staining to identify the composition of the carbonates proved to be fast and efficient. Because of

the relative ease of its preparation it is suggested that the staining method be adopted for routine field use.

Selected Bibliography on Staining Methods

Evamy, B.D., 1962, The application of a chemical staining technique to a study of dedolomitisation: Sedimentology, no. 2, p. 164, 1963.

Friedman, G.M., 1959, Identification of carbonate minerals by staining methods: Jour. Sed. Pet., v. 29, no.1, p. 87.

Lindholm, R.C., and Finkelman, R.B., 1972, Calcite staining; semi-quantitative determination of ferrous iron: Jour. Sed. Pet., v. 42, no. 1, p. 239.

APPENDIX - 2

Insoluble Residue

The surface samples collected and core samples from the drill hole about 4 miles north of the study area were subjected to insoluble residue analysis.

The following method was used to extract the insoluble residue from the rock:

1. Pass the sample through a primary jaw crusher. This should result in the sample being reduced to $\frac{1}{2}$"-$\frac{1}{4}$" chips.
2. Quarter the sample and retain the northwest and southeast quadrants.
3. Grind the remaining parts of the sample in a mechanical grinder to silt sized particles.
4. Prepare a cold 10% HCl solution, using 9 parts distilled water and 1 part concentrated HCl.
5. Weigh out approximately 2.0 grams of sample and weigh an empty 150 ml beaker. Place the sample in the beaker.
6. Add 100 ml of 10% HCl solution, slowly at first to prevent the loss of the sample through violent effervescence.
7. Let the sample be digested for 24 hours mixing it occasionally and then let it settle for at least 12 hours.
8. Draw off as much of the excess solution as possible by suction, being careful not to disturb the sediment.
9. Add 100 ml of distilled water, stir up the sediment and let it settle overnight.

10. Draw off as much of the excess water as possible by suction being careful not to disturb the sediment.
11. Put the beaker into an oven set at 130° C and allow any remaining water to evaporate.

The following method was used to calculate the weight percent of insoluble residue present:

1. Record the weight of the empty 150 ml beaker.
2. Weigh the beaker with the insoluble residue in it.
3. Subtract the weight of the empty beaker and record the weight of the residue.
4. Record the weight of the original sample.
5. Divide the weight of the residue by the weight of the original sample and multiply by 100 to find the weight percent.

The results of the insoluble residue determinations are summarized in Table 1 and illustrated in Figures 23, 24, 25, 26. Sections A, B and C refer to the surface sections mapped and illustrated in Figure 11 . Section N is the diamond drill hole N3 that was drilled outside the study area, but is included in the investigation for comparative purposes. The samples collected near the bottom of the Watt Mountain Formation were selected as the datum, because of the distinctive lithology that enabled good correlation from section to section.

X-ray diffraction analysis showed that the most common

minerals present in the insoluble residues were illite, chlorite, quartz and occasionally montmorillonite.

It was interesting to note that only a very small amount of insoluble residue may cause a colour change in the rock. Rocks with insoluble residue content as low as 1% or 2% were dark grey in colour on the fresh surface. Similarly, rocks that appeared extremely argillaceous in the field contained only 20-30% insoluble residue. These facts would caution against using visual estimates of argillaceous content to mark a contact in the field.

TABLE 1

The Distribution of Insoluble Residue Data

Section	Footage	Unit	Weight percent insoluble residue
A	0	Watt Mountain Formation	97.3
A	5	" " "	21.4
A	10	Lower Mudstone Member	2.6
A	20	" " "	5.4
A	29	" " "	19.4
A	41	" " "	8.3
A	71	" " "	2.7
A	72	Reefal Member	2.9
A	74	" "	3.0
A	79	" "	5.8
A	88	" "	4.7
A	92	" "	3.6
A	94	" "	13.4
A	99	" "	2.0
A	103	" "	2.5
A	105	" "	3.0
A	119	Nodular Member	31.5
A	127	" "	11.2
A	129	" "	9.4
A	136	" "	10.2
A	152	" "	6.6
A	165	" "	10.8
A	172	" "	10.3
A	179	" "	16.5
A	182	" "	7.0
A	184	" "	2.8
A	188	" "	7.4
A	195	" "	7.2
A	196	" "	6.7
A	207	" "	11.8
A	211	" "	12.0
A	261	Upper Mudstone Member	18.7
A	322	" " "	19.1
A	417	Besa River Formation	59.0
B	0	Watt Mountain Formation	96.1
B	7	" " "	84.8
B	17	Lower Mudstone Member	4.7
B	27	" " "	22.0
B	37	" " "	5.6
B	50	" " "	6.2
B	58	Reefal Member	4.5
B	65	" "	3.6
B	69	" "	4.0
B	74	" "	4.0
B	79	" "	2.1
B	80	" "	2.2

Section	Footage	Unit	Weight percent insoluble residue
B	81	Reefal Member	5.0
B	86	" "	2.1
B	89	" "	1.5
B	90	" "	4.2
B	92	" "	2.2
B	94	" "	3.0
C	58	Reefal Member	4.0
C	62	" "	7.8
C	64	" "	5.2
C	75	" "	22.1
C	81	" "	6.3
C	82	" "	20.7
C	84	" "	6.4
C	89	" "	5.5
C	91	" "	9.6
C	99	Nodular Member	13.7
C	107	" "	7.7
C	113	" "	4.9
C	139	" "	11.7
C	153	Upper Mudstone Member	11.8
C	163	" " "	13.1
C	188	" " "	18.2
C	203	" " "	19.2
C	213	Besa River Formation	50.1
N	0	Watt Mountain Formation	39.3
N	10	" " "	88.8
N	20	Lower Mudstone Member	75.9
N	30	" " "	52.2
N	40	Reefal Member	51.4
N	50	" "	62.9
N	60	" " (?)	31.7
N	70	" " (?)	8.8
N	80	" " (?)	9.2
N	90	" " (?)	11.0
N	100	" " (?)	16.2
N	110	" " (?)	1.4
N	120	" " (?)	21.3
N	130	" " (?)	5.6
N	140	" "	10.4
N	150	" "	16.6
N	160	" "	12.8
N	170	Nodular Member	19.1
N	180	" "	13.5
N	190	" "	18.0
N	200	" "	11.5
N	210	" "	16.5
N	220	" "	5.1
N	230	" "	9.5
N	240	" "	13.3
N	250	Upper Mudstone Member	5.5
N	260	" " "	11.0
N	270	" " "	12.0

FIGURE 23

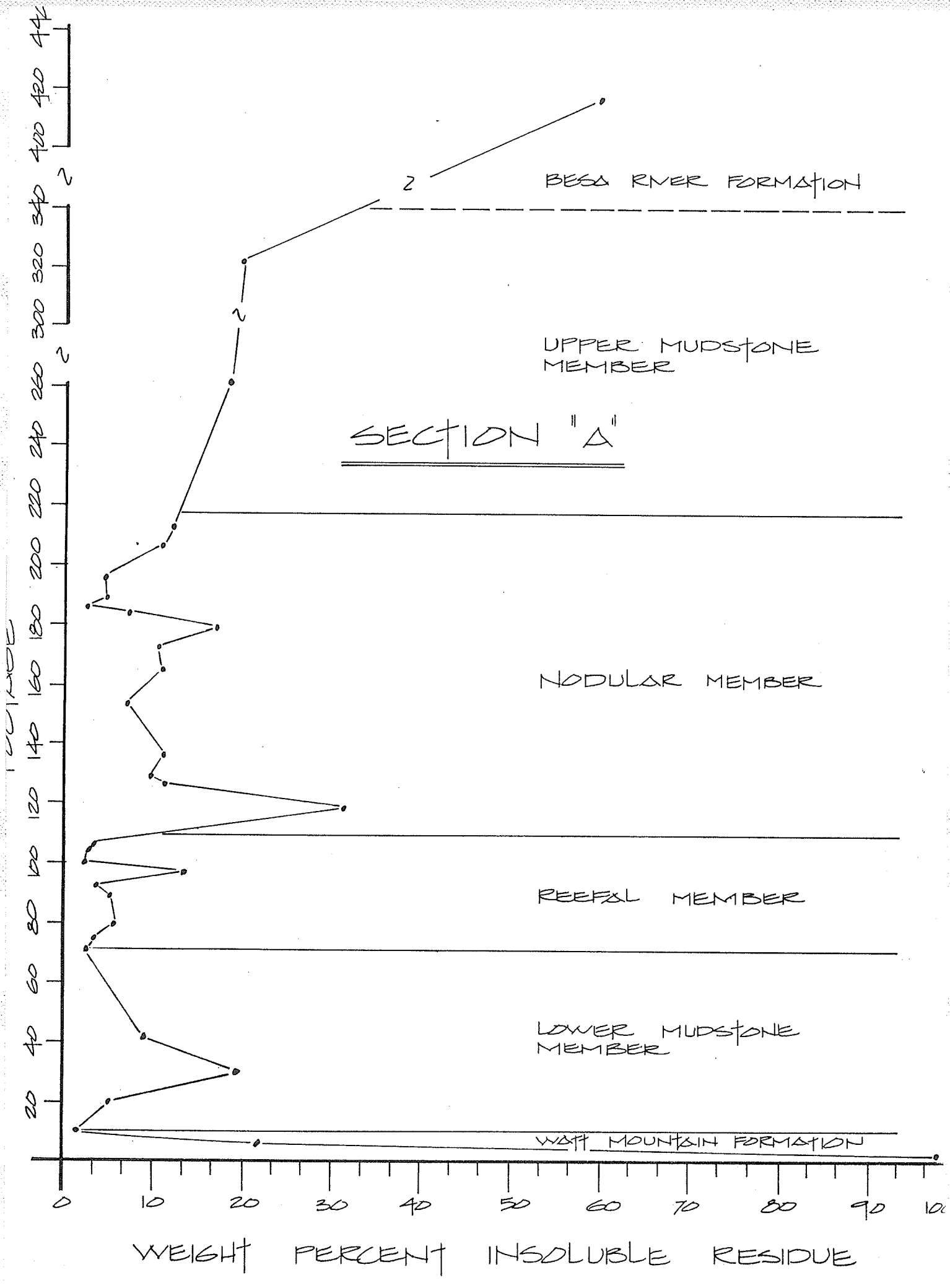

BESS RIVER FORMATION
UPPER MUDSTONE MEMBER
SECTION "A"
NODULAR MEMBER
REEFAL MEMBER
LOWER MUDSTONE MEMBER
WATT MOUNTAIN FORMATION
0
10
20
30
40
50
60
70
80
90
WEIGHT PERCENT INSOLUBLE RESIDUE

FIGURE 24

SECTION "B"

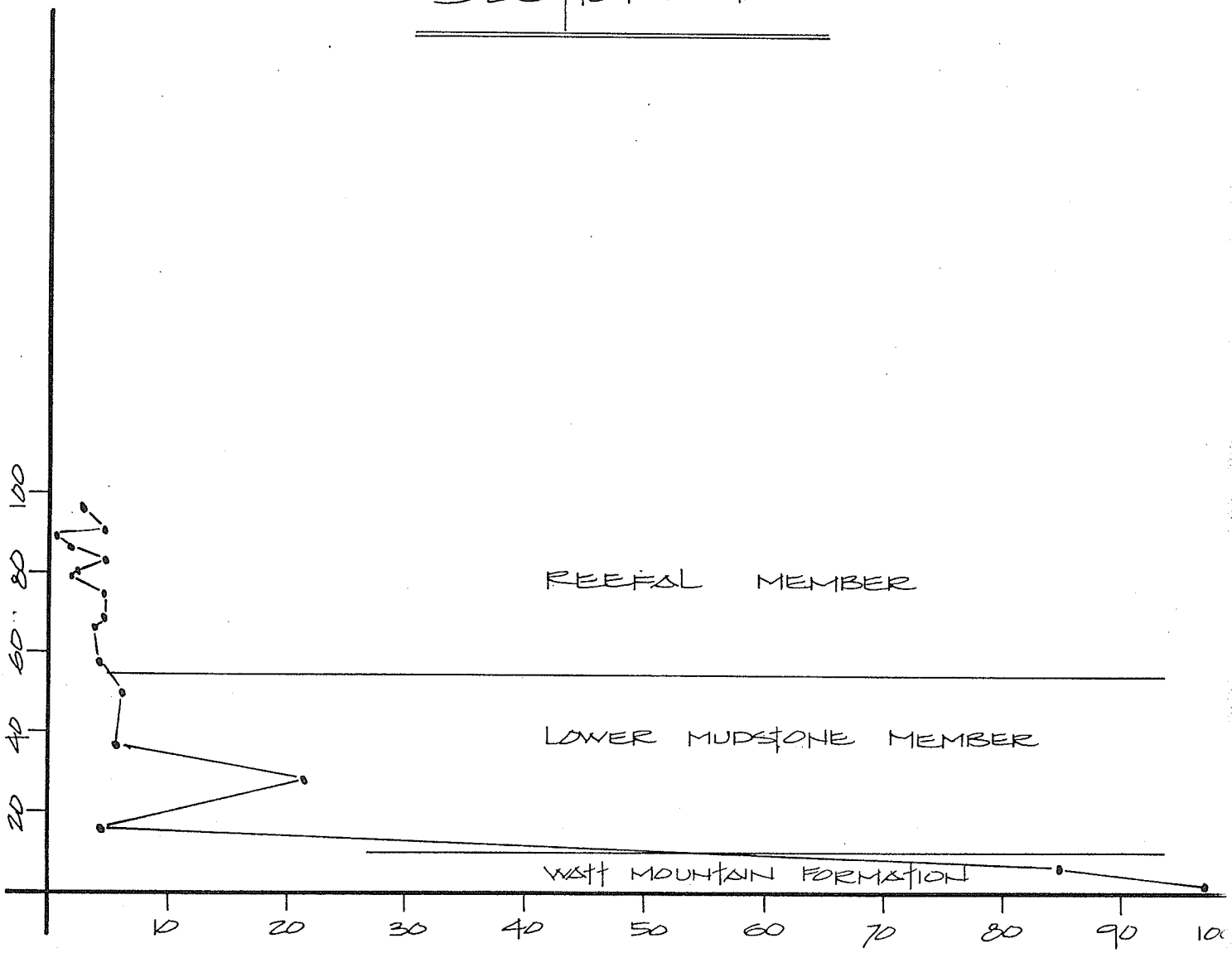

REEFAL MEMBER
LOWER MUDSTONE MEMBER
WATT MOUNTAIN FORMATION
10
20
30
40
50
60
70
80
90
100
WEIGHT PERCENT INSOLUBLE RESIDUE

FIGURE 25

SECTION "C"

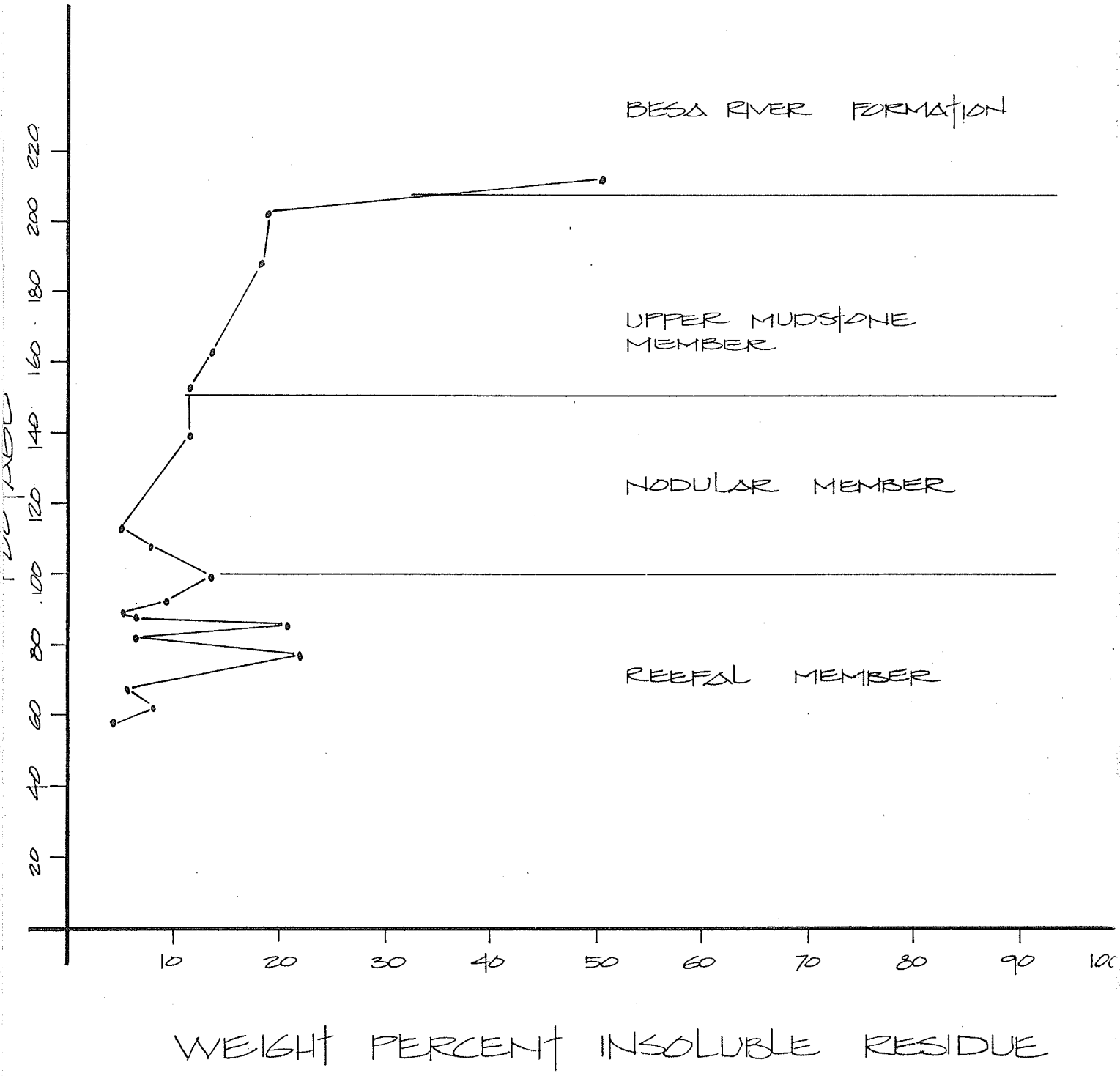
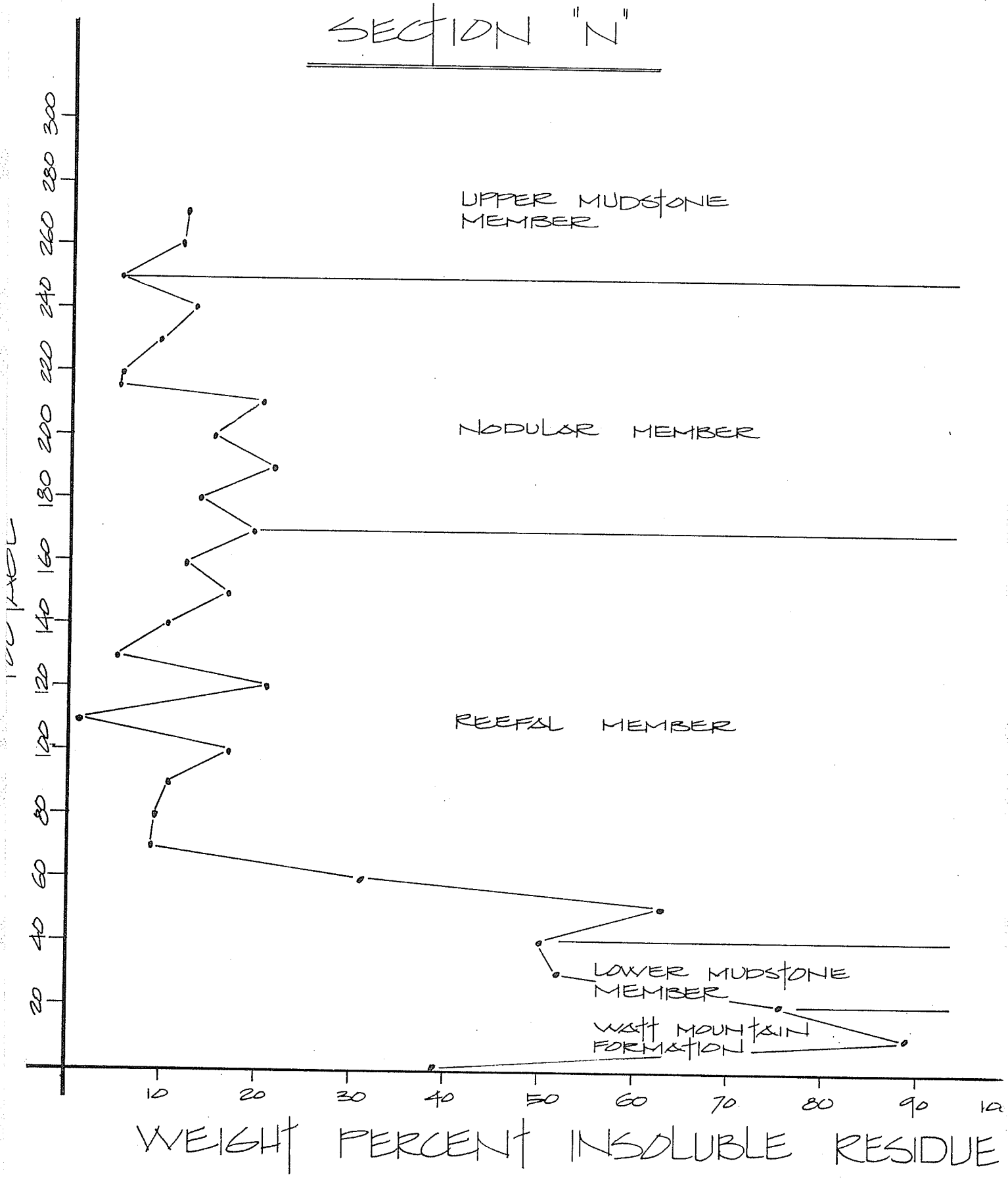

BESA RIVER FORMATION
UPPER MUDSTONE MEMBER
NODULAR MEMBER
REEFAL MEMBER
20
40
60
80
100
120
140
160
180
200
220
10
20
30
40
50
60
70
80
90
100
WEIGHT PERCENT INSOLUBLE RESIDUE

FIGURE 26

SECTION "N"


UPPER MUDSTONE MEMBER
NODULAR MEMBER
REEFAL MEMBER
LOWER MUDSTONE MEMBER
WATT MOUNTAIN FORMATION
FEET ABOVE SEA LEVEL
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
10
20
30
40
50
60
70
80
90
WEIGHT PERCENT INSOLUBLE RESIDUE

APPENDIX - 3

Detailed Drill Logs

The detailed drill logs are the original descriptions of the drill core from the ten diamond drill holes (Figure 3) completed within the study area, and the one hole included in the study located approximately 4 miles north of the area. The size of core recovered was approximately 1.0 inch in diameter. In the drilling industry it is called AQ core.

Holes 1 through 4 were logged by K.M. Carter, a Cominco geologist, during the fall of 1972. The remaining holes, 5 through 10 and hole N3 were logged by the author during the summer of 1973. There is a slight difference in terminology used between Carter's and Budrevics' descriptions, but wherever possible Carter's descriptions were modified. It is stressed that the core descriptions were made before any subdivisions within the Slave Point Formation were recognized, therefore no member names appear in the descriptions.

Drill Hole - 1

Location: West Nabesche River Elevation: 5890'

Collar Dip: - 75° Length: 204'

Formation tested: Slave Point

Depth	Lithological Description
0.0-5.0	Overburden - 5.0'
Slave Point Formation	
5.0-71.0	Crinoidal limestone - 66.0'
	dark grey, very fine crystalline, thin to medium bedded, crinoidal throughout, but percentage variable, below 30.0' limestones are laminated, many fossil remains - brachiopods and crinoids most obvious, bedding planes at 70°
	36.0-40.0 - large shelled brachiopods
	42.0-65.0 - extremely crinoid rich
	fractures: weak, narrow generally 2 mm thick, calcite filled, planar and sub-planar, fractures at 90°, 20°, 37°
	mineralization: pyrite finely disseminated, often replacing fossil remains, some crinoids completely replaced
71.0-83.5	Calcareous dolomite - 12.5'
	light grey, medium crystalline, homogeneous for most of the section, sucrosic
	79.0-83.5 - fractured and brecciated, coarse white sparite cement
	fractures: weak, 0.5-1.0 mm thick, planar, fractures at 55
	mineralization: little disseminated pyrite, sphalerite in coarse knots, amber to red in colour
	mode: 1.0-1.5" patches of sphalerite as open void filling
83.5-96.0	Dolomite breccia - 12.5'
	dark and light grey, medium crystalline moderately calcareous, coarse fragmental, conspicuous white dolomite cement between fragments. fragments are sub-angular, surrounded by a dolomite rim, rhombohedral dolomite crystals scattered

across short sections in a grey fine crystalline dolomite matrix, some pyrobitumen in coarser dolomite zones
fractures: poorly developed, subplanar, 1.0-1.5 mm thick, dolomite filled, fractures at 25°, 30°
mineralization: pyrobitumen in coarse white dolomite, fractures and along grain boundaries

96.0-113.5 Fossiliferous limestone - 17.5'

light and dark grey, fine crystalline, bioclastic in sections, fossils include thin shelled brachiopods, ½ mm diameter crinoids and possibly ostracods, also algal (?) remains and corals
fractures: planar, subplanar, .25 mm thick, dolomite filled fractures at 25°, 30°, 38°
mineralization: pyrite in thin stringers and fracture fillings

113.5-115.5 Dolomite - 2.0'

light grey, medium grained, homogeneous, some particles are angular, however, grain size changes, bedding planes at 55°
fractures: poor, non planar, dolomite fillled

115.5-163.8 Fossiliferous dolomite - 48.3'

dark grey, fine to medium crystalline, fossil assemblage similar to above limestone but far fewer fossils, ostracods (possible)
130.0-133.5 - equigranular dolomite
139.0-140.0 - coarse white dolomite, fracture filling
fractures: poor to moderately developed, planar and locally irregular, average 1.5 mm, fractures at 45°, 70°
mineralization: pyrite scattered irregularly throughout, isolated specks, short discontinuous stringers, also replacing fossils
at 121.5 - single large red crystals of sphalerite
at 147.5 - patches of large sphalerite crystals across 1.5"
155.5-158.0 - coarse red sphalerite, odd specks of sphalerite down to 161.4'

mode: sphalerite mineralization in a crenulated "laminate", dolomite, coarse and fine grained material

163.8-204.0 Dolomite - 40.2'

heterogeneous section, light and dark grey, fossilized and unfossilized, locally argillaceous and in part brecciated, dolomite; Thamnopora found throughout
163.8-167.0 - dark grey argillaceous dolomite
167.0-180.0 - brecciated sections with coarse pyrite and white dolospar
180.0-200.6 - medium to coarse dolomite with black argillite chips, breccias in many places, approximately 40% of total unit
at 182.0 - coarse grained dolomite
200.6-201.6 - black argillaceous dolomite
fractures: planar, dolomite filled, 2 mm thick
mineralization: pyrite in coarse breccia and finely disseminated in medium grained dolomite

204.0 Bottom of hole

Drill Hole - 2

Location: West Nabesche River Elevation: 5900'

Collar Dip: -75° Length: 150'

Formation tested: Slave Point

Depth	Lithological Description

0.0-3.5 Overburden - 3.5'

Slave Point Formation

3.5-16.0 Limestone - 12.5'

varigated light and dark grey, fine to very fine crystalline; local patches of red limestone (strong effervescent reaction in dilute HCl, red streak, hardness (3-3.5), not brecciated
at 4.5-5.5 - brown limestone strong effervescence, siderite (?) limestone somewhat argillaceous, thin bedded over 6" intervals
fractures: moderate to poor planar and

irregular, calcite filled, 1 mm-1.5 mm fractures at 20°, 30°
mineralization: sphalerite in brown carbonate material as tiny red grains at 8.0', also occurs in same way in grey 1.5'
13.0 - traces of galena, sphalerite
15.0 - sphalerite is associated with calcite in fractures

16.0-49.0 Nodular limestone - 33.0'

light grey nodules, dark grey to black matrix, nodules are interlocking, corners rounded, nodules contain varying amounts of crinoid stems, vague brachiopod outlines noted
at 20.5 - crinoid section begins; barren of fossils above
at 23.0 - brachiopods begin
at 34.5 - left hand coil gastropod
fractures: rough irregular surfaces, non planar
43.0-44.5 - intense fracturing, coarse white calcite fractures at 55°, 60°
mineralization:
at 14.5 - traces of sphalerite
14.5-20.5 - traces of sphalerite
at 38.5 - red speck of sphalerite

49.0-53.1 Limestone - 4.1'

unbrecciated, crinoid rich, slightly fractured

53.1-54.5 Dolomite - 1.4'

grey, medium crystalline
at 53.1 - amber sphalerite and pyrobitumen

54.5-59.3 Limestone - 4.8'

dark grey, crinoidal, homgeneous, fine to very fine crystalline, argillaceous
55.8-56.3 - brecciated with calcite

59.3-75.0 Dolomite - 15.7'

grey, medium-coarse crystalline, vuggy, very fossiliferous from 72.0 - 75.0; Thamnopora with lamellar stromatoporoid remains, light grey; white coarse crystalline dolomite in open spaces, short vuggy brecciated sections are mineralized with sphalerite

fractures: irregular, discontinuous, non planar dolomite filled, fractures at 13°, 40°
mineralization:
64.5-67.5 - coarse knots of red sphalerite
mode: coarse euhedral sphalerite in dolomitic mud matrix, black dolomite mud, white dolomite fragments

75.0-150.0 Fossiliferous limestone - 75.0'

light and dark grey, fossil content variable in proportion and type, some argillaceous sections, bedding planes at 65°, 70°
75.0-87.5 - thin bedded; dark grey fossiliferous limestone, crinoids, stromatoporoids and branching tabulate corals
87.5-129.0 - light grey, fine crystalline, poorly fossilized limestone with 0.5" to 6" beds of grey to black, fossiliferous limestone (usually thin bedded, fine to very fine crystalline)
89.0-91.5 - fossiliferous dark grey limestone, crinoids, thin shelled brachiopods and gastropods
129.0-131.0 - light grey limestone, stromatoporoids in dark grey matrix
131.0-134.4 - thin bedded, black, argillaceous limestone with pyrite along laminae, some crinoid and thin shelled brachiopod remains
134.4-150.0 - coarse fossiliferous, corals, Thamnopora, Amphipora (possible); black limestone mud between fossils, some lamellar stromatoporoid remains, bedding planes at 85°
fractures: poorly developed, non planar, irregular, calcite filled, 1-2 mm thick, fractures at 20°, 35°
mineralization: marcasite through most of argillaceous limestone sections, often replacing brachiopod remains
103.5-105.5 - marcasite 3-4%
129.0-131.0 - marcasite in stromatoporoid section

150.0 Bottom of hole

Drill Hole - 3

Location: West Nabesche River Elevation: 5880'

Collar Dip: - 75° Length: 200'

Formation tested: Slave Point

Depth	Lithological Description
0.0-5.0	Overburden - 5.0'
Slave Point Formation	
5.0-9.5	Nodular limestone - 4.5' light grey, nodules set in dark limestone mud, fossiliferous, brachiopods, 4"-6" sandy (?) intervals
9.5-18.0	Dolomite, dolomite breccia - 8.5' light grey, medium crystalline, white sparry dolomite between fragments, black argillaceous dolomite chips, fossilized crinoids fractures: non planar, irregular, calcite coated, 1-2 mm thick, fractures at 35°, 40° mineralization: mainly marcasite as individual grains, suspect sphalerite in coarse grained dolomite but not in significant amounts
18.0-20.2	Nodular limestone - 2.2' dark grey, tiny 1 mm crinoid remains, calcite filled fractures, some iron stain, brachiopod fragments
20.2-29.5	Dolomite breccia - 9.3' light grey, medium crystalline, fragments separated by thin cement of dark grey dolomite, short sections of sparite fractures: moderate, planar and very irregular, several generations, calcite 2 mm- 1.0 mm thick, fractures at 22°, 25° mineralization: at 20.5' and 22.5' iron oxides along fractures giving reddish yellow stain
29.5-30.5	Limestone - 1.0' light grey partially brecciated lamellar stromatoporoid unit

30.5-49.8 Dolomite breccia - 19.3'

light and dark grey, medium crystalline, some sections are distinct breccias whereas others contain stromatoporoid fragments. 1"-2" intervals are porous and vuggy
fractures: moderate, subplanar, calcite or dolomite filled, 1-2 mm thick, fractures at 15°, 20°, 50°, 60°
mineralization: marcasite
at 35.5 - coarse red grains of sphalerite

49.8-55.9 Dolomite - 5.2'

light grey, medium crystalline, black material (siliceous ?) in badly broken sections, moderately fractured
fractures: calcite coated, planar and subplanar, fractures at 16°

55.0-78.7 Dolomite - 23.7'

light and dark grey, medium and coarse crystalline, gradational contacts of coarse crystalline to fine crystalline, crinoid remains, some breccia containing black argillite chips
fractures: moderate, planar, dolomite filled, 1 mm thick, fractures at 33°, 50°, 55°

78.7-92.0 Dolomite - 13.3'

light grey, medium crystalline, thin, white, disjointed fractures, relatively homogeneous
fractures: distinct, planar, some irregular and non planar, 1-2 mm thick an average, fractures at 34°, 35°, 65°

92.0-109.5 Dolomite - 17.5'

fossiliferous, some unfossiliferous breccia, light and dark grey breccia
92.0-94.5 - mainly composed of brachiopod fragments
at 97.9 - 6" sparite
at 104.0 - 2" coarse amber sphalerite grains, scattered to 105.0

109.5-124.7 Dolomite - 15.2'

dark grey, medium crystalline, relatively

heterogeneous section, repetitive fossil sections and breccia zones, colour highly variable
152.7-157.5 - dolomite, fossil rich, breccia, brachiopods, Thamnopora, generally two species not mixed; sparite between fragments, one gastropod observed
157.5-162.0 - limey stromatoporoid unit, odd scattered Thamnopora
162.0-165.4 - dolomite fossil zone, Thamnopora, crinoids, brachiopods, dirty argillaceous material in brecciated zones
165.4-167.9 - Amphipora?, thin bedded, black limey unit
167.9-178.0 - light grey dense medium crystalline dolomite, short breccia sections, fractures moderate
172.0-174.0 - thin bedded black dolomite, Thamnopora, traces pyrite
178.0-182.3 - coarse grained varigated dolomite, fractures moderate at 50°, 70°
182.3-200.0 - light grey dolomite breccia, usually coarse and fine breccias are distinct
191.2-196.2 - unbrecciated

200.0 Bottom of hole

Drill Hole - 4

Location: West Nabesche River Elevation: 5880'

Collar Dip: - 75° Length: 186'

Formation tested: Slave Point

Depth	Lithological Description
0.0-2.0	Overburden - 2.0'

Slave Point Formation

2.0-10.0	Limestone - 8.0'

grey to light grey, fine crystalline, fossiliferous, crinoids, pyrite replaced brachiopods, gastropods, light brown carbonate (siderite ?)
fractures: planar, 0.6-1.0 mm thick, calcite filled, fractures at 20°, 35°
mineralization: pyrite rare, possible zinc oxide, pale rusty material

10.0-91.2 Nodular limestone - 81.2'

light grey, short dark argillaceous sections, large shelled brachiopods, tiny crinoids, nodules are light grey, subangular, angular and subrounded, dark grey to black argillaceous dolomite mud between fragments
fractures: very little fracture development, thin calcite filled fractures at 35°, 18°
mineralization: possible sphalerite at 18.5'

91.2-97.0 Fossiliferous limestone - 5.8'

light grey, crinoidal
fractures: rare, planar, calcite filled, 0.5-1.5 mm, fractures at 36°, 40°, 55°
mineralization: pyrite in odd scattered specks

97.0-109.5 Dolomite - 12.5'

light grey, coarse crystalline, homogeneous throughout
at 105.0 - 6" of sparite, pyrobitumen in fractures, in detail section is made up of coarse white dolomite crystals in black dolomite mud, slightly calcareous
fractures: thin, dolomite filled, subplanar, fractures at 12
mineralization: pyrobitumen, spherules of pyrite in fractures

109.5-110.5 Limestone - 1.0'

light grey, medium bedded moderately fractured

110.5-112.3 Amphiporoid limestone - 1.8'

70% Amphipora remains in dark grey lime mudstone matrix

112.3-113.0 Fossiliferous limestone - 0.7'

calcareous lamellar stromatoporoid remains

113.0-129.2 Fossiliferous limestone - 16.2'

light grey, fine to medium crystalline
113.0-114.8 - dolomitic, but fossil content remains the same, bedding plane at 90
118.6-119.6 - non-fossiliferous
120.5-121.0 - well developed lamellar stromatoporoids, other fossils - Amphipora, branching tabulate corals, brachiopods

homogeneous, fossils rare and scattered, crinoid stems present
at 111.2 - amber sphalerite grains
fractures: moderate to intense, in more intense sections local breccias developed, thin, calcite filled, fractures at 33°, 37°, 44°
mineralization: coarse subhedral amber sphalerite grains

124.7-142.5 Dolomite breccia - 17.8'

light grey, medium crystalline, coarse crystalline sections
124.7-127.0 - distinct dolomite breccia with fossil remains, vague circular fossils, lamellar stromatoporoid remains, some argillaceous dolomite between fragments, black argillaceous dolomite chips
127.0-132.5 - light grey, medium to coarse crystalline dolomite, black coarse sections are with very low effervescence even when powdered, medium crystalline material is dolomite
132.5-142.5 - light grey dolomite breccia, fossil fragments near top of unit, coarse white calcite with dolomite filled
mineralization: some brown stained pyrite

142.5-149.3 Limestone - 6.8'

thin laminated to medium bedded, fossiliferous locally dolomitic, crinoids, thin shelled brachiopods, partial replacement by pyrite, thinly laminated bioclastic layers, overall dark grey to black, bedding planes at 52°,63°
fractures: thin, planar or subplanar, calcite filled, at least two generations, fractures at 23°, 35°, 45°

149.3-152.7 Dolomite - 3.4'

black, dark grey to argillaceous, poor effervescence even when powdered, fine crystalline, some thin laminated sections which are partly fossiliferous
bedding planes at 60°
fractures: rare, planar, fractures at 35°
mineralization: very fine grained pyrite throughout

152.7-200.0 Dolomite, limestone partly fossiliferous breccia - 47.3'

fractures: poorly developed, sub-planar, irregular, calcite filled, fractures at 22.0°

129.2-162.2 Limestone - 33.0'

dark grey to black, thin bedded, locally brecciated, fossiliferous, mainly crinoid and brachiopod remains, bedding planes at 85°- 90°
fractures: poorly developed, calcite filled, fractures at 20°, 50°, 60°
mineralization: Pyrite mixed with fossil remains

162.2-175.0 Dolomite - 12.8'

dark grey to black, medium to very fine crystalline, thin to medium bedded, bedding planes at 45°
162.2-165.5 - black laminated dolomite, fractured at 164.8 - 2" coarse amber sphalerite in and around fragments in short breccia zone, scattered fine grained pyrite also present
166.5-170.0 - light and dark grey, convolute laminated dolomite with fine grained pyrite
170.0-175.0 - dark grey convolute dolomite - also high pyrite content as small specks and streaks parallel to laminae

175.0-186.0 Dolomite breccia - 11.0'

light grey fragments with white calcite or dolomite cement
181.0-186.0 - fine grained breccia

186.0 Bottom of hole

Drill Hole - 5

Location: West Nabesche River Elevation: 5870'

Collar Dip: - 70° Length: 219.5'

Formation tested: Slave Point

Depth	Lithological Description

0.0-2.8 Overburden - 2.8'

Slave Point Formation

2.8-3.5 Dolomite - 0.5'

mudstone, grey, fine crystalline,

massive in places, iron stained in places

3.5-4.8 Limestone - 1.5'

mudstone, grey, fine crystalline, 10% fossils, fossils replaced by white sparry calcite
mineralization: 1% pyrite replacing fossils
at 4.6 - a few sphalerite (?) specks

4.8-15.0 Nodular limestone - 10.2'

grey, light grey nodules (1/8"-6") in dark grey matrix; matrix is fine crystalline and contains many small crinoid fragments, thin shelled brachiopods and a few gastropods; nodules are subangular; in a few places very thin (1/16") calcite veinlets occur
at 7.6 - wackestone, 40% fossils

15.0-90.1 Nodular limestone - 75.1'

like above but higher concentration of nodules; both nodules and matrix contain some brachiopods and crinoids (both 1 and 2 holes)
at 24.0 - bituminous
mineralization: in the upper 15': 2-5% pyrite, predominantly occuring as tiny specks; in a few places fine grained pyrite occurs in a few scattered patches

90.1-97.6 Limestone - 7.5'

wackestone, light grey; fine crystalline matrix, fossil content 30%: mainly crinoid fragments
at 93.6 - argillaceous

97.6-101.1 Limestone - 3.5'

wackestone, black; fine crystalline argillaceous (15%) matrix; fossil content 5-15% mainly crinoids, a few brachiopods
at 100.0 - very argillaceous (25%)

101.1-103.1 Dolomite - 2.0'

black, breccia: black dolomite fragments ($\frac{1}{2}$"-1") in white sparry dolomite matrix, fragments are fine crystalline

103.1-103.6 Dolomite - 0.5'

wackestone, grey; matrix: fine crystalline, fossil content 10-15% mainly Thamnopora replaced by white sparry dolomite cement

103.6-103.7 Shale - 0.1'

black, calcareous, fine grained

103.7-106.4 Dolomite - 2.7'

wackestone, grey; matrix: fine crystalline, fossil content 10-15%: some brachiopods and many unidentified ghosts of fossils; some fossils are leached out leading to good fenestral porosity

mineralization:

at 103.7-104.0 - 10-15% sphalerite, red to amber in colour occurs in pods probably replacing fossils

at 106.0-106.4 - 15-20% sphalerite, red to amber occurs as vugs filling and fossil replacement

106.4-111.1 Dolomite - 4.7'

wackestone, grey, mottled; dolomitization destroyed most of the fossils giving mottled appearance; some fossils replaced by white sparry dolomite

111.1-111.4 Calcite - 0.3'

white sparry calcite vein

111.4-112.9 Dolomite - 1.5'

wackestone, grey; matrix: fine crystalline; fossil content 10-15%, main fossil probably Amphipora, most of fossils replaced and destroyed by white sparry dolomite

112.9-115.9 Dolomite - 3.0'

wackestone, black, highly fossiliferous

at 112.9-114.4 - packstone, fossil content 70-80% mainly Amphipora and Thamnopora
at 114.4-115.9 - fossil content 30-50%, same assemblage; fossil size decreases downward, they are mostly replaced by white sparry dolomite, and the whole unit is frequently cut by white sparry dolomite veinlets; matrix black to fine crystalline throughout

115.9-119.0 Limestone - 3.1'

black, mudstone, fine to medium crystalline, about 5% scattered fossils mostly crinoids and some scattered Thamnopora towards bottom of unit; clay content increases to 10% downward

119.0-120.7 Limestone - 1.7'

black, wackestone, matrix, fine crystalline, fossil content 15-20% concentrated in 2-3" bands, main fossils are crinoids and near lower contact a few Thamnopora, fossils are replaced by white sparry calcite, rock cut by small veinlets of calcite, in a few places there are shaly partings

120.7-127.5 Limestone - 6.8'

dark grey, wackestone, matrix fine crystalline with a few shaly partings
at 120.7-123.0 - fossil content 20% mainly lamellar stromatoporoids, corals (?) Thamnopora and small crinoids
at 122.6-123.0 - appearance of a few brachiopods; rock cut by small partings which occur in 4-6" bands; 5% scattered fossils, Thamnopora, crinoids and stromatoporoid heads
mineralization: 1% disseminated pyrite

127.5-129.4 Limestone - 1.9'

grey, wackestone, matrix fine crystalline, fossil content 40%, main fossil large ($\frac{1}{4}$"x1") Thamnopora, but many small brachiopods and unidentified skeletal fragments

129.4-130.8 Limestone - 1.4'

grey, mustone, fine crystalline matrix

fossil content 8%: unidentified skeletal fragments, contains a few lamellar stromatoporoid fragments, some shaly partings

130.8-174.1 Limestone - 43.3'

grey to black, mudstone, fine crystalline, fossil content less than 5%, scattered crinoids and small brachiopods, rock becomes blacker with increase in shale content
at 130.8-144.0 - grey, mudstone, fine crystalline cut by hair veinlets of white sparry calcite
at 144.0-148.7 - brecciated (?) - lighter coloured fragments in darker matrix, fragments are rounded, probably recrystallized large brachiopods, matrix same fine grained as previous
at 148.7-171.4 - dark grey, mudstone, fine grained crystalline, massive, frequent 1-2" bands of high shale content, usually there are associated unidentified skeletal fragments and small brachiopods - fossil content less than 5% in places hair veinlets of white sparry calcite

174.1-176.2 Limestone - 2.1'

black, mudstone, fine crystalline, fairly argillaceous (10%) clay content increases to 20-30% near bottom of unit, fossil content less than 5%; only unidentified skeletal fragments

176.2-178.8 Limestone - 2.6'

grey, mudstone - wackestone, fine crystalline, fossil content 50-60% mainly unidentified skeletal fragments but also occasional Thamnopora, and stromatoporoid heads
mineralization: 5% patchy pyrite with 60% pyrite in the patches

178.8-185.0 Limestone - 6.2'

black, mudstone, matrix, fine crystalline with a few shaly partings in places, few scattered Thamnopora

185.0-186.5 Limestone - 1.5'

grey, mudstone, fine crystalline, massive no fossils

mineralization: small nodules of pyrite and disseminated pyrite - total less than 5%

186.5-187.0 Dolomite - 0.5'

black, mudstone, fine crystalline, argillaceous (10%) with many shaly partings, massive
mineralization: 2% pyrite in small patches

187.0-188.3 Limestone - 1.3'

grey, mudstone, massive
mineralization: 1% disseminated pyrite

188.3-193.4 Limestone - 5.1'

black, wackestone, matrix fine crystalline, earthy, argillaceous (15%) fossil content 25-30%, main fossil: Thamnopora, in places corals (?) and lamellar stromatoporoids

193.4-200.9 Limestone - 7.5'

black, mudstone, fine to very fine crystalline, contains patches of lighter coloured material which usually contain disseminated pyrite (2%), in a few places scattered Thamnopora, brachiopods, gastropods, but unidentified skeletal fragments are throughout the unit

200.9-206.8 Dolomite - 5.9'

black, packstone-grainstone, highly recrystalliezed to the point of not recognizing fossils, fossil size ¼" highly replaced by calcite/dolomite, matrix is black, fine crystalline, rock has a very massive appearance
at 203.6-206.8 - great increase in clay content downward to about 30%, replaced fossils occur in thin bands

206.8-207.5 Limestone - 0.7'

black, mudstone, fine crystalline argillaceous (10%) contains some unidentified skeletal fragments and small brachiopods
mineralization: ¼" band of pyrite (70%)

207.5-209.0 Dolomite - 2.5'

grey, mudstone, fine crystalline, fairly massive, has some leached areas filled with white sparry dolomite, lower 0.5' has no leached areas

209.0-219.5 Limestone - 10.5'

grey, mudstone, microcrystalline, varying argillaceous content from 0-7%, unidentified skeletal fragments occur in a few places, fossils replaced by white sparry calcite

219.5 Bottom of hole

Drill Hole - 6

Location: West Nabesche River Elevation: 5910'

Collar Dip: - 71° Length: 208.7'

Formation tested: Slave Point

Depth	Lithological Description
0.0-5.0	Overburden - 5.0'

Slave Point Formation

5.0-35.1 Limestone - 30.1'

grey, wackestone, fine crystalline, matrix fossil content 10-15% main fossil is crinoid, some unidentified skeletal fragments

at 14.0-30.1 - slightly nodular, nodules of grey mudstone in black crystalline matrix, main fossils brachiopods and unidentified skeletal fragments; rock mostly has a very massive appearance in a few places there are some shaly partings

35.1-87.8 Nodular limestone - 52.7'

black and grey, nodules are rounded ($\frac{1}{4}$"-2") in size, grey lime mudstone, matrix is black lime mudstone, fossil content 10%, main fossils are unidentified skeletal fragments but has

scattered brachiopods; black limestone has higher shale content but still less than 5%
at 72.0-87.8 - contains scattered gastropods

87.8-95.3 Limestone - 7.5'

black, mudstone, very fine crystalline, fossil content 10%, main fossils: crinoids, some unidentified skeletal fragments, fossils usually occur in concentrated bands
mineralization: 1% pyrite, disseminated throughout

95.3-129.3 Limestone - 34.0'

grey to dark grey wackestone
at 95.3-98.7 - wackestone, fossil content 40%, main fossils Thamnopora and brachiopods, few broken lamellar stromatoporoid fragments, matrix is a black mudstone, contains unidentified skeletal fragments
at 98.7-110.3 - grey to black wackestone, fossil content 25-35%, mainly stromatoporoids, and unidentified skeletal fragments, some brachiopods; matrix is microcrystalline; in places "sedimentary breccia" in other places white massive; fossils are replaced by white sparry calcite cement; rock has a mottled appearance
at 110.3-112.9 - black wackestone, fossil content 25% mainly Amphipora, matrix is black, microcrystalline
at 112.9-116.0 - mudstone-wackestone fossil content 10% scattered Thamnopora, corals (?) unidentified skeletal fragments; matrix: black, microcrystalline
at 116.0-129.3 - wackestone-mudstone, fossil content 20%, main fossil crinoid scattered throughout and concentrated in places, scattered stromatoporoids, Thamnopora and corals, lower 2.0 scattered lamellar stromatoporoids
at 129.0-129.3 - lamellar stromatoporoids

129.3-182.1 Limestone - 52.8'

dark grey to black, mudstone, microcrystalline massive, fossil content less than 5%: mainly small brachiopods, very few gastropods, colour of the rock varies with the clay content, i.e. darker, more

shale, shalier areas seem to contain more fossils, in a few places slightly nodular
mineralization: 2% pyrite disseminated, in a few places replaces fossils

182.1-208.7 Limestone - 26.6'

black, wackestone, fine crystalline, argillaceous matrix
at 182.1-184.7 - wackestone, fossil content 25-35% predominantly large fossils, stromatoporoids and corals, unidentified skeletal fragments, and scattered brachiopods, the odd Thamnopora
at 184.7-186.7 - mudstone, fossil content less than 5% scattered Thamnopora, unidentified skeletal fragments
at 186.7-191.5 - mudstone, massive black, less than 3%, unidentified skeletal fragments
at 188.4-188.8 - abundant Thamnopora
mineralization: 1% pyrite scattered specks
at 191.5-193.6 - wackestone, fossil content 10-30%, main fossils Thamnopora, unidentified skeletal fragments
at 193.6-196.6 - wackestone, fossil content 20-25%, main fossils stromatoporoids, corals, some Thamnopora
at 196.6-208.7 - mudstone, fossil content 5%, unidentified skeletal fragments, scattered brachiopods, Thamnopora in one place 5" layer of stromatoporoids, brecciated in a few places

208.7 Bottom of hole

Drill Hole - 7

Location: West Nabeshe River Elevation: 5880'

Collar Dip: - 67° Length: 293.5'

Formation tested: Slave Point

Depth	Lithological Description
0.0-10.0	Overburden - 10.0'

Slave Point Formation

10.0-19.5 Limestone - 9.5'

dark grey to black, mudstone, argillaceous, microcrystalline, clay content

20-25% increases downward, in places cut by calcite veinlets

19.5-39.2 Shale - 9.7'

black, calcareous shale, very finely laminated
at 34.0 - appearance of unidentified skeletal fragments and thin Amphipora, in places some brachiopods, fossil content under 3%

39.2-55.7 Limestone - 16.5'

grey, mudstone, fine to very fine crystalline, argillaceous (10%), laminated with fine shale partings; fossil content 5%; few scattered thin shelled brachiopods
at 47.0-52.3 - wackestone-mudstone, fossil content 10-15%; mainly thin shelled brachiopods and some unidentified skeletal fragments

55.7-144.8 Nodular limestone - 89.1'

grey-black, mottled; nodules are light grey, rounded ($\frac{1}{4}$-2") limestone; matrix black, fairly shaly, fossiliferous with unidentified skeletal fragments
at 58.0-65.0 - nodulation less pronounced, fossil content 15% mainly unidentified skeletal fragments, tiny brachiopods, crinoids and lamellar stromatoporoids in places; starting at 117.7 rock becomes very crinoid rich, grey nodules not pronounced but present
at 128.0-133.0 - very small nodules ($\frac{1}{4}$")
mineralization: 2% pyrite in scattered patches

144.8-153.2 Limestone - 8.4'

dark grey to black mudstone, microcrystalline, fossil content 5% mainly crinoids and unidentified skeletal fragments
mineralization: 2% pyrite in scattered patches

153.2-163.6 Dolomite - 10.4'

at 153.0-156.0 - a dolomitized version of above lithology
at 156.0-163.6 - wackestone, fossil content 40%, main fossils probably Amphipora, also

unidentified skeletal fragments, matrix: coarse crystalline dolomite
at 157.9-158.6
mineralization: 20% sphalerite occuring in large patches up to 1" in diameter; sphalerite colour is red to brown, most of the mineralization occurs in patches; 2% scattered pyrite, but does not seem related to the sphalerite; most rock is a black, grey, white mottled dolomite, no apparent fossils, occuring below the mineralization relict Amphipora 1% in black massive dolomite mudstone

163.5-170.4 Dolomite - 6.8'

black and white, wackestone-packstone fossil content 30-70%
163.6-164.6 - wackestone, fossil content 30-35%, mainly Amphipora
at 164.6-165.9 - packstone, fossil content 70%: Amphipora
at 165.9-170.4 - wackestone, fossil content 40-50%, main fossils: Thamnopora, stromatoporoids, corals (?), crinoids and unidentified skeletal fragments, matrix - fine crystalline black dolomie in places brecciated; all fossils replaced by white sparry dolomite, in places cut by massive white sparry dolomite veins, large vugs filled with sparry dolomite very often centre of these vugs contain a euhedral quartz crystal

170.4-183.2 Dolomite - 12.8'

black, mudstone-wackestone, fossil content 15%, mainly crinoids and unidentified skeletal fragments, some scattered Amphipora, matrix is a fairly shaly, microcrystalline rock, appears very massive
at 182.7-183.0 - lamellar stromatoporoid rich bed

183.2-217.1 Dolomite and limstone - 33.9'

black to grey mudstone, colour varies with clay content, mostly dolomite but in places there are limestone patches approximately 1" in width, cut in places by hair veinlets of white sparry dolomite, in some places white sparry dolomite fills vugs, sometimes brecciated but mostly a very massive rock
at 209.0-211.0 - mudstone - coarse crystalline in areas of high clay content rock is

limestone and contains some unidentified skeletal fragments
mineralization: 1% disseminated pyrite

217.1-219.4 Dolomite - 2.3'

black to grey, wackestone, fossil content 40%, mainly stromatoporoids, crinoids, unidentified skeletal fragments, some minor Thamnopora; all fossils replaced by white sparry dolomite, presence of bitumen in a few places, cut by dolomite veinlets in places

219.4-226.0 Dolomite - 7.6'

black, mudstone, microcrystalline, fossil content 7%, unidentified skeletal fragments, some crinoids, one or two scattered Amphipora, cut in a few places by dolomite veinlets

226.0-228.4 Dolomite - 2.4'

wackestone, fossil content 35-40% main fossil Thamnopora, some lamellar stromatoporoid fragments and unidentified skeletal fragments, matrix fine crystalline grey dolomite

228.4-235.3 Dolomite - 6.9'

grey, mudstone, microcrystalline, fossil content 2%, unidentified skeletal fragments and few crinoids, brecciated in places but cut by dolomite veinlets in places, clay content varies 0-15%, very massive appearing rock

235.3-261.6 Shaly dolomite - 26.3'

black, mudstone, massive, microcrystalline, earthy, fossil content 2%, unidentified skeletal fragments, few scattered brachiopods and poorly preserved Thamnopora, in a few places slightly brecciated by white sparry dolomite
mineralization: 1% disseminated pyrite

261.6-293.5 Dolomite - 31.9'

grey to black, mudstone-wackestone fossil content 20%, main fossils Thamnopora, some stromatoporoids, scattered brachiopods, corals (?) near top of unit;

matrix: fine grained massive mudstone; the whole rock has been completely brecciated by solution, all fossils replaced by white sparry dolomite, breccia matrix is white sparry dolomitic cement
mineralization: 2% disseminated pyrite

293.5 Bottom of hole

Drill Hole - 8

Location: West Nabesche River Elevation: 5820'

Collar Dip: - 64° Length: 159.6'

Formation tested: Slave Point

Depth	Lithological Description
0.0-13.0	Overburden - 13.0'
Slave Point Formation	
13.0-26.7	Limestone - 13.7'
	black, mudstone, shaly, fine crystalline, in places a calcareous shale, fossil content less than 5%, mainly thin shelled brachiopods; clay content decreases downward, fossils replaced by white calcite cement mineralization: 1% pyrite in small scattered patches
26.7-96.6	Nodular limestone - 69.9'
	black and grey, mottled, nodules are light grey, varying in size from 1/8"-2", matrix: black, fine grained fossil fragments occur in both nodules and matrix, fossil content 20%; main fossils: brachiopods, gastropods, crinoids and unidentified skeletal fragments, brachiopods are more associated with the matrix; all fossils replaced by white calcite cement at 54.5-64.8 - more massive grey limestone but some stringer of matrix present at 79.4-93.2 - predominant fossils are crinoids; fossil content 5-15%
96.6-116.2	Limestone - 19.6'
	black, mudstone, very fine to micro-

crystalline, fossil content less than 10%; main fossils crinoids and unidentified skeletal fragments, few scattered 6"-8" stromatoporoids, in places many shaly partings
mineralization: 1% scattered pyrite grains

116.2-122.3 Limestone - 6.1'

grey, mottled breccia, primary nature; fragments of mudstone origin and matrix contains many rounded particles, fossils (?) breccia fragmens (?), some Thamnopora-like fossils; fossils are replaced by white calcite/dolomite

122.3-129.2 Limestone - 6.9'

black; packstone-wackestone, fossil content 60-70% mainly small Amphipora increasing in size downward; matrix is a fine crystalline to microcrystalline
at 125.3-129.2 - wackestone, fossil content 40% main fossils: Thamnopora, stromatoporoids and corals (?), matrix is a black, mudstone with 5% crinoids

129.2-159.6 Limestone - 30.4'

black, mudstone-wackestone, fossil content 10-20%, main fossils: unidentified skeletal fragments, crinoids, tiny brachiopods a few gastropods and few and scattered Thamnopora
at 141.2 - lamellar stromatoporoid rich bed
143.0-159.6 - much less than 5% fossils, main fossil: thin shelled brachiopods, clay content varies (0-10%)
from 150.3 - nodular texture, in several places shaly partings with pyrite hair veinlets
at 157.1 - minor Thamnopora (1%)
mineralization: 2% pyrite replaces unidentified skeletal fragments, also tiny hair veinlets

159.6 Bottom of hole

Drill Hole - 9

Location: West Nabesche River Elevation: 5945'

Collar Dip: - 67° Length: 71.0'

Formation tested: Slave Point

Depth	Lithological Description
0.0-4.2	Overburden - 4.2'
Slave Point Formation	
4.2-27.0	Limestone - 13.0'
	grey to black, mudstone, to wackestone, matrix is microcrystalline, fossil content 15-25% mainly crinoids, in places slightly nodular; clay content varies from 3-15%, in places cut by calcite hair veinlets
27.0-28.1	Shale - 1.1'
	black, calcareous shale, finely laminated, fossil content 2% mainly a few crinoids and brachiopods, cut by calcite and bitumen veins
28.1-30.6	Dolomite - 2.5'
	grey, mudstone microcrystalline, dolomitized version of limestone above; main fossil: crinoids (15%), few shaly partings, in places cut by dolomite stringers
30.6-35.2	Shale - 4.6'
	black, calcareous shale, laminated, no visible fossils, in places cut by dolomite stringers mineralization: 2% disseminated pyrite
35.2-38.9	Dolomite - 3.7'
	grey, mudstone, microcrystalline, fossil content 10%, mainly crinoids, very massive rock in places shaly partings, cut by dolomite veinlets
38.9-43.2	Dolomite - 4.3'
	black to grey, wackestone, fossil content 35%, main fossils: Amphipora, stromatoporoids and crinoids, some scattered

Thamnopora, matrix is fine crystalline, all fossils replaced by white sparry dolomite
mineralization: 2% sphalerite, red, total amount is represented by 2 specks

43.2-48.0 Dolomite - 4.8'

grey and white, breccia, fragments are a grey mudstone, medium grained and massive; matrix is white sparry dolomite cement
45.6-46.0
mineralization: 10% sphalerite, red to brown occuring in fractures associated with dolomite cement; occurs as small ($\frac{1}{4}$") subhedral crystals

48.0-61.2 Dolomite - 13.2'

grey to black, wackestone, fossil content 20%, main fossils:crinoids, stromatoporoids, few scattered Amphipora and Thamnopora, all fossils replaced by dolomite, matrix is grey-black, microcrystalline, colour varying with shale content
at 56.0 - lamellar stromatoporoid fragments
at 61.0 - stromatoporoid fragments about 4" thick

61.2-71.0 Limestone - 10.2'

black to grey, mudstone, shaly, microcrystalline, fossil content 5%; scattered unidentified skeletal fragments and thin shelled brachiopods; cut by calcite veinlets; some shaly partings

71.0 Bottom of hole

Drill Hole - 10

Location: West Nabesche River Elevation: 5875'

Collar Dip: - 65° Length: 103.0'

Formation tested: Slave Point

Depth	Lithological Description
0.0-4.0	Overburden - 4.0'
Slave Point Formation	
4.0-9.0	Limestone - 5.0'
	black, mudstone, microcrystalline, argillaceous (less than 5%), no visible fossils
9.0-15.6	Limestone - 6.6'
	black, mudstone-wackestone, fine grained, fossil content 10% mainly brachiopods, crinoids and unidentified skeletal fragments, odd stromatoporoid
15.2-22.7	Limestone - 7.1'
	black, mudstone, microcrystalline, massive, in places slightly nodular
22.7-30.6	Limestone - 7.9'
	black, wackestone, matrix: microcrystalline, fossil content 30-35%, main fossils: Amphipora, stromatoporoids, Thamnopora, unidentified skeletal fragments and crinoids
	at 24.3-25.2 - packstone, fossil content 70%, all Amphipora increasing in size downwards
30.6-42.3	Limestone - 11.7'
	black, wackestone, fossil content 40%; main fossils crinoids and unidentified skeletal fragments, scattered Thamnopora, matrix, shaly mudstone, many shaly partings; clay content varies irregularly
	at 38.0 - concentration of crinoids and some Thamnopora
	at 42.3 - about 4" layer of lamellar stromatoporoids

42.3-94.4 Limestone - 52.1'

black, mudstone, microcrystalline, fairly massive, about 5% fossils scattered randomly mainly crinoids and unidentified skeletal fragments, some brachiopods, in places shaly

94.4-103.0 Limestone - 8.6'

black, wackestone, mudstone, fossil content 40%, mainly stromatoporoids, Thamnopora, lamellar stromatoporoid fragments (?) and unidentified skeletal fragments, matrix: argillaceous (10%), microcrystalline with many shale laminae

103.0 Bottom of hole

Drill Hole -N3

Location: West Nabesche River Elevation: 6250'

Collar Dip: - 65° Length: 566'

Formation tested: Slave Point

Depth	Lithological Description

0.0-10.0 Overburden - 10.0'

Slave Point Formation

10.0-19.0 Limestone - 9.0'

black, shaly lime mudstone, shale content 20-40%, contains 1-2" beds of thin shelled brachiopods, fossil content 2%, fossils replaced by white sparry calcite

19.0-31.2 Limestone - 12.2'

black, shaly, lime mudstone, shale content 5-10%, relatively unfossiliferous, but there are scattered thin shelled brachiopods, thick shelled brachiopod fragments, and crinoids

31.2-113.0 Nodular limestone - 81.8'

at 31.2 - starts to show the characteristic nodular texture
at 31.7 - some cavities filled with rusty

material
at 40.0 - shaly limestone, shale content 10%, contains thick shelled brachiopod fragments
at 43.0 - large and small crinoids first start to appear among the nodules, fossil content 10% in concentrated areas, nodules consist of grey limestone
49.0-53.0 - development of the nodules very good
at 66.7 - cut by sparry calcite veinlets
at 77.0 - proportion of characteristic thick shelled brachiopod increases to about 15% fossils, thin shelled brachiopods often outline nodules, depositional fabric warps around the nodules
at 86.0 - 8" bed containing small crinoids, fossil content 10%
89.0-91.5 - scattered crinoid fragments, fossil content 5%, fossils very prolific in black matrix surrounding the nodules, contacts of the nodules may be sharp or diffuse, pyrite abundant throughout rock

113.-142.3 Limestone - 29.3'

black, shaly lime mudstone, fossil content 5% mainly small crinoid fragments, scattered pyrite shale content 5-10%, massive
at 127.5 - strikingly unfossiliferous
131.0-132.0 - tiny brachiopods or ostracods (?) small stromatoporoid fragment or algal oncolite, fossil content 5-10%
132.0-137.6 - very finely laminated shaly limestone, unfossiliferous, black, mudstone

142.3-143.2 Limestone - 0.9'

top 0.7', lime packstone-wackestone, fossil content 60-80%, mainly Amphipora, some Thamnopora; bottom 0.2' wackestone containing thin shelled brachiopods

143.2-152.1 Limestone - 8.9'

grey, lime wacke-packstone, appears to be detrital debris bed, grain size increases downward from silt to sand size, fragments are a mixture of brachiopods, crinoids, corals and stromatoporoids

152.1-157.0 Limestone - 4.9'

black, argillaceous, lime wacke-mudstone,

fossil content 15-20%, mainly unidentified skeletal fragments and corals, very few crinoids

157.0-160.8 Limestone - 3.8'

sharp contact between black and grey detrital mudstone, black lime wackestone, fossil fragments include brachiopods, crinoids, corals and stromatoporoids
158.5-159.0 - Thamnopora, wackestone, black, argillaceous, fossil content 15-20%

160.8-175.4 Limestone - 14.6'

black, argillaceous (20%) lime mudstone, fossil content 0-5%, mainly crinoids, thin shelled brachiopods and some gastropods, matrix very rich in unidentified skeletal fragments, in a few places the nodular texture present, some sections extremely shaly, scattered pyrite, cut by calcite veinlets

175.4-183.7 Nodular limestone - 8.3'

grey and black nodular texture, main fossils thin shelled brachiopods and unidentified skeletal fragments

183.7-233.4 Limestone - 49.7'

black, argillaceous, lime mudstone, main fossils are unidentified skeletal fragments and brachiopods, in places very massive and unfossiliferous
208.6-208.8 - fractures filled with unidentified brown material, suspected to be rusty dolomite
226.8-227.0 - algal layering or lamellar stromatoporoids
at 230.0 - algal layering (?) 20% thin shelled brachiopods, very shaly

233.4-246.4 Dolomite - 13.0'

grey, argillaceous, medium crystalline dolomitic wackestone, fossil content 20-30%, main fossils are corals, brachiopods and unidentified skeletal fragments, Thamnopora most predominant species, matrix is grey to black, medium crystalline mudstone, rock has many shaly partings

244.3-246.4 - detrital wackestone containing Thamnopora, other tabulate coral fragments, unidentified skeletal fragments, at the base of the unit algal layering or lamellar stromatoporoids

246.4-252.6 Limestone - 6.2'

black, shaly, lime mudstone, relatively unfossiliferous except for some unidentified skeletal fragments and a few thin shelled brachiopods, some nodular texture, pyrite associated with the nodules

252.6-253.6 Limestone - 1.0'

cut severely by calcite veinlets, contains 30% Thamnopora fragments, marker bed

253.6-259.2 Dolomite - 5.6'

grey, fine crystalline, dolomitic mudstone

259.2-264.0 Nodular limestone - 4.8'

black, shaly, lime mudstone, grey nodules, fossil content 5-25%, mainly thin shelled brachiopods

264.0266.0 Limestone - 2.0'

black to grey, wacke-mudstone, fossil content 15-20%, matrix, fine grained mudstone composed primarily of unidentified skeletal fragments, main fossils, Thamnopora, lamellar stromatoporoids, crinoids and brachiopods, rock has a mottled texture

Watt Mountain Formation (?)

266.0-282.0 Limey sandstone - 16.0'

grey, fine grained limey sandstone, contains lithoclasts, fossil fragments, rock has a very distinctive mottled appearance

Sulphur Point Formation (?)

282.0-360.5 Massive limestone - 78.5'

Pine Point Formation (?)

360.5-566.0	Dolomite breccia - 205.5'
566.0	Bottom of hole

APPENDIX - 4

Measured Outcrop Sections

The measured outcrop sections are located on two east-west trending ridges that are found in the study area (Figure 2). The top of the red weathering Watt Mountain Formation was used as a datum, from which sections were measured upwards into the overlying shales. In places where the Watt Mountain Formation was covered the base of the Reefal member was used as a datum.

Section A

Location: West Nabesche River Latitude 56° - 16' - 03"
Longitude 123° - 26' - 52"

Section starts at top of red weathering sandstone bed - Watt Mountain Formation and is measured upwards.

Footage	Lithological Description

Slave Point Formation

Lower Mudstone member 0 - 62'

0 - 7 Limestone - 7'

black, fine crystalline, lime wackestone; 10-15% fossil content, mainly scattered Thamnopora

7 - 11 Limestone - 4'

dark grey to black, fine crystalline, lime wackestone-mudstone; less than 5% fossil content mainly scattered brachiopods and gastropods

11 - 54 Limestone - 43'

black, fine crystalline, argillaceous, lime mudstone; no fossils; clay content 5-10%; at 20' - two foot flaggy interval

54 - 62 Limestone - 8'

black, fine crystalline, argillaceous, lime mudstone; 5-10% fossil content, scattered brachiopods and Amphipora (?)

Reefal member 62 - 118'

62 - 63 Dolomite - 1'

light grey, medium crystalline, dolomite wackestone-packstone; 20-30% fossil content, predominantly lamellar stromatoporoids and unidentified skeletal fragments

63 - 83 Dolomite and Limestone - 20'

dark grey, medium crystalline, dolomite wackestone-packstone; 20-30% fossil content, mainly Thamnopora, lamellar stromatoporoids, small brachiopods, occasional

overturned massive stromatoporoid heads and unidentified skeletal fragments

67 - 72'
black, fine crystalline, dolomite mudstone; less than 10% fossils, unidentified skeletal fragments and few crinoid fragments

78 - 80'
light grey, fine crystalline, lime wackestone; 35-40% fossil content mainly crinoid fragments

83 - 88 Limestone - 5'

black, fine crystalline, argillaceous lime packstone; 70-80% fossil content mainly branching stromatoporoids, some Thamnopora and lamellar stromatoporoids. Fossil fragments graded upwards into smaller grains, Thamnopora and lamellar stromatoporoids found only near bottom two feet of this interval; clay content up to 20%

88 - 93 Limestone - 5'

light grey, fine crystalline, lime mudstone, less than 10% fossils mainly brachiopods and crinoid fragments; this unit has a blocky appearance

93 - 118 Limestone - 15'

light grey, fine crystalline, lime wackestone; 20-40% fossil content mainly crinoid fragments and thin shelled brachiopods

95 - 115'
main fossils are thick shelled brachiopods occasional massive stromatoporoid heads and near top of interval, Amphipora (?)

Nodular member 118 - 211'

118 - 201 Limestone - 83'

dark grey, fine crystalline, argillaceous lime mudstone exhibiting a nodular texture, nodules sometimes are outlined by very large brachiopod shells; less than 10% fossil content mainly brachiopods

128 - 130'
dark grey, fine crystalline, lime wackestone; 25-30% fossil content mainly crinoid fragments and gastropods (?)

138 - 145'
fossil content may increase to 20% mainly brachiopods of various sizes

179 - 181'
black, fine crystalline, lime wackestone; 20-30% fossil content mainly crinoid fragments

184 - 187'
black, fine crystalline, lime wackestone-packstone; 50-60% fossil content mainly brachiopods

189 - 196'
lime mudstone becomes increasingly argillaceous; clay content 15-20%; alternating 6 inch beds containing brachiopods and massive argillaceous limestone

201 - 211 Argillaceous limestone - 10'

dark grey, fine crystalline, argillaceous; lime mudstone-wackestone; 5-15% fossil content mainly brachiopods; clay content 20%, slaty cleavage, weathers light grey

Upper Mudstone member 211 - 313'

211 - 261 Argillaceous limestone - 50'

black, very fine crystalline, highly argillaceous, lime mudstone; no fossils; clay content 25-40%, slaty cleavage attitude 96°/44° S; thinly bedded; contains vugs filled with brown sandy soil

261 - 313 Covered interval on top of ridge; contact with Besa River Formation interpreted at 313'

End of section

Section B

Location: West Nabesche River Latitude 56° - 16' - 53"
Longitude 123° - 25' - 12"

Section starts at the top of a red weathering sandstone bed - Watt Mountain Formation and is measured upwards.

Footage	Lithological Description

Slave Point Formation

Lower Mudstone member 0 - 49'

0 - 15 Dolomite - 15'

light grey, fine to medium crystalline, dolomite mudstone-wackestone; 10-20% fossil content, mainly Thamnopora; occurrences of authigenic quartz crystals

15 - 49 Argillaceous limestone - 34'

black, very fine crystalline, argillaceous lime mudstone; clay content 10-35%, earthy lumpy and ropey weathering

28 - 40'
5-10% fossil content, scattered brachiopods and gastropods

Reefal member 49 - 87'

49 - 65 Dolomite - 16'

light grey, fine crystalline, dolomite, wackestone-packstone; 30-60% fossil content mainly Thamnopora (most abundant near bottom of interval), lamellar stromatoporoids and occasional overturned massive stromatoporoid heads

65 - 73 Limestone - 8'

black, fine crystalline, lime packstone; 70-80% fossil content mainly branching stromatoporoids, some lamellar stromatoporoids near the bottom of the interval and scattered Thamnopora

73 - 83 Dolomite - 10'

light grey, medium crystalline, dolomite, mudstone; no fossils; crosscutting dolomite

veinlets; in places pseudobreccia

81 - 83'
20-30% fossil content mainly branching and massive stromatoporoids

83 - 87 Dolomite - 4'

light grey, medium crystalline, dolomite breccia (?); fragments vary in size from 1/8 to 4 inches; they are lighter in colour than the matrix

86 - 87'
60% fossil content mainly branching and massive stromatoporoids

End of section

Section C

Location: West Nabesche River Latitude 56° - 17' - 04"
Longitude 123° - 24' - 38"

Section starts at the bottom of one foot thick lamellar stromatoporoid bed at base of Reefal member and is measured upwards.

Footage	Lithological Description

Slave Point Formation

Lower Mudstone member - covered

Reefal member 0 - 47'

0 - 1 Limestone - 1'

dark grey, fine crystalline, lime wackestone-packestone; 20-30% fossil content mainly lamellar stromatoporoids and unidentified skeletal fragments

1 - 15 Limestone - 14'

black, fine crystalline, lime packstone-wackestone; 20-50% fossil content predominantly massive stromatoporoids and crinoid fragments, few brachiopods

15 - 22 Limestone - 7'

dark grey, fine crystalline, lime mudstone; less than 10% fossil content mainly thin shelled brachiopods and crinoid fragments

22 - 28 Limestone - 6'

dark grey, fine crystalline argillaceous, lime wackestone; 25-35% fossil content mainly lamellar stromatoporoids, Thamnopora and brachiopods; clay content 10-20%

28 - 30 Limestone - 2'

dark grey, fine crystalline, lime packstone-wackestone; 60-70% fossil content, mainly branching stromatoporoids and Thamnopora

30 - 47 Limestone - 17'

dark grey to black fine crystalline lime wackestone-packstone; 30-60% fossil content mainly brachiopods, branching stromatoporoids, lamellar (?) stromatoporoids in lower part of the interval and scattered crinoids

45 - 47'
dark grey, fine crystalline, lime wackestone; fossil content 30% mainly well preserved brachiopods

Nodular member 47 - 95'

47 - 58 Limestone - 11'

dark grey to black, fine crystalline, argillaceous, lime mudstone; no fossils; jointed

58 - 63 Limestone - 5'

dark grey, medium crystalline, lime mudstone; 5% fossil content mainly scattered crinoid fragments

63 - 95 Limestone - 32'

dark grey to black, fine crystalline, argillaceous, lime mudstone; less than 5% fossil content mainly scattered crinoid fragments and thin shelled brachiopods; clay content 10-20% increasing upward in the interval; rock has developed slaty cleavage and has exfoliated parallel to the cleavage

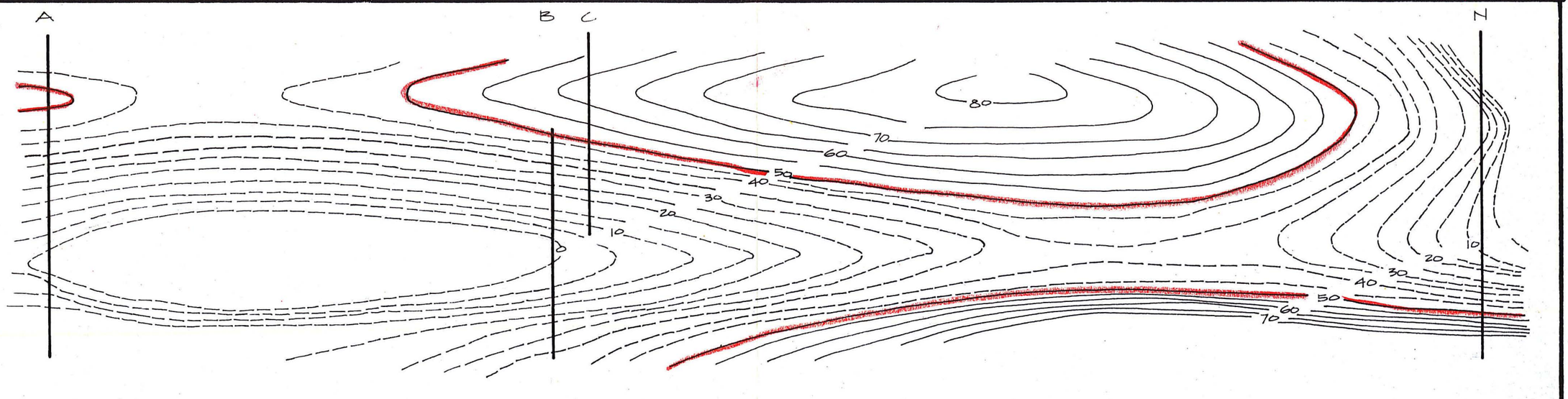
Upper Mudstone member 95 - 155'

95 - 155 Argillaceous limestone - 60'

light grey, fine crystalline, argillaceous, lime mudstone; no fossils; clay content 20-30%; contact with Besa River Formation set first occurrence of brown shale

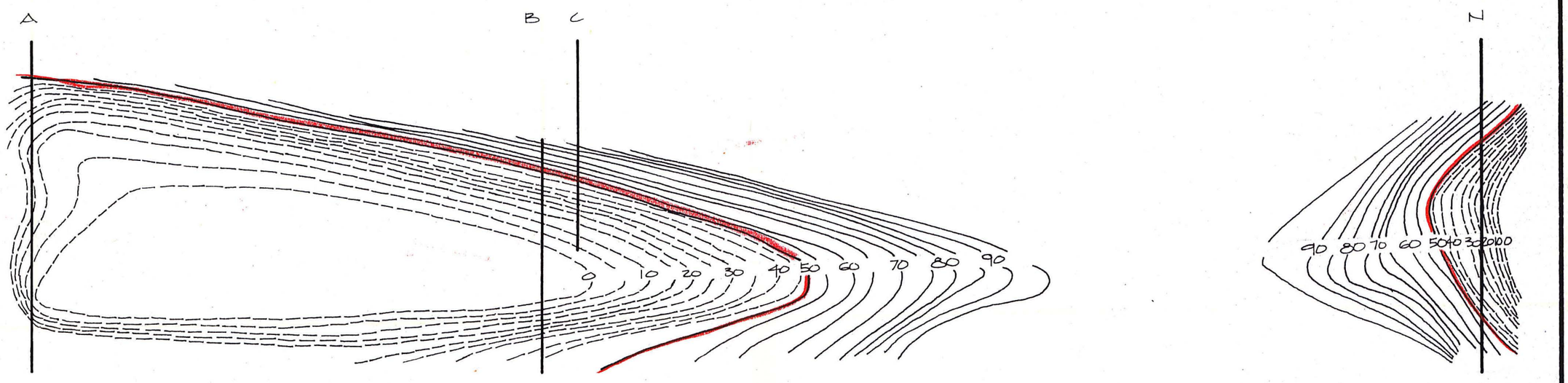
End of section

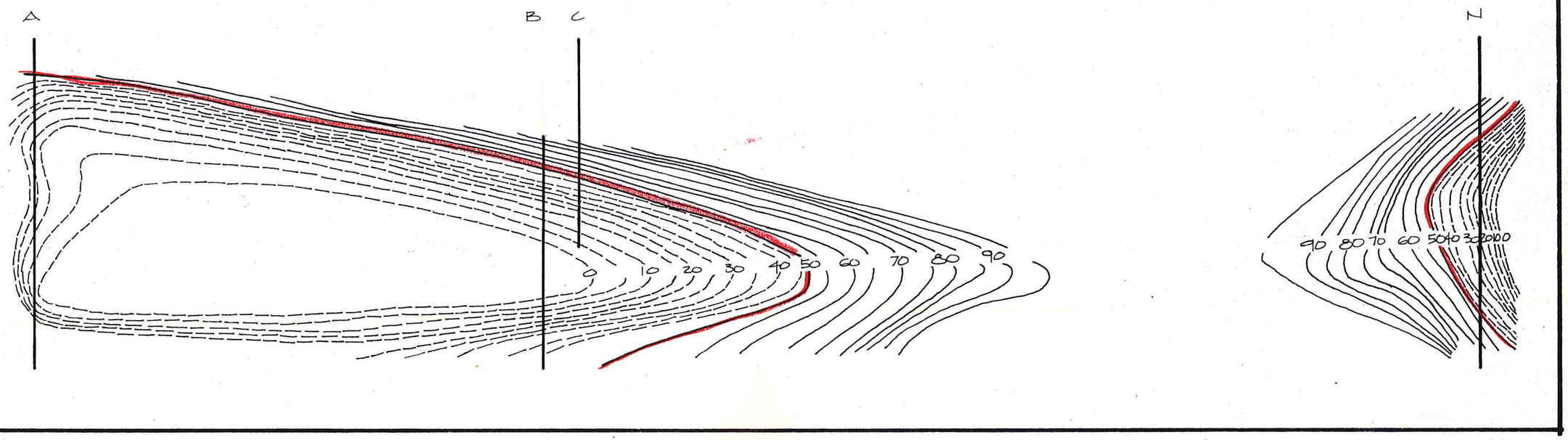
TREND SURFACES OF INSOLUBLE RESIDUE DATA



THIRD ORDER SURFACE

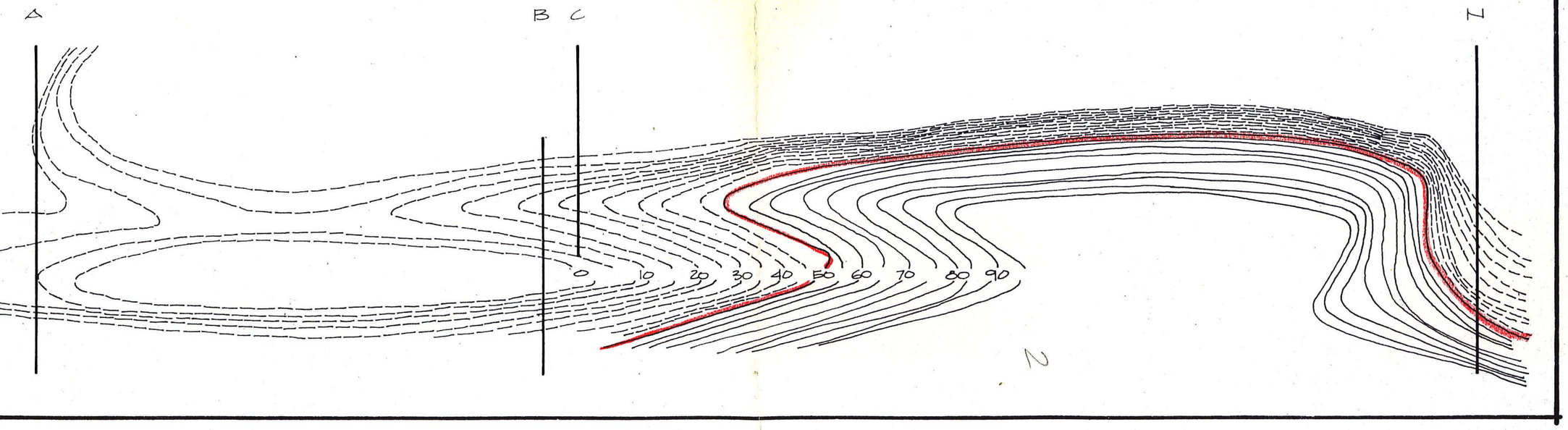
CORRELATION COEFFICIENT
0.7384





FOURTH ORDER SURFACE

CORRELATION COEFFICIENT
0.8040



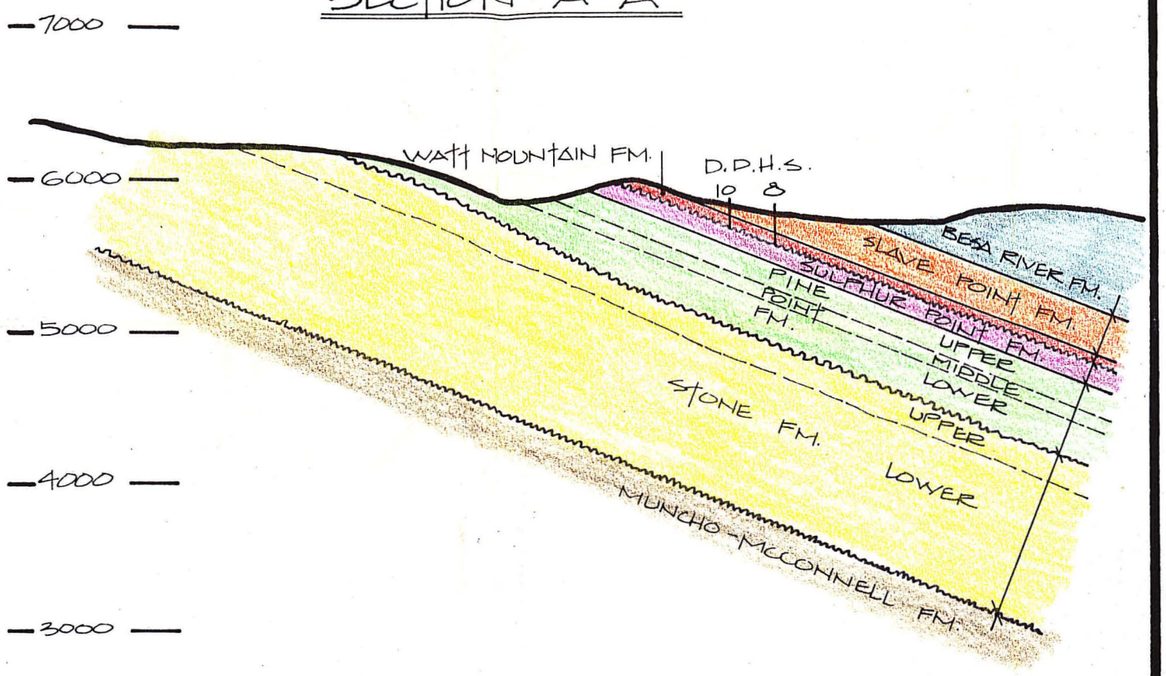
FIFTH ORDER SURFACE

CORRELATION COEFFICIENT
0.8121

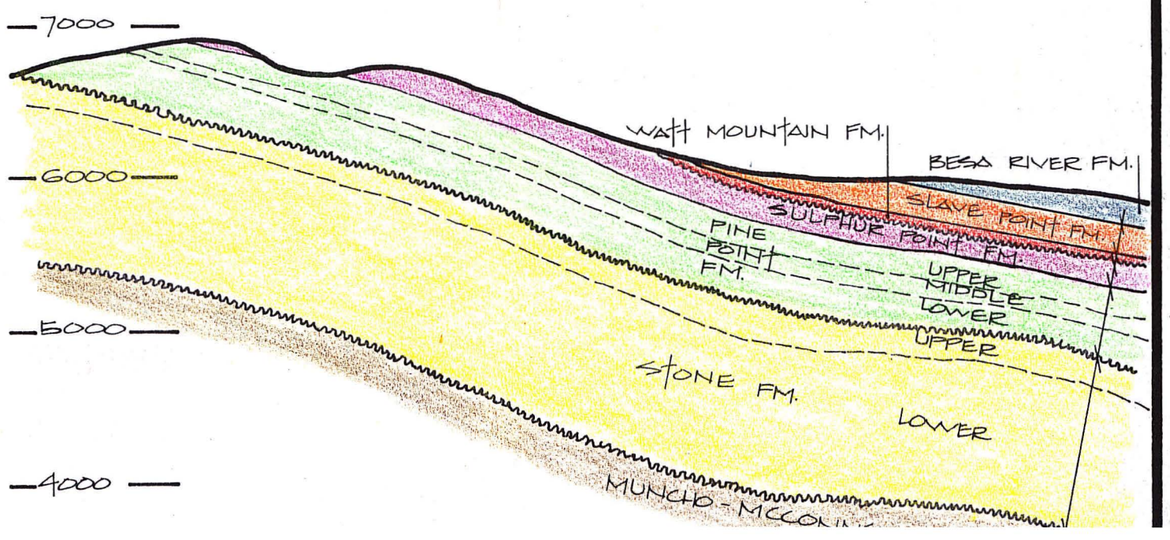
FIGURE 27.

PERCENT INSOLUBLE RESIDUE CONTOUR INTERVAL - 5%
VERTICAL SCALE - 1" ≈ 170'
HORIZONTAL SCALE - 1" = 1700'

SECTION A-A'

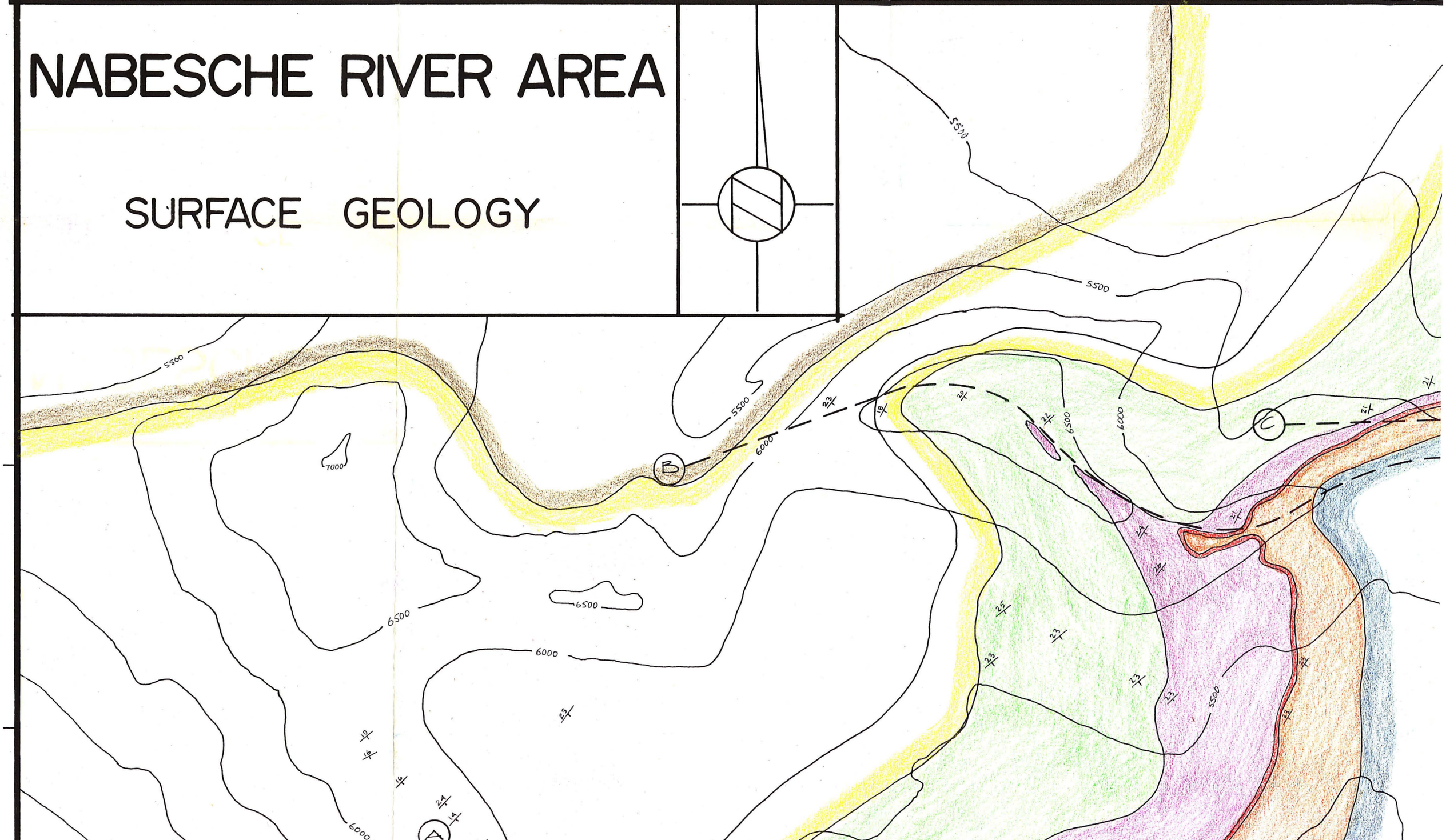


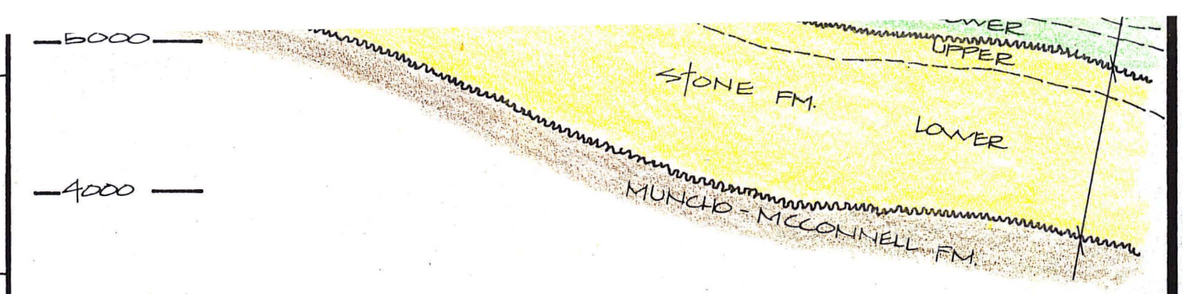
SECTION B-B'



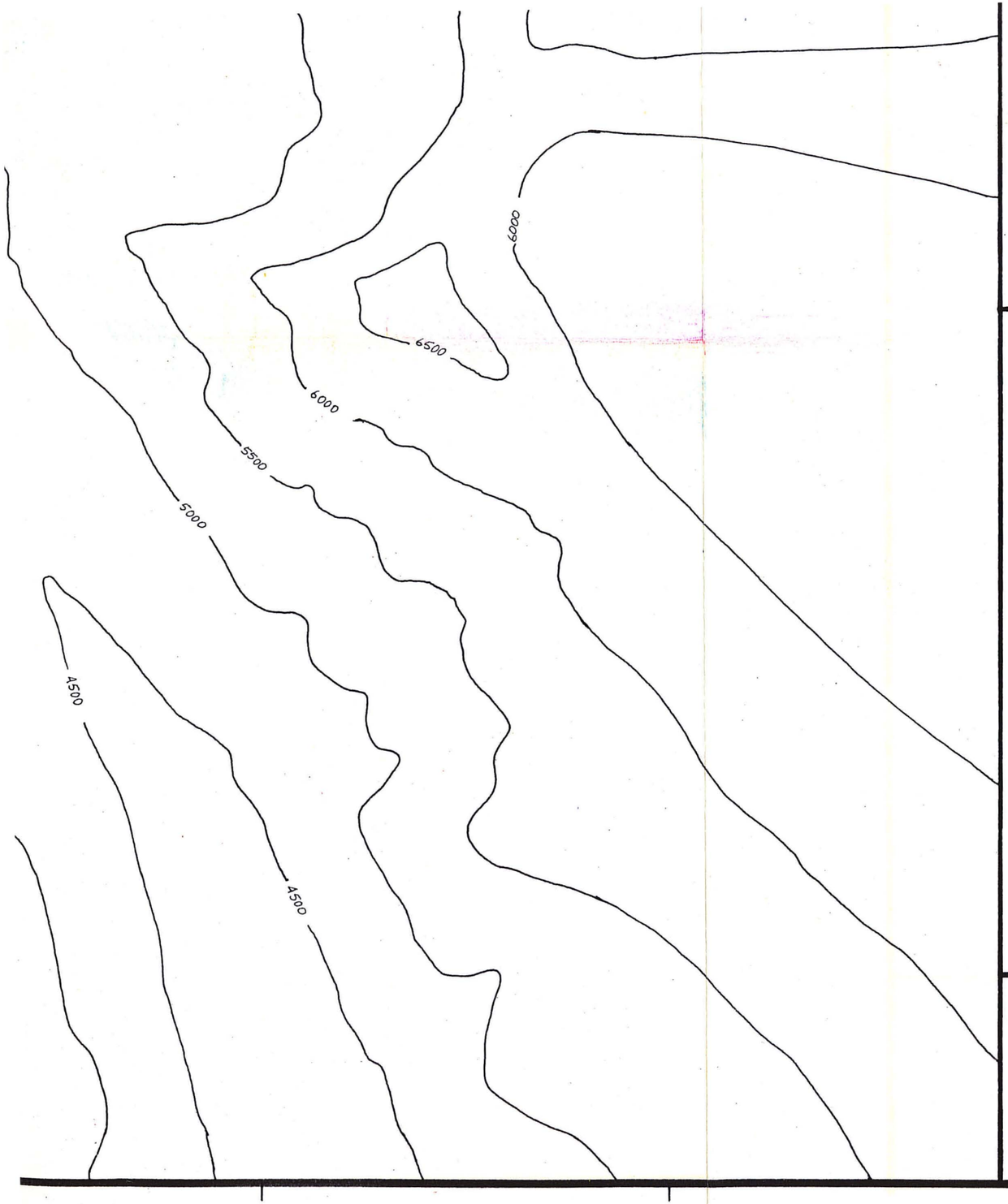
NABESCHE RIVER AREA

SURFACE GEOLOGY





HORIZONTAL SCALE – 1" = 1000'



LEGEND

UPPER DEVONIAN

BESA RIVER FORMATION	SHALE, CALCAREOUS SHALE

MIDDLE DEVONIAN

SLAVE POINT FORMATION	FOSSILIFEROUS, ARGILLACEOUS LIMESTONE AND DOLOMITE.
WATT MOUNTAIN FORMATION	SANDSTONE AND SEDIMENTARY BRECCIA
SULPHUR POINT FORMATION	MASSIVE LIMESTONE AND DOLOMITE
PINE POINT FORMATION	MASSIVE, FOSSILIFEROUS AND BRECCIATED DOLOMITE AND MINOR LIMESTONE
STONE FORMATION	ARENACEOUS DOLOMITE AND INTERBEDDED LIMESTONE AND SANDSTONE

LOWER DEVONIAN

MUNCHO-MCCONNELL FORMATION	DOLOMITE, ARENACEOUS DOLOMITE

25 ATTITUDE OF BEDDING

UNCONFORMABLE CONTACT

GEOLOGICAL CROSS-SECTION

TOPOGRAPHIC CONTOUR INTERVAL 500'

SCALE – 1" = 1000'

123°-24'-00"

123°-23'-00"

FIGURE 2.

-30"

-00"

-30"

-00"

WEST NAASESCHE RIVER

6000

5500

5000

4500

4000

3500

4500

4000

5000

5500

6000

5500

5000

4500

A

A'

DRILLED AREA

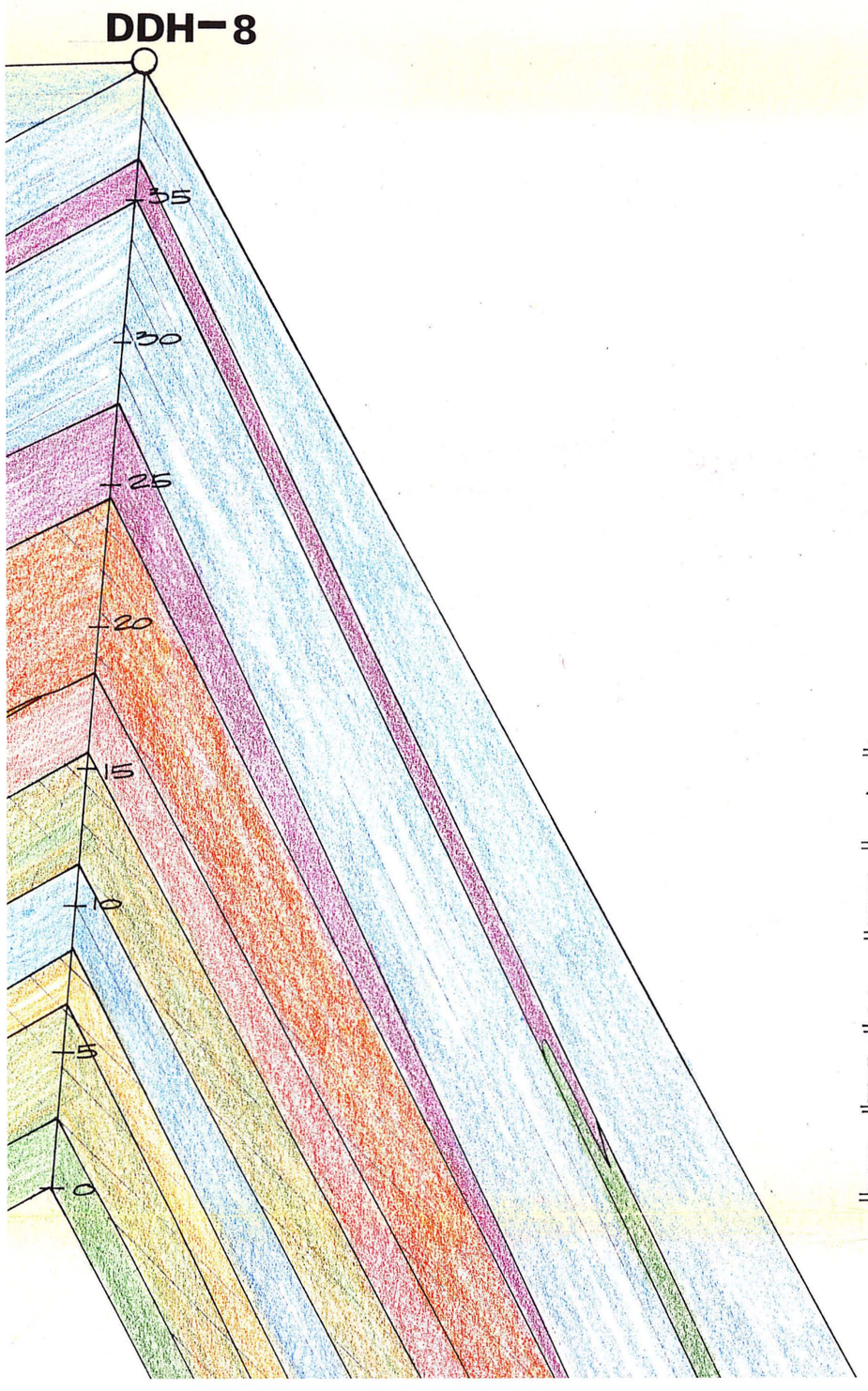
29°-29'-00"

29°-28'-00"

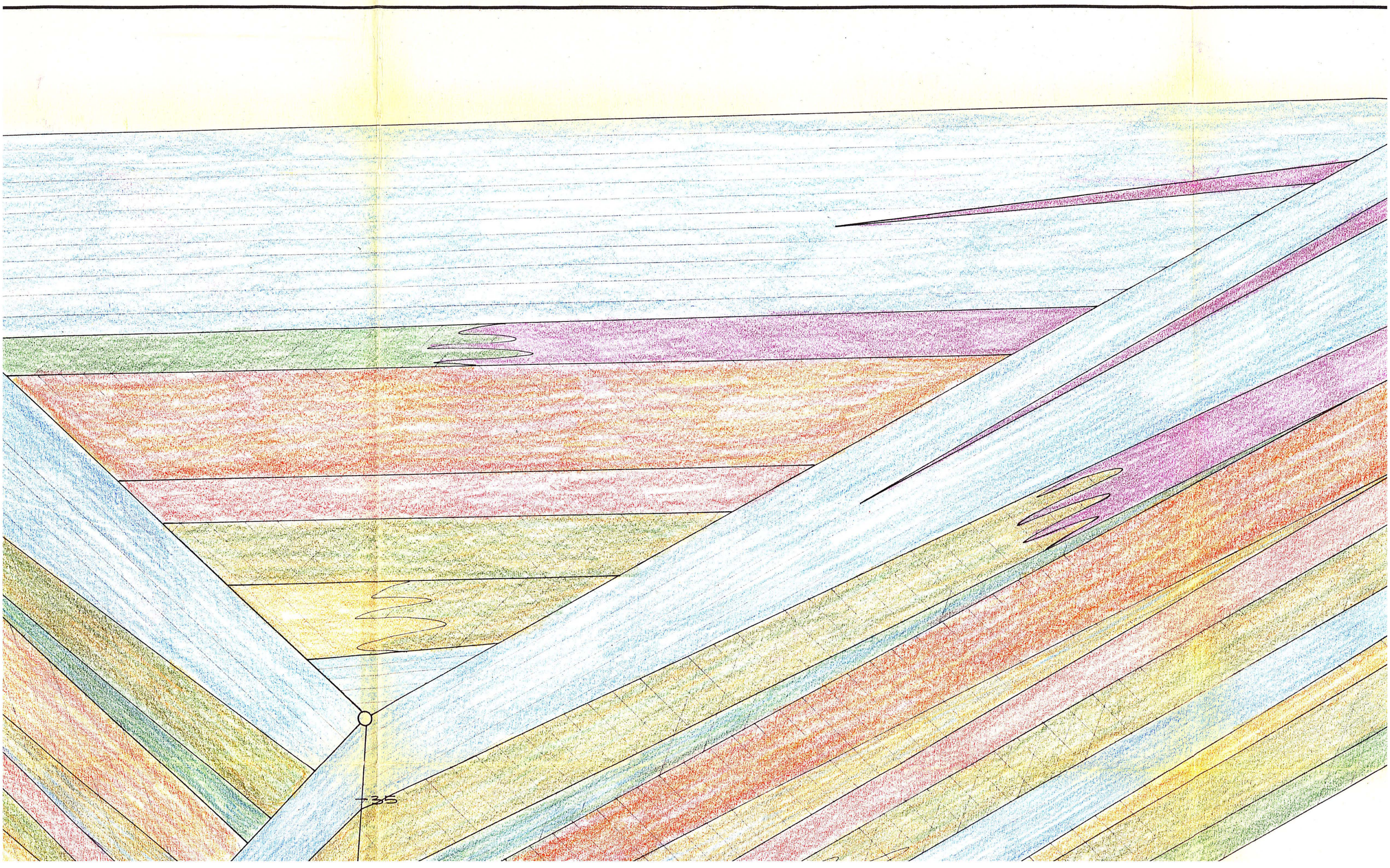
29°-27'-00"

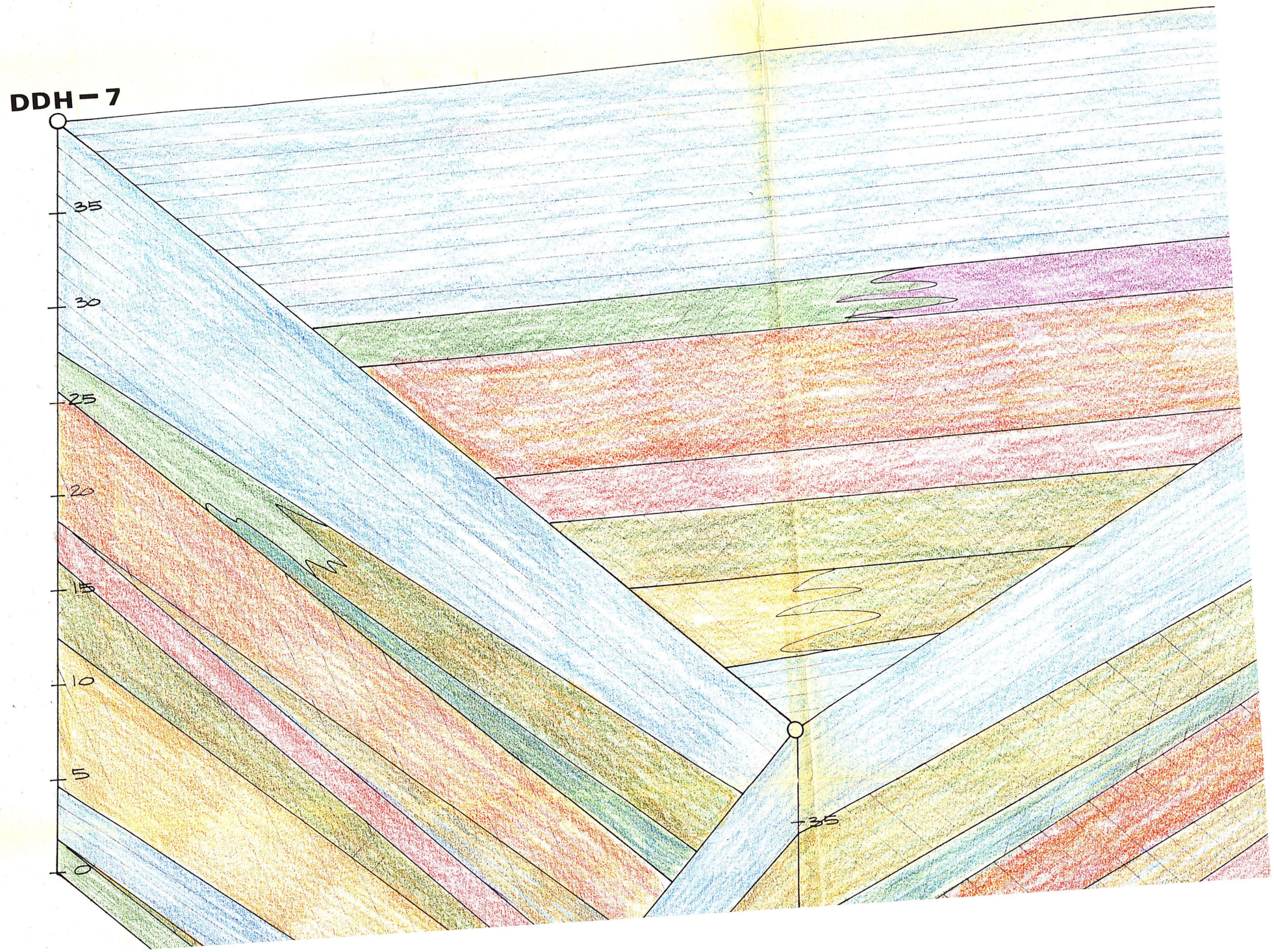
29°-26'-00"

29°-25'-00"



A FENCE DIAGRAM ILLUSTRATING THE DISTRIBUTION OF BIOFACIES IN THE REEFAL MEMBER OF THE SLAVE POINT FORMATION IN THE DRILLED AREA - NABESCHE RIVER AREA


-35


DDH – 7
35
30
25
20
15
10
5
0
35

DDH-10

35

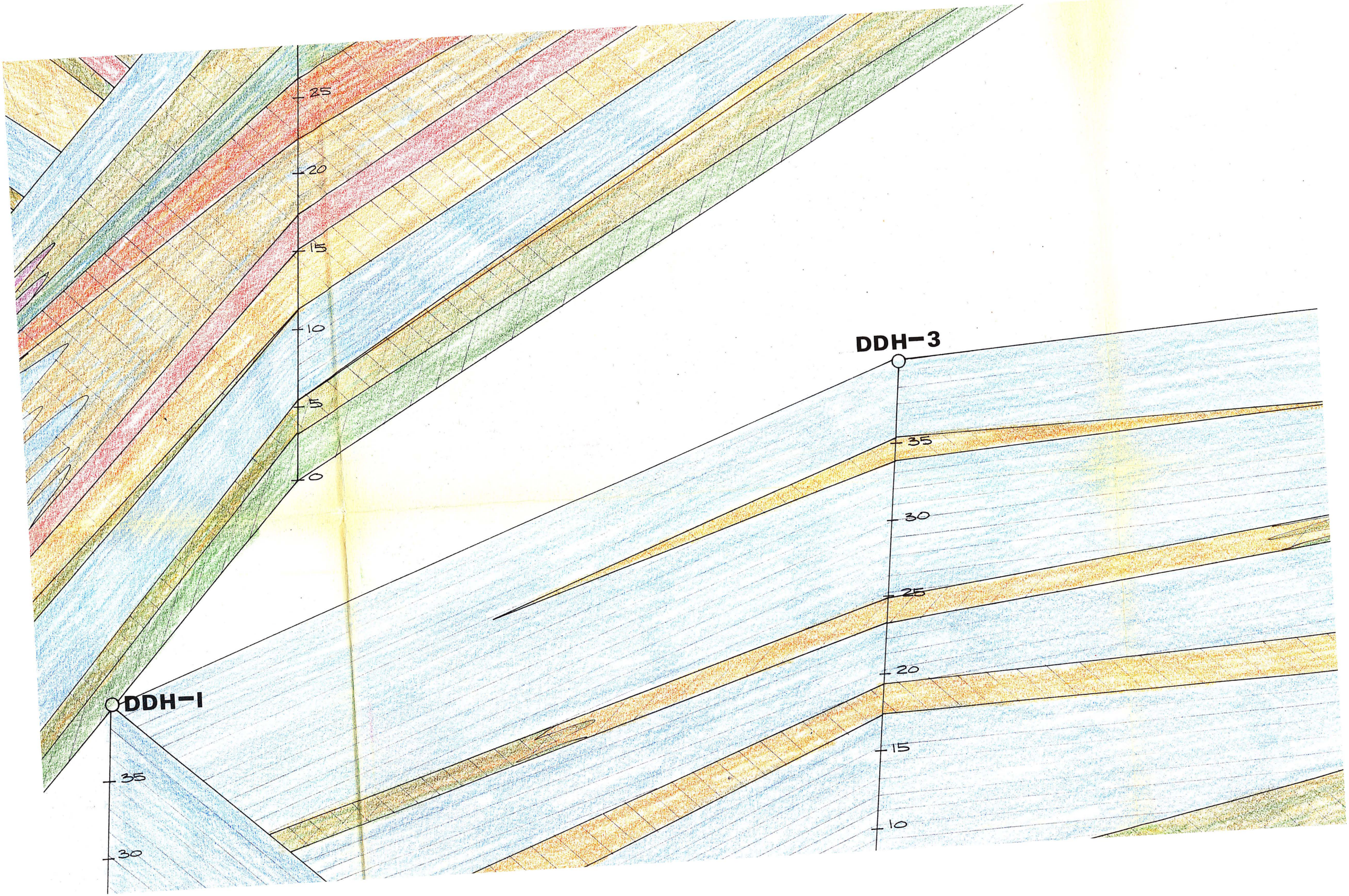
30

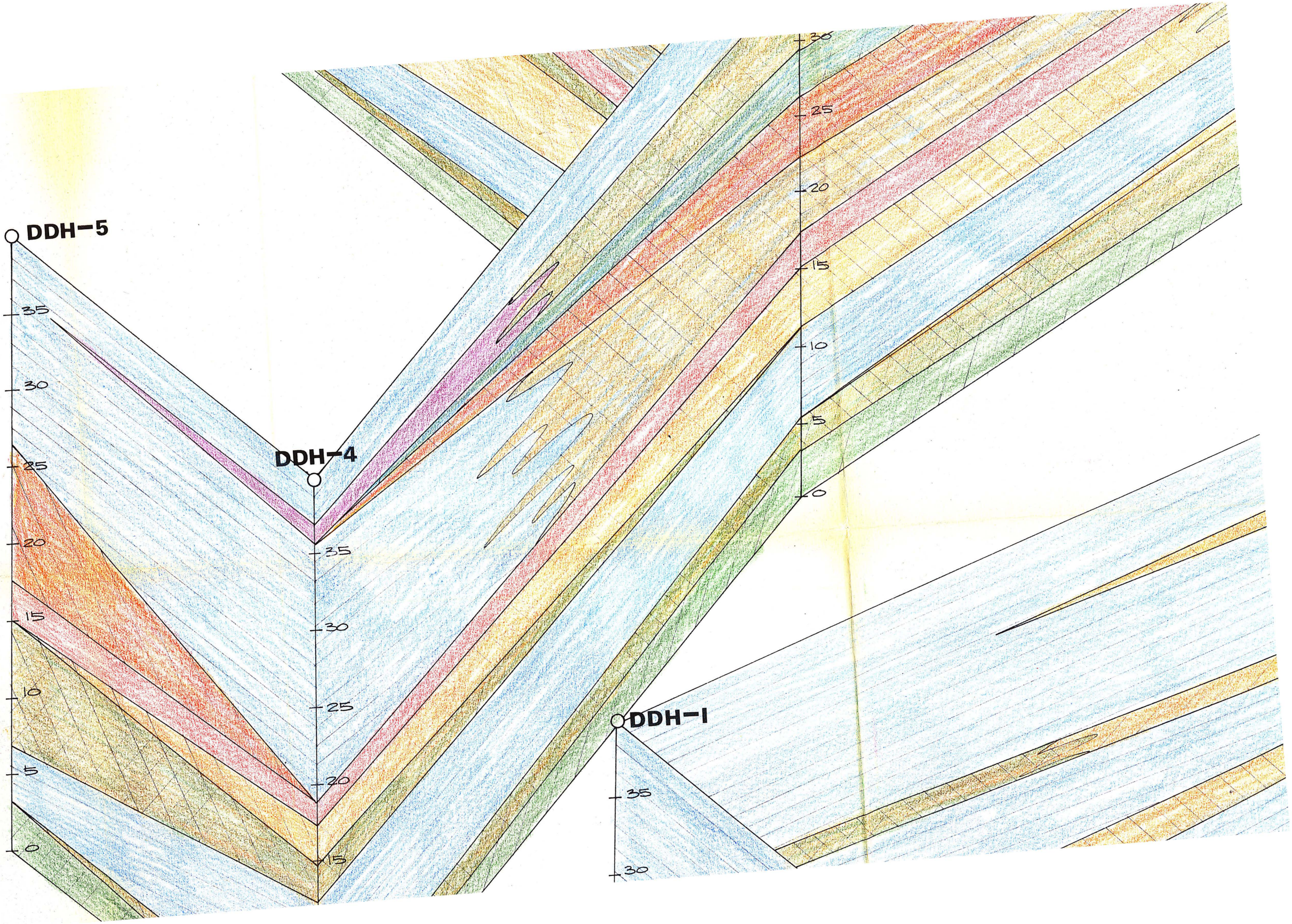
25

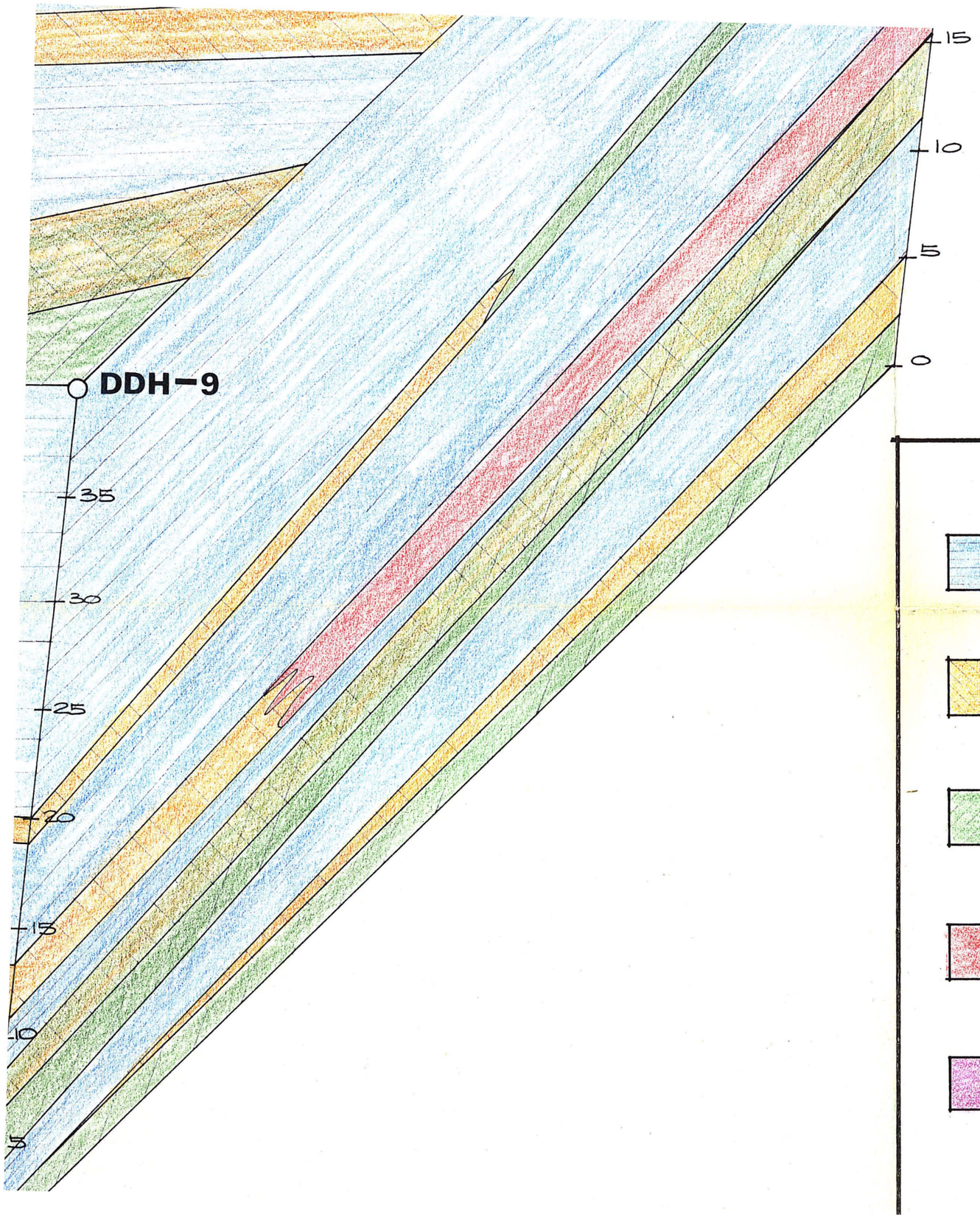
20

15

10


25
20
15
10
5
0
DDH-3
35
30
25
20
15
10
DDH-1
35
30


DDH-5
35
30
25
20
15
10
5
0
DDH-4
35
30
25
20
15
DDH-1
35
30
25
20
15
10
5
0



LEGEND

CRINOID BEARING MUDSTONE FACIES

BLACK, VERY FINE CRYSTALLINE, FOSSILIFEROUS LIME MUDSTONES - WACKESTONES.
MAIN FOSSILS ARE CRINOIDS, THICK AND THIN SHELLED BRACHIOPODS.

TABULATE CORAL FACIES

DARK GREY TO BLACK, FOSSILIFEROUS, SLIGHTLY ARGILLACEOUS, LIME AND DOLO-WACKESTONES.
MAIN FOSSILS ARE BRANCHING AND COLONIAL TABULATE CORALS, (THAMNOPORA MOST COMMON SPECIES).

LAMELLAR STROMATOPOROID FACIES

BLACK TO DARK GREY, FOSSILIFEROUS, LIME WACKESTONES AND PACKESTONES.
MAIN FOSSILS ARE LAMELLAR STROMATOPOROIDS AND SILT SIZED ABRADED FOSSIL FRAGMENTS.

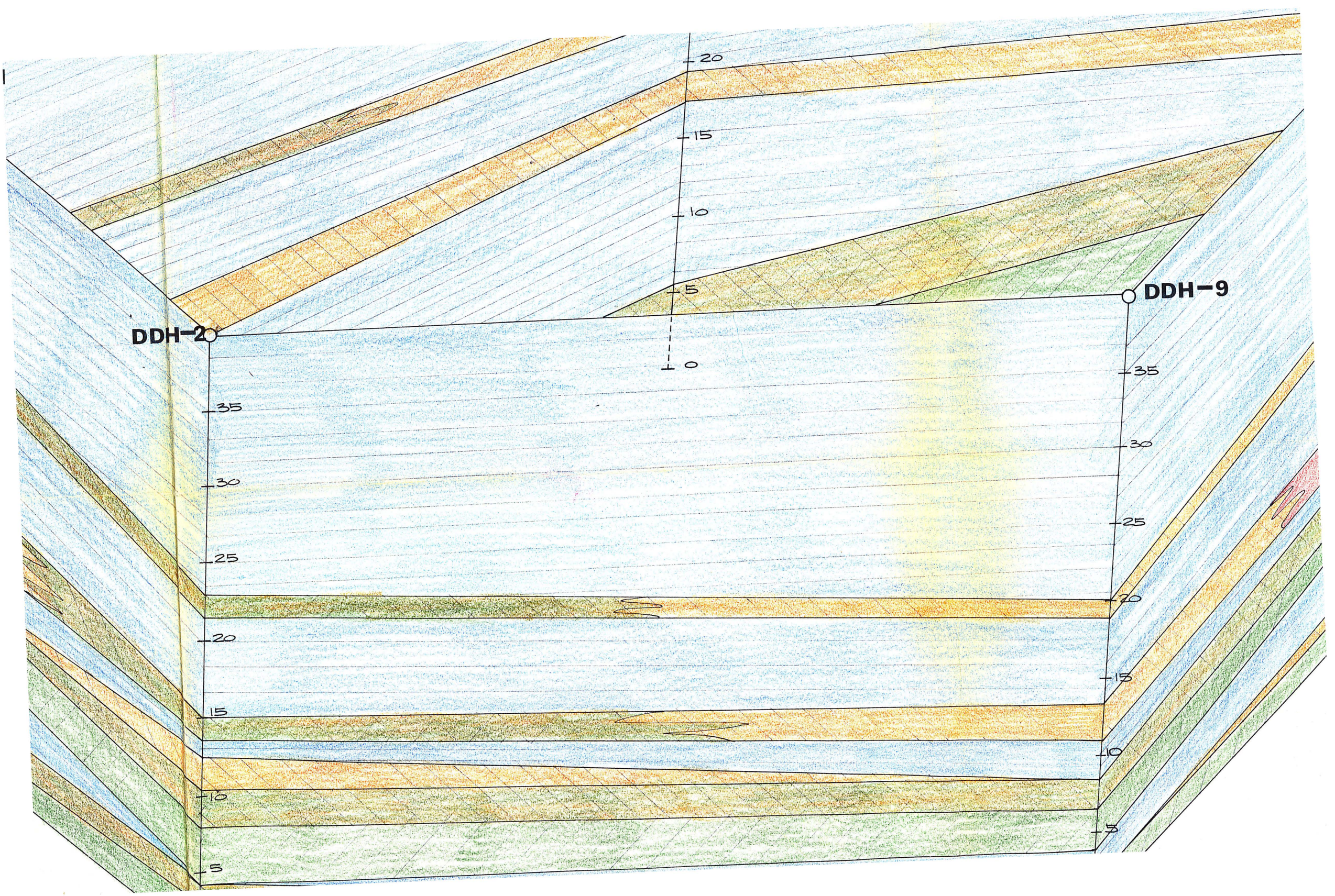
BRANCHING STROMATOPOROID FACIES

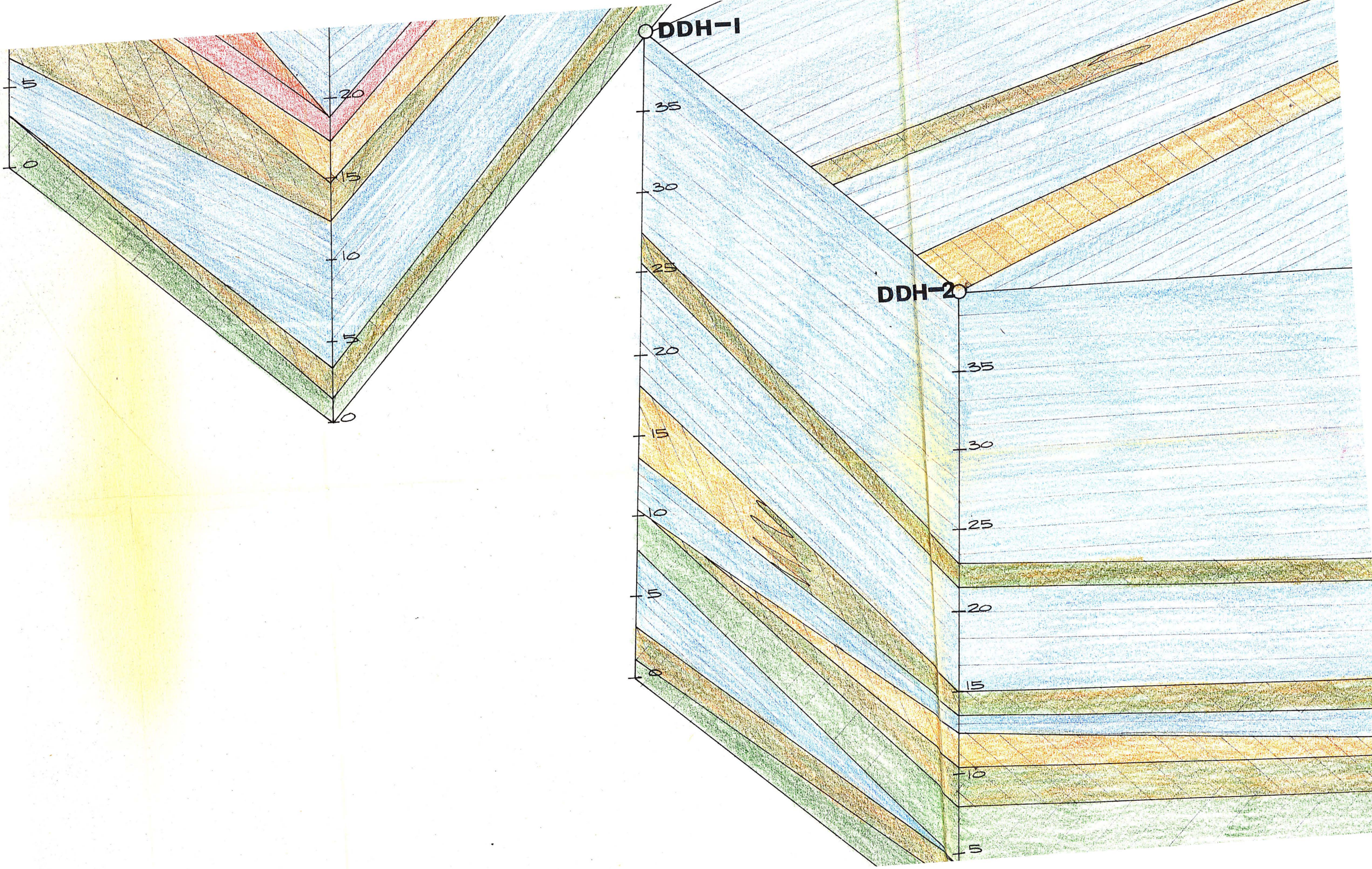
GREY TO DARK GREY, FOSSILIFEROUS, DOLOMITIC PACKESTONES AND WACKESTONES.
MAIN FOSSILS ARE BRANCHING STROMATOPOROIDS

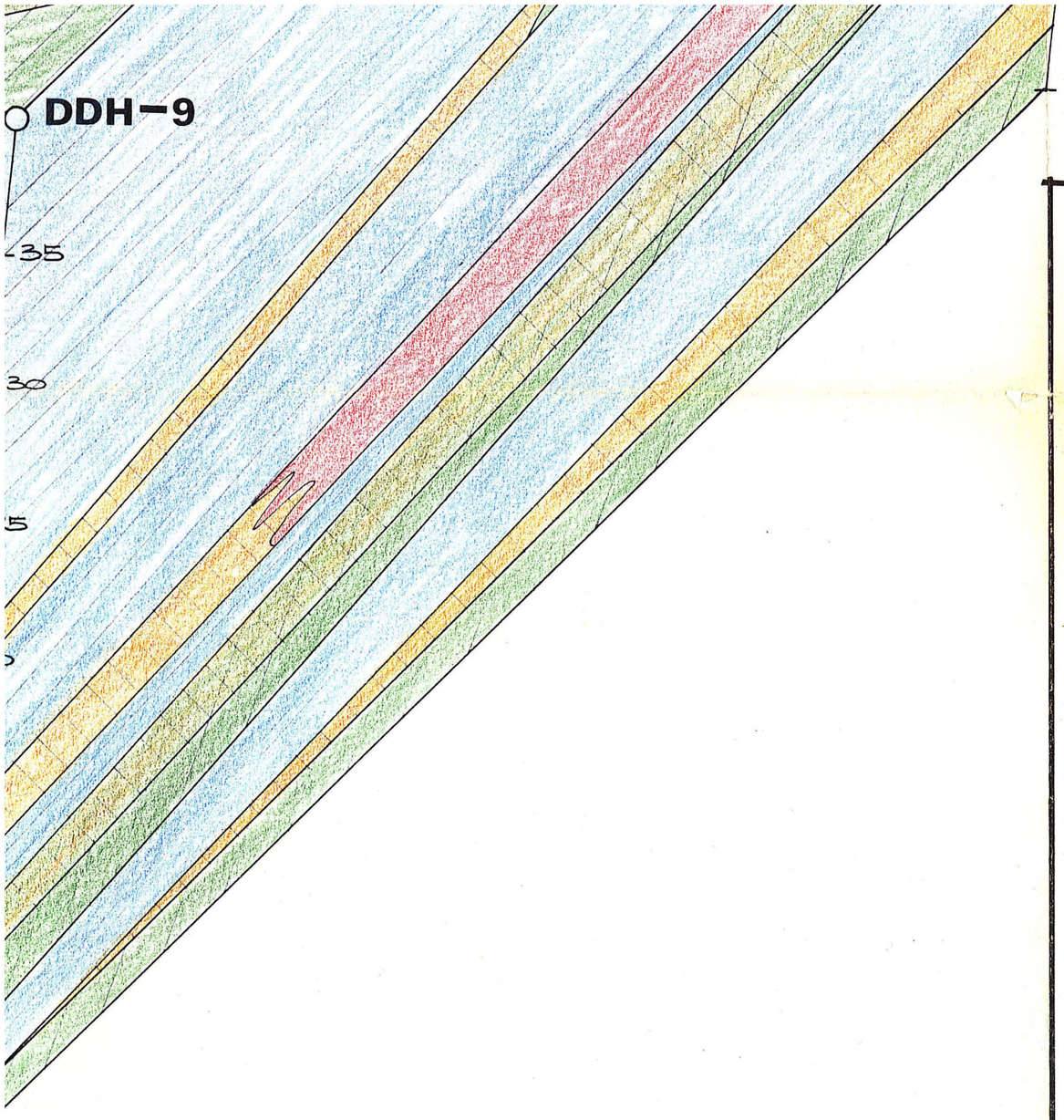
MASSIVE STROMATOPOROID FACIES

BLACK, FINE CRYSTALLINE, ARGILLACEOUS, FOSSILIFEROUS, LIME WACKESTONES AND PACKSTONES.
MAIN FOSSILS ARE BULBOUS, HEMISPHERICAL AND TABULAR STROMATOPOROIDS.

Horizontal scale 1"=20'


20
15
10
5
0
DDH-2
DDH-9
35
30
25
20
15
10
5
35
30
25
20
15
10
5


DDH-1
DDH-2
35
30
25
20
15
10
5
0
35
30
25
20
15
10
5
0
5
0
20
15
10
5
0



LEGEND

CRINOID BEARING MUDSTONE FACIES

BLACK, VERY FINE CRYSTALLINE, FOSSILIFEROUS LIME MUDSTONES - WACKESTONES.
MAIN FOSSILS ARE CRINOIDS, THICK AND THIN SHELLED BRACHIOPODS.

TABULATE CORAL FACIES

DARK GREY TO BLACK, FOSSILIFEROUS, SLIGHTLY ARGILLACEOUS, LIME AND DOLO-WACKESTONES.
MAIN FOSSILS ARE BRANCHING AND COLONIAL TABULATE CORALS, (THAMNOPORA MOST COMMON SPECIES).

LAMELLAR STROMATOPOROID FACIES

BLACK TO DARK GREY, FOSSILIFEROUS, LIME WACKESTONES AND PACKESTONES.
MAIN FOSSILS ARE LAMELLAR STROMATOPOROIDS AND SILT SIZED ABRADED FOSSIL FRAGMENTS.

BRANCHING STROMATOPOROID FACIES

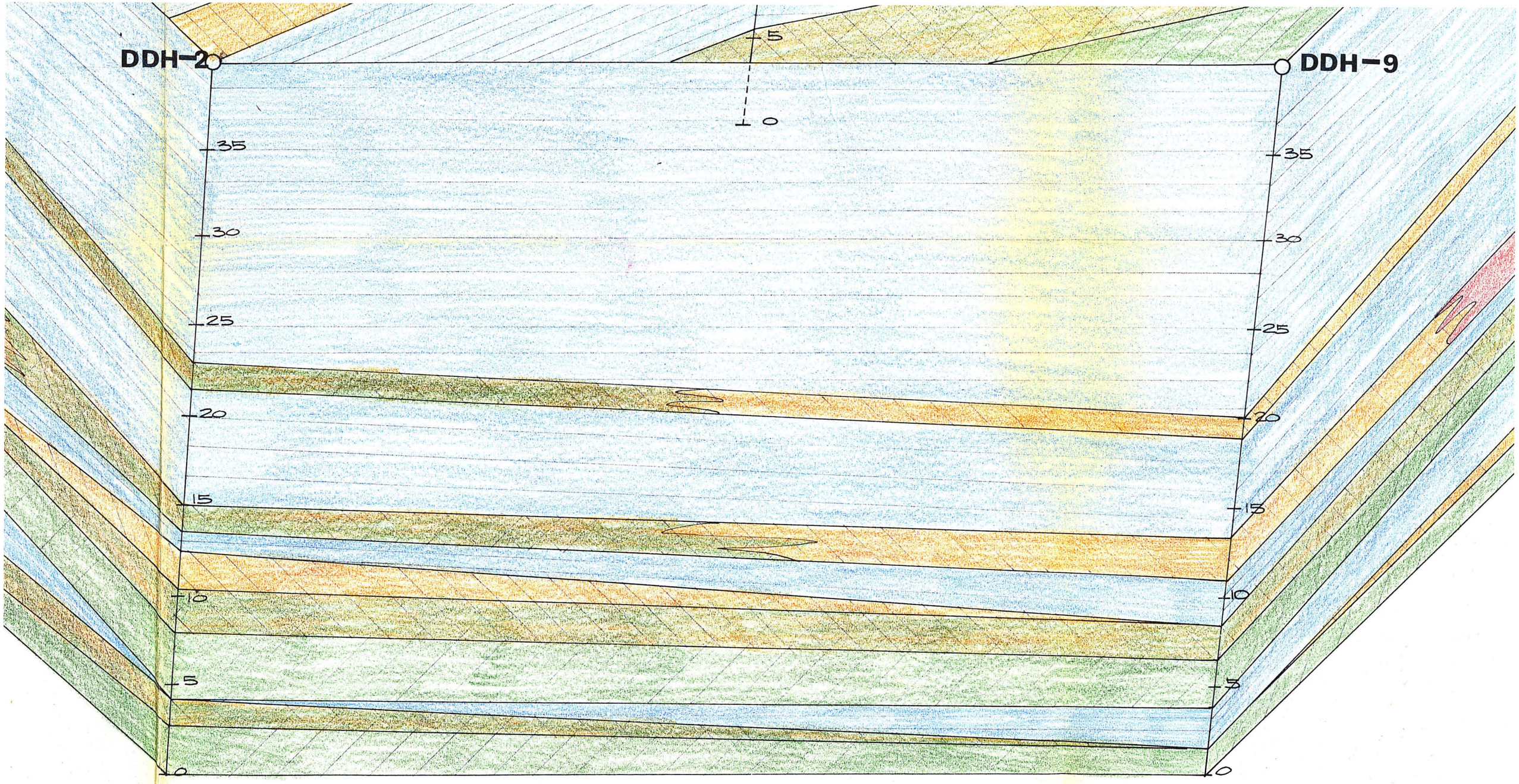
GREY TO DARK GREY, FOSSILIFEROUS, DOLOMITIC PACKESTONES AND WACKESTONES.
MAIN FOSSILS ARE BRANCHING STROMATOPOROIDS

MASSIVE STROMATOPOROID FACIES

BLACK, FINE CRYSTALLINE, ARGILLACEOUS, FOSSILIFEROUS, LIME WACKESTONES AND PACKSTONES.
MAIN FOSSILS ARE BULBOUS, HEMISPHERICAL AND TABULAR STROMATOPOROIDS.

HORIZONTAL SCALE 1" = 20'
VERTICAL SCALE 1" = 5'

FIGURE 13.


DDH-2
DDH-9
5
0
35
30
25
20
15
10
5
0
35
30
25
20
15
10
5
0

5

0

DDH-2

25

20

15

10

5

0

35

30

25

20

15

10

5

0